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Conference Review Procedure

These proceedings are a published record of the Fourth Biennial Conference of the South African Society for Engineering Education (SASEE). The purpose of these proceedings is to disseminate original research and new developments within the discipline of Engineering Education.

All papers and extended abstracts accepted for this conference went through a multiple-review process *prior to publication*. Authors initially submitted extended abstracts which were double-blind reviewed by three reviewers. Based on the outcome of this review, authors were invited to either develop this extended abstract into a full paper, or were invited to revise their extended abstracts based on the reviewers comments for resubmission. The resultant papers were then further reviewed by three reviewers using a double-blind peer review process. Authors were required to consider and implement the suggested changes where required.

The reviewers for the papers and extended abstracts were drawn from the SASEE Executive, SASEE membership, and the Centre for Research in Engineering Education (CREE) as appropriate.

The rejection rate for extended abstracts was 12% and for full papers was 7%.

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What should engineers be trained for in SA?

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It is a challenge to formulate a curriculum for a bachelor's degree in engineering, aimed at preparing graduates to become professional engineers after a few years of practical experience. There are so many different roles that engineers play in practice, that it is not possible to tailor a curriculum for each role. Curriculum design therefore inevitable entails many compromises. The research question in this paper is, from a curriculum design perspective: what types of work do engineers in the following engineering disciplines do in South Africa: chemical, civil, electrical & electronic, industrial, mechanical and mechatronic. The research method chosen was to survey a sample of Stellenbosch University engineering graduates three to seven years after graduation. The paper summarises the results from 128 responses in the survey. Firstly, the nature of the work, irrespective of the engineering discipline, is considered. These results show that the most common types of work are (in order of decreasing prominence): project management; general management; consulting; development of systems, processes and products; and quality assurance. In the second section of the survey, respondents were asked how often their work involves each of a set of technical areas. The technical areas presented to the respondents were different for the different engineering disciplines. This section showed that civil, electrical & electronic and mechanical engineers work over wide respective ranges of technical areas and therefore broad programmes are appropriate in these disciplines. The results for chemical, industrial and mechatronic engineers were inconclusive, because of low response rates or because the survey omitted significant technical areas in these disciplines. Although the survey has significant limitations in its general applicability, the results in the paper provides a rare quantification of the nature of engineering work in South Africa and therefore provide useful input to curriculum designers.

Introduction

It is a challenge to formulate a curriculum for a bachelor's degree in engineering aimed at preparing graduates to become professional engineers after a few years of practical experience. There are so many different roles that engineers play in practice, that it is not possible to tailor a curriculum for each role, particularly in a country like South Africa where the funding available for engineering education requires large class groups to achieve a financial break-even. Persons responsible for curriculum design therefore have to find a compromise that will suit a wide range of engineering roles, emphasising the most common roles or certain strategically chosen roles.

The research question in this paper is therefore what "types of work" do engineers in the following engineering disciplines do in South Africa: chemical, civil, electrical & electronic, industrial, mechanical and mechatronic. This information is intended for curriculum design in Washington Accord type engineering programmes. Here "type of work" is considered in terms of, firstly, which phase of the system or product life cycle the engineer is involved in and, secondly, what technical knowledge does the engineer mostly use.

Previous work

Although there have been previous studies in recent years on related topics, they have mostly been conducted in first world countries and have focussed on generic skills, graduate

attributes or outcomes, rather than on the technical content of the programmes. Much of this work has found expression in the accreditation requirements of Washington Accord members, such as the Engineering Council of South Africa (ECSA).

ECSA's accreditation requirements for the content of engineering programmes are expressed in terms of knowledge areas and exit level outcomes. Table 1 shows the minimum number of credits per knowledge area required by ECSA E-02-PE [2014]. It should be noted that the same definitions for the knowledge areas, given in ECSA E-01-P [2014], are applied to all engineering disciplines, and also to engineer, technologist and technician qualifications. ECSA, however, has different minimum credit requirements for engineer, technologist and technician qualifications, respectively.

ECSA's requirements for exit level outcomes, according to ECSA E-02-PE [2014], are summarised in Table 2.

Table 1. ECSA knowledge area requirements

Knowledge area	Minimum Credits
Mathematical sciences	56
Natural sciences	56
Engineering sciences	180
Design and synthesis	72
Complementary studies	56
Subtotal	420
For reallocation	≥140
Total credits	≥560

Table 2. ECSA exit level outcomes

Exit Level Outcome	Paraphrased Description
1 Problem solving	Identify, formulate, analyse and solve complex engineering problems creatively and innovatively.
2 Application of scientific and engineering knowledge	Apply knowledge of mathematics, natural sciences, engineering fundamentals and an engineering speciality to solve complex engineering problems.
3 Engineering design	Perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.
4 Investigations, experiments and data analysis	Demonstrate competence to design and conduct investigations and experiments.
5 Engineering methods, skills and tools, including Information Technology	Demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.
6 Professional and technical communication	Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.
7 Sustainability and impact of engineering activity	Demonstrate critical awareness of the impact of engineering activity on the social, industrial and physical environment.

8	Individual, team and multidisciplinary working	Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments.
9	Independent learning ability	Demonstrate competence to engage in independent learning through well-developed learning skills.
10	Engineering professionalism	Demonstrate critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within own limits of competence.
11	Engineering management	Demonstrate knowledge and understanding of engineering management principles and economic decision-making.

The exit level outcomes in Table 2 are required by ECSA for all engineering disciplines, as well as for engineers, technologists and technicians, but the level descriptors are different for the three latter categories. For engineers, ECSA E-02-PE gives the following level descriptor:

Level Descriptor: Complex engineering problems:

a) require in-depth fundamental and specialized engineering knowledge;

and have one or more of the characteristics:

b) are ill-posed, under- or overspecified, or require identification and refinement;

c) are high-level problems including component parts or sub-problems;

d) are unfamiliar or involve infrequently encountered issues;

and their solutions have one or more of the characteristics:

e) are not obvious, require originality or analysis based on fundamentals;

f) are outside the scope of standards and codes;

g) require information from variety of sources that is complex, abstract or incomplete;

h) involve wide-ranging or conflicting issues: technical, engineering and interested or affected parties.

In the context of this paper, it is noteworthy that ECSA does not give any detailed requirements for the curriculum content, but only states [E-02-PE, 2014, section 10.3]:

This standard does not specify detailed curriculum content. The engineering fundamentals and specialist engineering science content must be consistent with the designation of the degree.

Another dimension of engineering curriculum design that has been considered by many researchers is more related to the pedagogical approach taken in the programme. Here the Conceive-Design-Implement-Operate (CDIO) approach [Crawley, Malmqvist, Östlund, Brodeur, Edström, 2014] has found some prominence and Woollacot [2009] claims the latter to be "the most detailed single statement of this kind currently found in the literature". The CDIO approach has many similarities with "project based learning", but Crawley, *et al.* [2014: Chapter 5] point out some important distinctions between these approaches.

This paper considers a different view of engineering curricula, where the technical knowledge that students have to develop is the main focus, and not the generic skills, nor the pedagogical approach. This paper's contribution is therefore complementary to the above-mentioned views and it is conceivable that the paper's results can be implemented in a CDIO approach (or a project-based, problem-based or more conventional pedagogy), while also developing and assessing the exit level outcomes that ECSA requires.

Research Method

A case study methodology was selected for this research. Although it would have been more valuable to do a national, or even international, study of the "types of work" that engineers

do, such a study was not feasible. Stellenbosch University's (SU) engineering graduates of 2009 to 2013 were therefore selected for a case study. Restricting the study to this subset of engineers does limit the applicability somewhat, since SU does not offer some engineering disciplines (such as mining engineering or agricultural engineering), but SU does offer the most common engineering disciplines in South Africa (i.e. mechanical, civil, electrical & electronic and chemical), as well as two less common disciplines (i.e. industrial and mechatronic). One should also acknowledge that the boundaries within and between disciplines are not the same at all universities, not even within South Africa, and far less so internationally. For example, what is considered to be an elective stream within electrical & electronic engineering at SU is considered to be a distinct programme at other universities (e.g. computer engineering).

The research method chosen to find answers to the research question was to survey a sample of SU engineering graduates in practice. When choosing a sample, it was assumed that the impact of education will diminish as engineers proceed through their careers. Therefore the survey was aimed at engineers relatively early in their careers. However, many recent graduates are in training for the first few years of their careers and the nature of their work is therefore not representative of what they would do a few years later. The compromise struck in the survey was to target graduates who have worked for about three, or slightly more, years after graduation. The three-year threshold corresponds to the minimum years of practical experience that ECSA requires before a graduate can apply for professional registration. The ECSA criterion therefore indicates that within three years, or shortly thereafter, young engineers will be doing the type of work expected of a professionally registered engineer.

The Engineering Faculty at SU in 2016 conducted a survey of some of its graduates, as part of its quality assurance and feedback processes. Parts of this survey were formulated to answer this paper's research question.

In the first relevant (to this paper) section of the survey, the nature of the work, irrespective of the engineering discipline, was considered. This perspective corresponds somewhat to the phase of the system or product life cycle the engineer is involved in. The survey question was phrased as follows:

How often does each of the following describe the nature of your work?

Since the "nature of your work" could mean many things, and to simplify the analysis of the responses, the survey gave a list of 13 items (which are shown in the results section of the paper) and respondents could mark one of the following five responses for each item: Never, Rarely, Sometimes, Often, Routinely. Respondents were not asked to rank the 13 items, since some of the items would overlap, but their responses for each answer item in the list would still indicate which items occur more regularly.

In the subsequent section of the survey, the focus was on the technical knowledge that the engineers mostly use. The responses here were grouped according to the engineering discipline. The respondents were therefore first asked to select their "primary discipline" and the survey then only displayed the options for that discipline.

The items in both sections of the survey (i.e. the nature of work and the technical knowledge areas) were compiled by the Engineering Faculty's Programme Committee, comprising representatives from each of the departments that host the engineering programmes and the vice-dean: teaching of the faculty. The items offered to survey respondents, in particular the technical areas, therefore reflect the current curricula of these programmes. Since the survey in which these questions were embedded was quite lengthy, the technical areas were limited

to seven items per discipline, but that provided sufficient resolution to evaluate the main knowledge streams within each of the engineering disciplines offer by SU.

Institutional ethics clearance was obtained for the graduate survey (reference number SU-HSD-000494) on the basis that the responses were given anonymously.

Survey Results

The names and email addresses of 986 BEng graduates of SU, who graduated from 2009 to 2013, were obtained from the SU's Alumni Office. In this period, the faculty produced 1769 graduates and therefore 56% of these graduates were invited to complete the survey. Of them 128 responded, i.e. 7.2% of the graduates. Table 3 gives the number of graduates and respondents for each year. Although there are regular small changes to the BEng programmes, in a process of continuous improvement, there were no major changes to the programmes during these years. There was therefore no reason to separate the responses for the different years.

Table 4 gives the break-down of graduates and respondents in terms of discipline.

Table 3. Respondents vs graduation year

Year	Graduates	Respondents
2009	277	14
2010	306	31
2011	355	28
2012	423	25
2013	408	30

Table 4. Respondents per discipline

Discipline	Graduates	Respondents
Chemical	199	8
Civil	530	37
E&E	300	29
Industrial	211	14
Mechanical	314	25
Mechatronic	215	15

The survey responses were collected by sending the above-mentioned graduates an email inviting them to participate in the survey. A link to a survey constructed in Checkbox was provided in the email. Six days later, a reminder email was sent to those who had not responded.

The survey responses were analysed using a custom program. The following figures show the processed responses, with the mean, variance and 95% confidence intervals indicated. The responses were considered to be ordinal data, and integer values of 1 (for "never") to 5 (for "routinely") were allocated to the potential responses. The statistics were calculated using the integer values. The number of responses for each item on the horizontal axis is shown in

square brackets with the item description. Respondents were allowed to leave an item unanswered.

Figure 1 shows the responses for the question about the nature of work for all disciplines combined. Most respondents answered all items, except "Other". The confidence intervals for the means are typically quite narrow, indicating that the number of responses overall are statistically sufficient to draw conclusions about the means. However, the spread in responses is shown by the large variances.

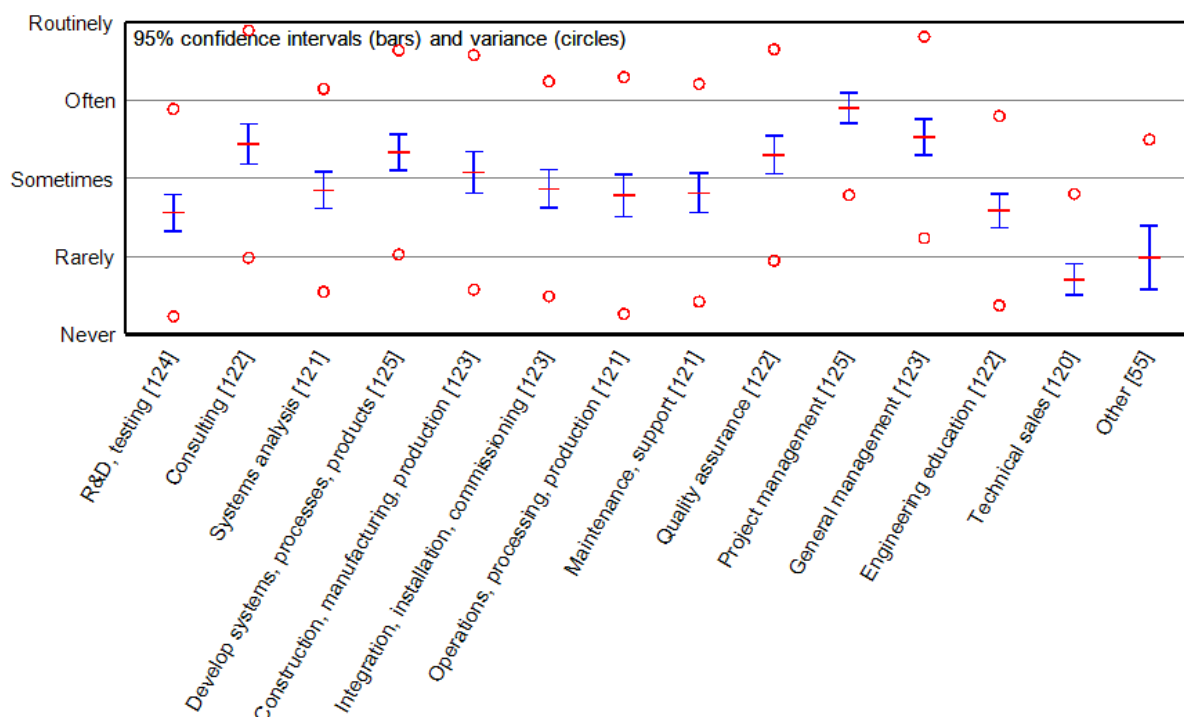


Figure 1. Survey responses to the question "How often does this describe the nature of your work"

Table 5 gives a qualitative comparison of the discipline-specific means, relative to the mean for the whole response group. "H" indicates that the discipline's mean is higher (closer to "Routinely"), and conversely for "L". Only items with substantial variations between disciplines are included in Table 5. The comments regarding chemical engineering should be considered with caution since the differences between chemical engineering and other disciplines were generally smaller than the confidence intervals for chemical engineering. The small number of respondents in chemical engineering results in wide confidence intervals for that group.

The processed responses for each discipline for the technical knowledge items are shown in Figures 2 to 7.

Table 5. Disciplinary deviations from mean of all respondents

Item	Chemical	Civil	E&E	Industrial	Mechanical	Electronics
R&D, testing	H	L			H	
Consulting				H		L
Construction, manufacturing, production		H	L	L	H	
Operations, processing, production	H	L	L	H	H	L
Maintenance, support			H	L	H	
General management			L	H		L

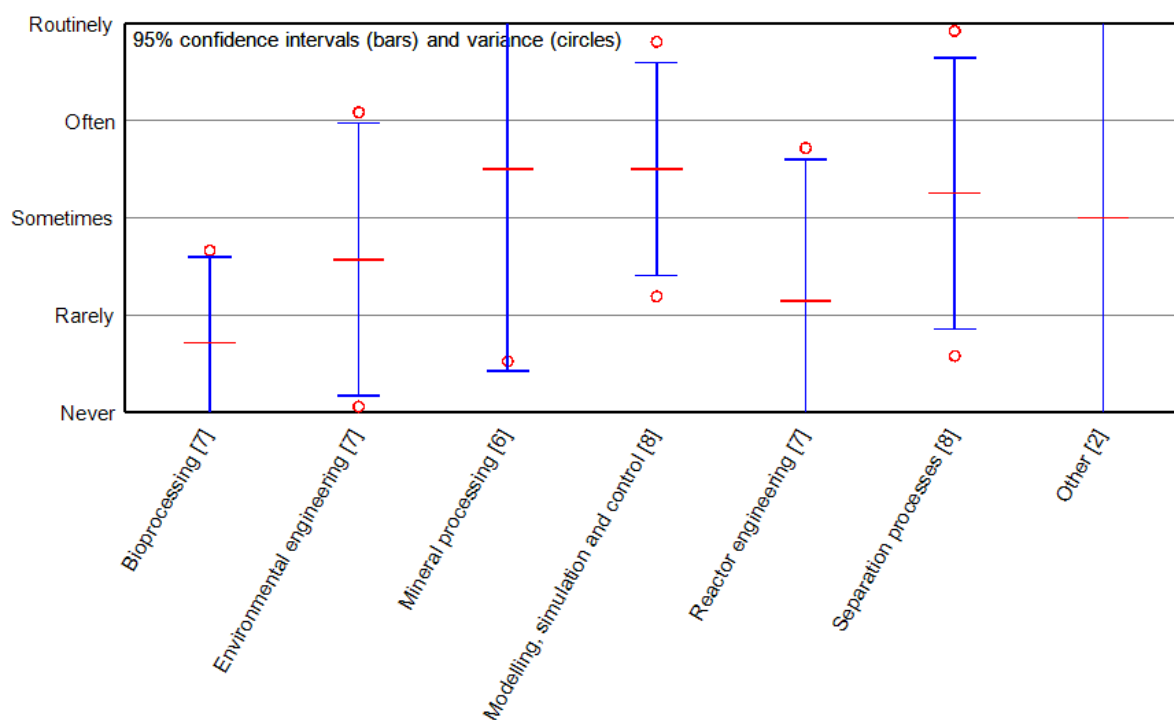


Figure 2. Responses for frequency of work in technical areas in chemical engineering

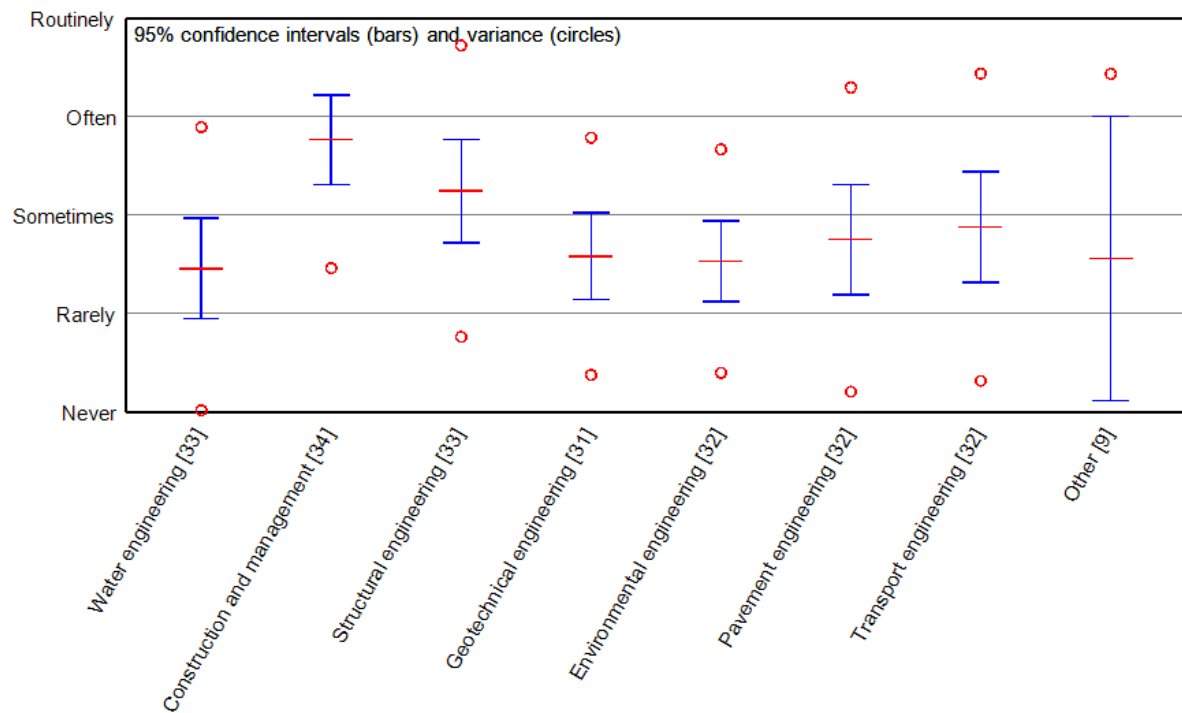


Figure 3. Responses for frequency of work in technical areas in civil engineering

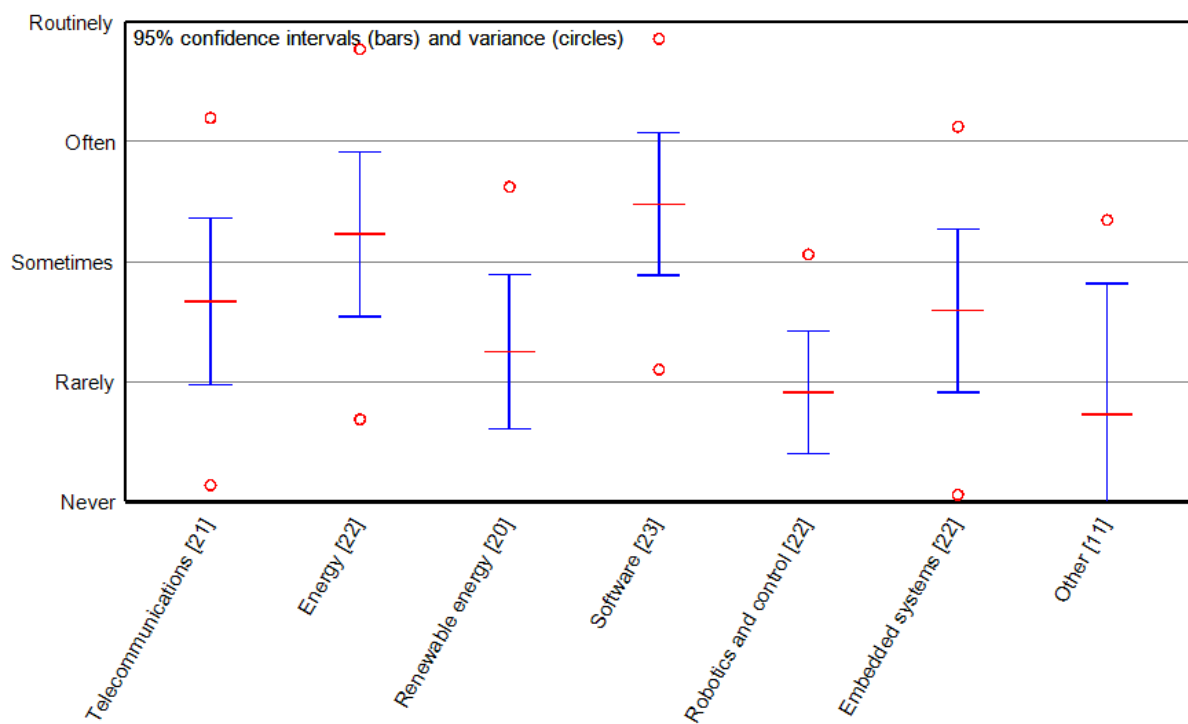


Figure 4. Responses for frequency of work in technical areas in E&E engineering

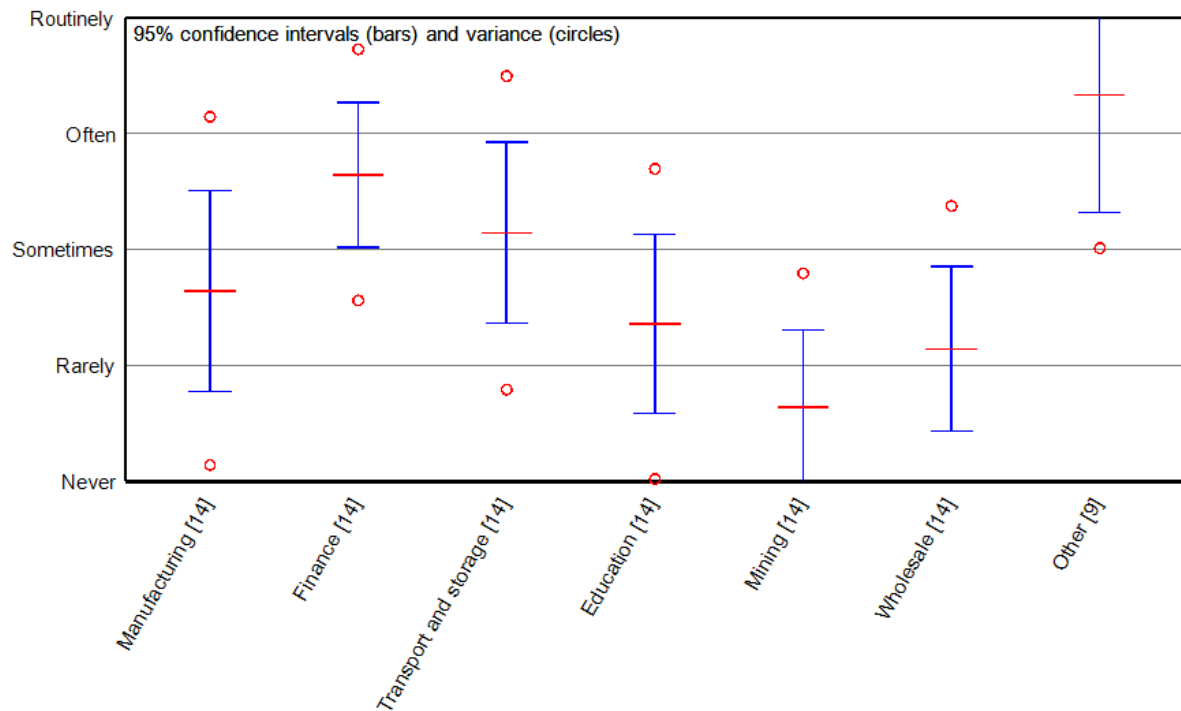


Figure 5. Responses for frequency of work in technical areas in industrial engineering

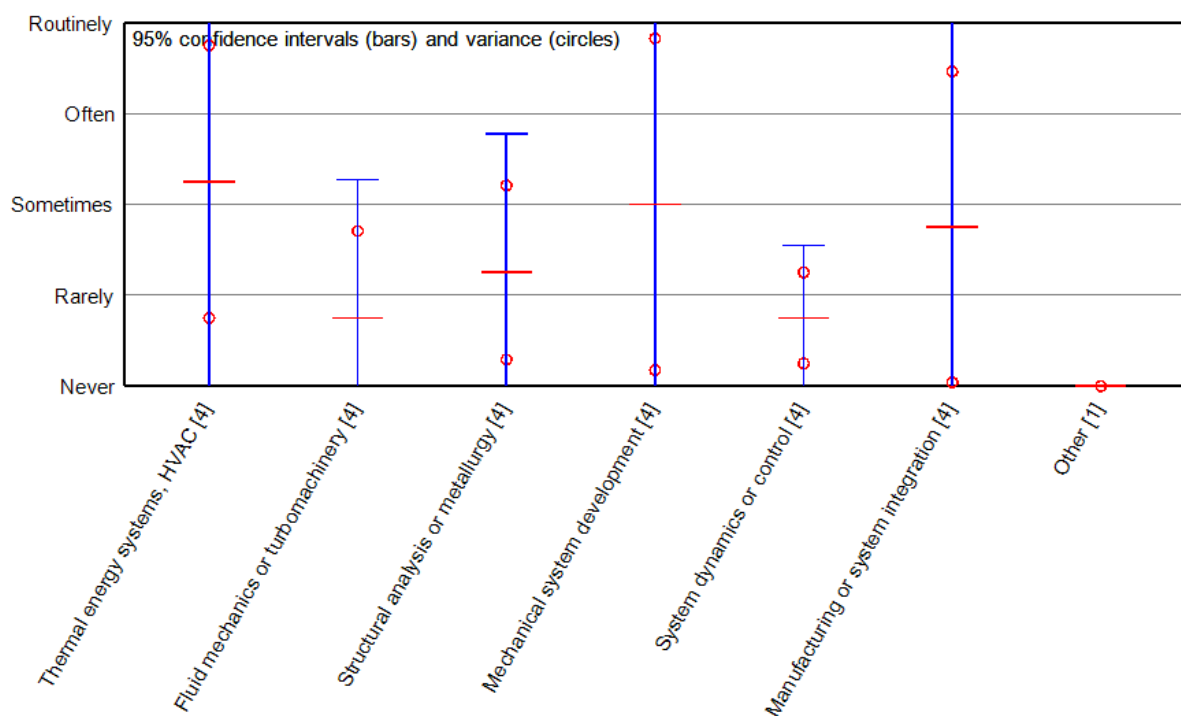


Figure 6. Responses for frequency of work in technical areas in mechanical engineering

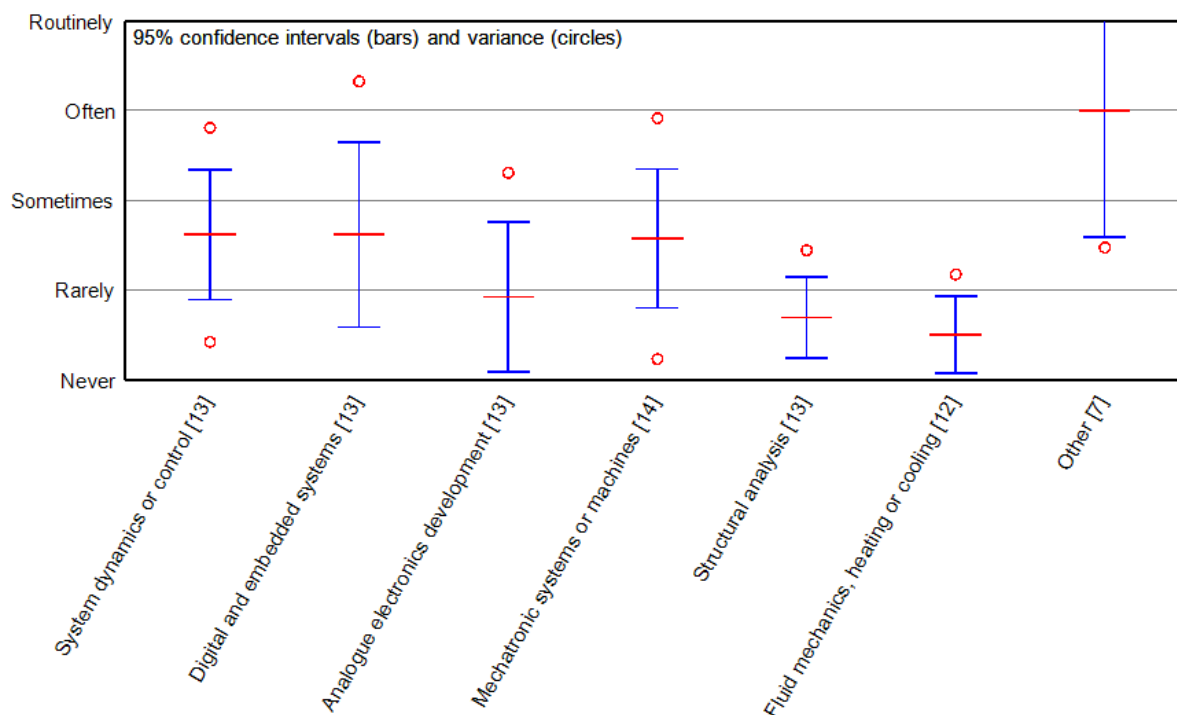


Figure 7. Responses for frequency of work in technical areas in mechatronic engineering

Discussion

The results give a useful impression of the situation inside South Africa, with the possible exception of the chemical engineers, since their response rate was so low. Regarding the extent to which the study's results can be applied outside South Africa, it is worth noting that the respondents in the survey indicated, in a question not reported above, that about 36% of their employers' work is for South Africa, 17% for the rest of Africa, 11% for Europe and between 5% and 10% for each of the Middle-East, North America, the Far East and Australia/New Zealand. This demonstrates that South African engineers work quite internationally and therefore the results presented in this paper will have some validity outside South Africa too.

The number of respondents was sufficient to draw useful conclusions from the results, with the exception chemical engineering. Although the confidence intervals for the means are quite wide (as were the standard deviations), that is also a reflection of the wide diversity of engineering work.

This diversity is clearly illustrated in Figure 1, where engineers "sometimes" work in nearly all of the "nature of work" categories listed on the horizontal axis. It is, however, notable that "project management" has the highest score, with the median response close to the "often" category, and that "general management", "consulting", "development of systems, processes, products" and "quality assurance" also received high responses. The mean of the responses for the "other" category was "rarely", which indicates that the categories provided in the questionnaire succeeded in capturing most of the nature of engineering work in South Africa.

The diversity amongst disciplines is shown in Table 5, where the significant disciplinary differences are shown for six of the "nature of work" categories.

The results of the section of the survey where respondents were asked to indicate how often their work involves each of a set of technical areas, are presented in Figures 2 to 7 for each discipline. The technical areas presented to the respondent were different for each of the engineering disciplines. In all of these figures, the large standard deviations for most technical areas indicate that there is a wide spread amongst the respondents, which is evidence that engineers in practice specialise in one or two categories within each discipline. Respondents are therefore likely to mark "often" or "routinely" in one or two categories and "rarely" or "never" in others.

Figure 2 shows that the confidence intervals for the chemical engineering results are so wide (due to the small number of respondents), that it would be inappropriate to draw conclusions for this discipline.

For civil engineering, Figure 3 shows that "construction and management" occurred most often, followed by "structural engineering". The other technical areas were all rated similarly. The mean for "other" is similar to the other technical areas, but the confidence interval is low since only 10 of the civil engineering respondents marked this category. Since this represents fewer than a third of the civil engineering respondents, it is reasonable to conclude that the technical areas presented to the respondents succeeded in capturing a substantial range of civil engineering work. From a curriculum design perspective, the results show that a civil engineering programme should aim to include all of the technical areas listed in Figure 3 since one standard deviation above the mean is close to "often" for all the technical areas, indicating that each of these areas have a significant number of engineers working in that area.

Figure 4 shows the corresponding results for electrical and electronic engineers. Here the response in the "other" category was also weak, indicating that the range of technical areas was adequately captured in the survey. "Software" and "energy" received strong responses for this discipline, while "robotics and control" received a weak response.

For industrial engineers, Figure 5 shows a high score for the "other" category, indicating that the survey only partially captured the range of technical areas for this discipline. Also, in this figure, the confidence intervals are quite large (due to a modest number of respondents), but the variation in the means are still larger than the confidence intervals. Figure 5 therefore indicates that a large number of respondents worked in areas related to "finance" and, to a lesser extent, in "transport and storage", while few worked in "mining" or "wholesale". It should be noted, however, that this discipline's categories were more aligned with economic sectors than with technical areas.

The responses for mechanical engineering (Figure 6) show that engineers from this discipline work over a wide range since five of the six technical areas provided have just about the same mean. Only "system dynamics or control" is lower than the others. As with civil engineering, Figure 6 gives justification for a mechanical engineering programme that covers a broad range of technical areas.

The number of respondents in the mechatronic discipline was low, as shown in Figure 7, resulting in wide confidence intervals. Further, about half of the respondents marked the "other" category which has a mean of "often". The latter indicates that the survey categories did not capture their range of work sufficiently. Keeping these caveats in mind, the survey results still show that the categories "structural analysis" and "fluid mechanics, heating or cooling" received very weak responses (the upper standard deviation marker is near "rarely"). These two technical areas were included in the survey for mechatronic engineers since the

latter technical area is included in SU's mechatronics programme as a specialist area, and anecdotal evidence before the survey suggested that a significant number of mechatronic engineers worked as mechanical engineers. The survey gives a strong indication that these engineers do more commonly work in areas that would be considered to be classical mechatronic engineering.

Conclusions

This paper has given a rare quantification of the types of work and the technical areas that are most prevalent for South African engineers. Although the survey has limitations in its general applicability (being limited to Stellenbosch University graduates), the results in the paper provide useful input to engineering curriculum designers. No recent publications with similar information, even for first world countries, could be found in a Scopus search.

All the respondents were considered together for the "nature of work" dimension. The survey here clearly showed that engineers work over a wide range of categories, with most categories offered in the survey having "often" as a response within one standard deviation of the mean. The "other" category in this part of the survey received a mean response of "rarely", indicating that the categories provided captured the breadth of engineering work.

For the technical knowledge areas, the results for the larger disciplines, i.e. civil, electrical & electronic and mechanical, are quite conclusive since the number of respondents was large enough to give confidence in the results and the weak responses in the "other" category indicate that the options provided in the survey captured most of these disciplines' technical areas. The number of respondents from chemical engineering was so low, that the confidence intervals for their responses were too wide to draw firm conclusions. For industrial and mechatronic engineers, the strong responses in the "other" category indicate that the survey omitted technical areas of significance for these disciplines.

This paper has therefore partially succeeded in answering the research question. For the larger disciplines, the results are convincing, but for the smaller disciplines, further study would be required. The paper also provides a base for further research surveying other universities' graduates which will provide a more complete picture of South African engineering work.

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A narrative of a meaningful relationship between technology and pedagogy using open educational practice

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Abstract

During Semester 2, 2016 the #feesmustfall (#FMF) movement prohibited students from accessing in-class learning to complete their remaining curriculum. In a bid to rescue the academic project a case of alternative pedagogy emerged in an undergraduate exit level subject. Open educational practice (OEP) was used to facilitate online learning. Students were managed through online content on the Blackboard learner management system (LMS), via LMS blog via WhatsApp. The learning material developed comprised videos, pdf Power Point material, a design workbook and LMS assessments. In light of the inequity of technological access and data requirements as brought about by #FMF, LMS activity was reduced to completing or uploading assessments by deferring the learning to WhatsApp using PowerPoint pdfs and audio clips. Feedback was provided regularly by either blog or email and additional assessments were made available to improve the overall result. A blog was used to assist the student in navigating the assessments. Due to anonymity, the blog could not be used as part of the student's major formative assessments however it reduced repetition by forming a repository of activities. Positive effects of online learning relates primarily to how the facilitator used technologies to achieve learning outcomes in light of the inequity of technological access. The measure of a meaningful relationship between pedagogy and technology is demonstrated by the evaluation of assessment results, student tracking to gauge response rates, a survey of student satisfaction and the lecturer's reflections of how open practice and other elements attributed to the success of the online learning experience.

Keywords: technology, pedagogy, open educational practice, blog,

Introduction

Since late 2015 higher education in South Africa has been heavily affected by student protests within the #feesmustfall (#FMF) movement. In both 2015 and 2016 universities had to close down over months-long periods due to those protests. Classes were cancelled and exams had to be postponed. In the first semester of 2016, as in 2015, the lecturer provided students with pre-lecture resources to help reduce their in-class cognitive load. Pre-lecture resources included YouTube videos, online reading material and some power point presentations. Blackboard assessments were used to test understandings and misconceptions. The evaluation of the implementation was measured by considering outcomes of more significant class tests. Findings from the class tests were that deeper understanding of the material took place due to

the pre-lecture resources. In mid-2016, the lecturer began developing open educational resources (OER) for this same subject as part of an institutional project. At the same time the lecturer participated in ongoing conversations around OEP, appropriate teaching methodologies and the use of social media in education. At the onset of #FMF 2016, the lecturer recognised that in-class learning was immediately and possibly indefinitely threatened. These earlier experiences helped the lecturer to formulate an alternative strategy in achieving the academic project; namely online learning. This strategy presented as a solution which would circumvent the challenges imposed by #FMF. The primary goal of online learning was to rescue the academic project as much as possible so that students could achieve the outcomes as close to normal as possible. The lecturer moved the remaining curriculum to Blackboard a couple of weeks before the formal shut down of the campus. The lecturer communicated the online learning strategy to students in the remaining classes in the event of a campus shutdown. A design workbook was developed and disseminated to students in the remaining class time. The lecturer instructed the students to look for the instructional videos which would be placed on Blackboard. A copy of the design workbook was also placed on Blackboard. Eventually campuses were shut down from October 2016 until January 2017. This paper recounts an experience between open educational practice and the use of technology toward completing the academic project in an exit level subject within an undergraduate engineering programme at Cape Peninsula University of Technology in semester 2, 2016.

Literature Review

The goal of the online learning experience was to construct learning material in a manner that would emulate the delivery of learning material in the classroom. This also required the lecturer to change her pedagogic practice to methods which supported online learning. OEP Guidelines (2011) provided an understanding of what OEP was and guidance toward the development of OEP in the lecturer's pedagogy. OEP practice contains the creation, use and management of open educational resources which attempts to innovate education.

Hegarty (2015) cites eight attributes of openness which is summarised as: 1. A participatory technology in which resources are freely shared, so that they can be reconstituted to a context and redistributed. 2. Openness and trust is a fragile thing and a student's willingness to learn is directly proportional to the level of trust that is evident in the management of the open tool. 3. Educational technologies must be used to develop innovative learning models that personalize experiences and with creativity. 4. There is a higher level of comfort among OEP practitioner's when there is a sharing of ideas and resources in the form of an interactive online presence or their material is a product of established practice. 5. Development of open resources which have meaning to the student is more likely to encourage a connected community of sharing and collaboration. 6. Learner-generated product is to be encouraged as they will share, discuss, reconfigure and redeploy. 7. Through collaboration and sharing, a reflective practice emerges toward a deeper understanding of open practice and flanked by a changed in pedagogical approaches. 8. Users publish open tools with peer interactions and

critique embedded into the learning experience becoming accustomed to the input rather than critique of others.

The lecturer had already co-ordinated and developed pre-lecture resources to reduce in class cognitive load (Seery and Donnelly, 2012). This material could be vetted by students and peers and thereafter be issued as OER with appropriate licencing in place such as creative commons licencing (CC-Wikipedia, 2011). This is one of several public copyright licenses that enable the free distribution of an otherwise copyrighted work. A CC license is used when an author wants to give people the right to share, use, and build upon a work that he/she has created.

The OER material was to be uploaded to Blackboard for easy access by the students. Studies show that the use of OER utilised alongside the LMS known as Blackboard can positively affect learning outcomes (Ruben, et al, 2010). Any positive effect relates primarily to how facilitators use technologies therefore where no meaningful relationship exists between the technology and pedagogy, the tools itself loses value (DeRosa et al, 2015). OER material was referred to directly in the students design workbook.

In this study new OER material took the form of worked examples carried out in Power Point or Excel, captured on video and narrated by the course notes. The initial student response rate and questions on the blog supported the belief that the material was adequate in closing the learning gap created by #FMF. However early on enough students communicated how expensive it was to access the material from Blackboard. Brown et al (2013) reported that students in Cape Town had limited internet access outside of tertiary institutions and identified free Wi-Fi locations in Cape Town where students could browse and download; observing a daily limit. The lecturer realised the most accessible hardware was the students cell phones and that WhatsApp was an established form of communication within the institutional programme. WhatsApp is a free messenger application that sends multimedia such as files, photos, videos, audios and simple text messages. Gon and Rawekar (2015) assessed the affectivity of social media like WhatsApp in delivering knowledge to 4th semester students and to compare the improvement of knowledge gain through e-learning and didactic lecture. Two groups of students were taught the same topics by two different Teaching and Learning activities i.e., through WhatsApp and via didactic lectures. Assessment of knowledge was done by giving pre and post-test questionnaire of 20 marks for each topic. The marks difference was not statistically significant. It was recommended that contact times be set and thematic responses be given respectively. This study supported the lecturer's decision to reformat the learning material to pdf format with audio clips where needed and disseminate it via WhatsApp.

Gomez, J (2010) conducted a study evaluating student perceptions of the pedagogical use of blogs in the classroom. Opinions was collected from second and third year students in different faculties through discussions which were hosted before and after a blog design assessment as well as emails between teacher and student as a way to measure doubts, preconceptions, and reflections. Common opinions were grouped (thematic analysis) together and findings indicated that blogs enhanced motivation, acted as a repository of activities, aided technological literacy, made more training necessary for teachers, required better

infrastructure, was an aid to teaching, helped in changing the traditional teaching and made better management of technological resources necessary. However in this study students used the Blackboard blog to communicate questions on the assessments. The posts or emails put forward by students was recorded anonymously by the lecturer before it was circulated on blackboard or email as it was one of the requirements of #FMF was not to be seen actively learning. Students also commented on learning material. This feedback subsequently led to the revision and reissue of learning material. The questions in the blog formed a repository of activities which other students could use to supplement understanding and reduced repetition by the lecturer. Eventually the questions stopped as there was simply nothing left to ask. Unfortunately as the students use this tool anonymously and it could not be used as part of their assessment portfolio. The order of activities on the blog also assisted students with easier navigation of the design concepts.

Fedynich (2015) conducted a study wherein graduate students perceptions of online learning were measured by way of a survey to identify positive components that led to their satisfaction and perceived challenges that inhibited it. The survey related to topic areas such as 1. instructional design and delivery, 2. assessment and feedback/lecturer roles, 3. student roles and responsibilities, and 4. management and support systems. The statements on the survey were grouped into four major topic areas which underpinned the research question of the study, namely one of student satisfaction with online learning. Some questions addressed more than one category. Findings from the study indicated that students were satisfied in all topic areas. The lecturer's role was identified as being vitally important to students' satisfaction. Challenges identified were the need for varying instructional design and delivery to facilitate students' desire to learn. In this study *to ensure that students were engaged in a meaningful experience*, student opinions was necessary to inform of the online experience and the institution as to the quality of this specific undergraduate programme during the S2-2016 semester. Hence this survey was adapted with permission by the author and expanded to suit the needs of this online experience

Objective

The aim of the intervention was to deliver the remaining academic project in a meaningful manner that would allow students to achieve their outcomes and to measure their experiences to this end accordingly. This objective is translated in to the research questions below.

1. What was the student response?
2. What was the impact of the online experience on the student's marks this semester as well as compared to other semesters?
3. What was the student's perceptions of the online experience?
4. Was the lecturer's pedagogic practice open enough toward successful delivery of the academic project during #FMF?

Methodology

Blackboard was already used to host course notes and a few theory based multiple choice assessments. Data collection involved the student response rate, distribution of student grades, student perceptions of online learning and the lecturer's reflections of the online learning experience. The data collections are explained in more detail below.

Response Rate. Each assessment was tagged with a tracking function. Data was collected through the analysis of student activity (peaks and dips) and the influences which might have caused it, e.g. when students became active, changes in the delivery of the academic project, due dates, etc.

Assessments comprised three design concepts, a project report and laboratory report with a weighting of 5%, 15% and 15% respectively toward the final result. An anonymous Blackboard blog was established to answer questions pertaining to any of the assessments. Copies of the blog was also emailed to the students on a weekly basis to stimulate their thinking. Data is extracted here as grade distribution reports with emphasis placed upon a distribution of >70% and <49% as indicating high and low competence respectively. The distribution of 50% - 59% indicates there is surface engagement with the learning material whereas 60% - 69% indicates a deeper engagement with the learning material and synthesis of knowledge to the design context. Data collection surrounding the use of a Blackboard blog is taken up in the student survey. Specific assessment analysis is discussed below.

- The three design concepts took the form of calculations. A design concept was taught by video which conveyed the various contexts and demonstrated a sample calculation. The students understanding is assessed on Blackboard via multiple choice assessment of another example. Each of these calculations reflected a methodology comprising critical steps. Each critical step was posed as a question in the assessment. The choice of answer includes the correct answer as well as other possible answers based upon their interpretation of the information provided. Thus later questions (steps) in the assessment can be affected by earlier selections in the assessment. The score achieved is a reflection of the student's competence of that particular concept and informs the lecturer holistically if and where intervention is required for that assessment. An intervention could be an email to all students addressing a particular concern followed by a second attempt at the assessment.
- Project and Laboratory reports assess integrated knowledge of the earlier design concepts as well as subjects completed earlier on in the programme. The student's competence is graded by using a plagiarism item on Blackboard, a memo to check calculations and a rubric for essay and report evaluation. The report was retrieved from the plagiarism submission, marked and returned in pdf format via email. Given the narrow feedback window only incorrect elements were commented on. After the assessment closed students were given holistic feedback on elements which required reflection ahead of the final test.

- In the three preceding semesters, almost identical assessments had been carried out and had been supplemented with power point presentations in class and circulated to students thereafter. Therefore a trend analysis of student performance was carried out against the three preceding semesters to measure comparative performance as well as the consistency of the lecturer's pedagogic practice.

An *online survey* released midway during #FMF allowed for the student perceptions of the online experience to be captured. The survey employed both Likert Scale statements and open ended questions. The Likert Scale employed the variations of Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree. In the analysis of the results an allowance is made for unanswered questions. The score for Strongly Agree and Agree is added together (similarly for Disagree and Strongly Disagree) to indicate the statement result. The 23 Likert statements are grouped together into nine topic areas (see objectives) and the averaged result indicates the student perception per topic area. During sorting it was found that many of the statements applied to more than one category. The 4 open ended questions were analysed using thematic analysis where either themes or repetitive phrases guided the groupings. The survey questionnaire and question groups per topic area are shown in the appendix.

The *lecturer's reflections of the online experience* consisted of an evaluation of the openness of her pedagogic practice as per the attributes of open practice as defined by Hegarty (2015). Further she discusses the effect of hardware, software and the role of the lecturer and student in the online learning experience.

Discussion

Student Response

A minimum response of 81% of registered students completed assessments during #FMF. Figure 1 overleaf (right hand side) lists the assessments as they should have been completed. At commencement of online learning, an immediate and steady level of activity is visible in October 2016 (graph) with an initial spike in the second week of October. This spike can be attributed to the advent of WhatsApp and email somewhat in distributing pdf learning material such as power point presentations of videos and copies of the blog. There is a lower distribution of activity on the LMS in November with two spikes on the 11th and 18th of the month respectively; both assessment due dates. The months of October and November show a similar level of activity holistically (left hand side), however the lower distribution of activity on the LMS in November reflects the influence of WhatsApp in effectively distributing learning material and reducing LMS activity.

Up to 25 (19%) registered students completed their assessments after the resumption of the academic project in early January 2017. These students completed their assessments in the same manner as done during #FMF. The only exception was that there was no active discussion on the blog as all possible questions had already been asked, hence it was used as a repository of activities. Also the lecturer was formally available to them (as per timetable)

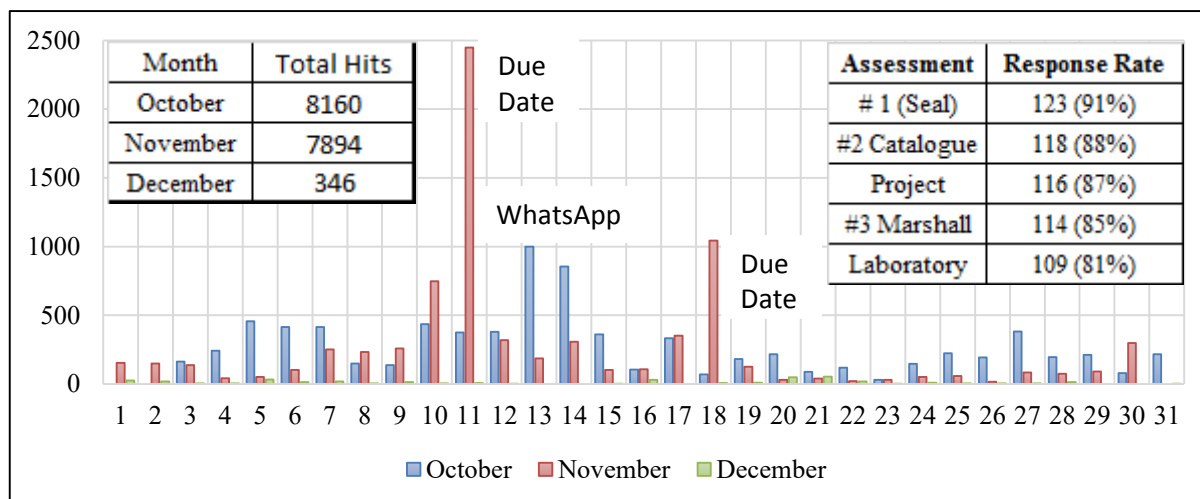


Figure 1: Daily/Monthly Student Activity on LMS (one subject only)

however class attendance was a handful of students who had already completed the required subject work and used the time and venue to complete other academic work.

Assessments are presented as Design Concepts, namely Assessment #1, #2 and #3 below as well as Project Report and Laboratory Report. In Assessment #1 (see Table 1 below), 56% of students did not complete the assessment successfully. There were no videos here as the content had already been taught during class time and examples had been supplemented with memos in the course material. Further the blog conveyed a lengthy exchange between lecturer and students on the individual design examples. There were late requests for videos here which was refused given the earlier in class learning. Significantly more than 40% of students were successful in this assessment with 10% achieving well. One could conclude that the in class offering and blog was not unsuccessful. Conversely the high failure rate could also be a reflection of those students who made a late start with their cognitive load, reducing the amount of time available to them to navigate concepts successfully. Assessment #1 was not assigned a second attempt; however the possibility exists that there could have been an improved result here in lieu of a second attempt.

Table 1: Assessment Distribution

Distribution (%)	#1 Seal	#2 Catalogue	Project	#3 Lab Ass	Lab Report
90 – 100	3%	68%	0%	8%	8%
80 – 89	3%	4%	2%	3%	48%
70 – 79	4%	4%	13%	8%	21%
60 – 69	8%	6%	39%	40%	17%
50 – 59	26%	5%	27%	24%	1%
40 – 49	20%	3%	18%	11%	0%
< 40	36%	10%	1%	6%	5%

Conversely Assessment #2 indicates a higher number (87%) of students achieving success. The improved result over assessment #1 (43%) can be attributed to a video and a second attempt

on the LMS. Videos allow students to revisit material as often as is necessary to grasp the concept.

The integrated context of the project reflects pre- and co- requisite knowledge along with the core subject knowledge. The student is required to group data to be representative of the smaller design calculations (known context). Much of the errors of assessment #1 were carried over into the project. The distribution of the project was boosted by the higher competence of assessment #2. Based upon the pass rate (81%) students can achieve the assessment criteria which includes amongst others a recall of knowledge, applying familiar problems and applying relevant knowledge to a specific context. The 15% achievement at the higher end of the grade distribution (>70%) indicates that few students demonstrate a competence of application of unfamiliar problems and critical analysis taking into account the subject knowledge and procedures. A review of the blog shows that activities were more focused on the smaller design concepts with little queries around the practical meaning of the end result.

Laboratory work is formulaic and can be successfully completed using Excel. However the student's competence in using Excel can reduce their ability to interpret the results correctly. The video here addresses both technical competence in Excel as well as the design concept. The grade distribution of Assessment #3 is more consistent than Assessment #1 and #2. The laboratory report demonstrates a strong performance as a result of synthesis from Assessment #3. Although there was no discussion on the blog to support laboratory work it is evident that the video addressed all design concerns. It is worth noting that in the closed book final test a high number of students were able to complete this calculation indicating cognitive understanding.

Figure 2 overleaf provides a trend analysis of assessments grade distributions for the last four semesters. The alternative pedagogy used to deliver the Laboratory assessment (s2-2016) did not detract from the student's mastery of the concepts, rendering this assessment with displaying the most consistent trend along with preceding semesters. This trend in Laboratory assessment is defined by a deviation of less than 10% within each grade distribution, a decrease in the '60% - 69%' distribution and a seemingly proportional increase in in the '>70%' distribution. This positive and consistent shift over consecutive semesters is an attribute of steady pedagogy which was well translated into video material. Trends in the Project assessment indicates a high pass rate of almost 80% over consecutive semesters. Further there is a decreasing trend in the lower distributions (50-59%) and an increase in the higher distribution (60%-69%). This is noteworthy as cumulatively these two distributions are where most of the earlier 80% of passing students are achieving, indicating that these students are engaging more meaningfully with their design work and achieving their exit level outcomes. This could very well be as a consequence of the older online material and more recent videos which underpin the student's deeper engagement with course material. At first glance, trends in the Final test, which comprises mostly design work and some parts theory, render a rather poor result of almost 50% of student achieving a distribution of <49%. The lecturer has noted over consecutive semesters that in the Final Test, students would perform poorly in one area

of design and in the theory sections, hence the poor cumulative performance as depicted in Figure 2. Upon closer inspection there is a significant deviation within the distributions ($>10\%$) and ultimately a downward trend for this assessment. It would appear that students perform poorly in the summative assessments in contrast to the upward trend of the formative assessments. The greater weighting of the formative assessments sway the final outcome in the students favour. However the positive trends in some assessments are noteworthy in lieu of the gradual introduction of various learning resources over the last few semesters allowing deeper individual engagement by students. This could possibly also have been enhanced by the isolation imparted by #FMF instead of the more prevalent peer to peer learning in normal learning conditions.

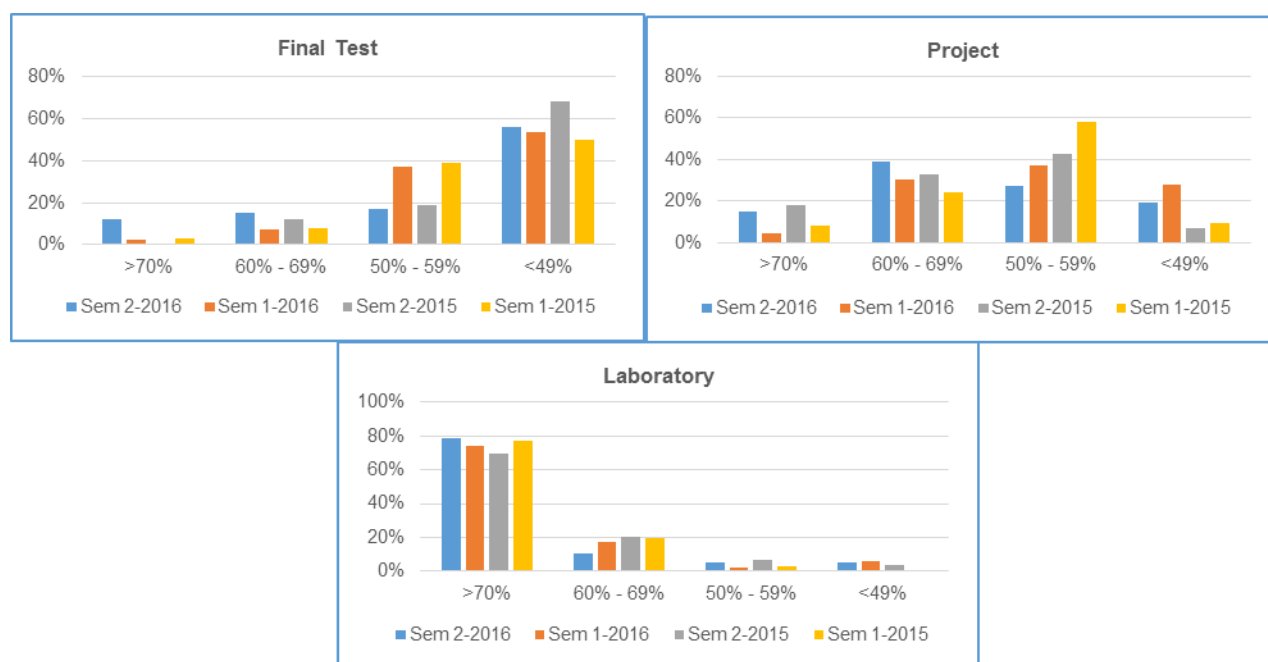


Figure 2: Trend Analysis of Grade Distribution in 2015 and 2016 (various assessments)

An initial sluggish response to the *survey* motivated the addition of 0.5% toward their final grade upon completion of the survey. Seven of the nine topic areas were addressed by Likert Scale design. As presented in Figure 3 overleaf, students were similarly satisfied ($>70\%$) with five of the seven topic areas, which is discussed individually hereafter.

Student satisfaction with the *instructional design and delivery of a material* is mostly achieved by the multiple ways in which students could participate (Item 6) and by multiple activities which develop critical thinking skills (item 13). The most significant disagreement (10%) was that online courses did not promote a student's desire to learn in disruptive learning environments.

Students were satisfied with *teacher roles, including feedback and assessment*. The instructor facilitates the desire to learn by providing clear instruction (item 9), multiple opportunities to interact in a variety of ways (item 16) and to develop critical thinking skills (item 13). The instructor facilitates student self-motivation (item 7) through the use of a variety of sources

(item 12) meant to assist student learning. Therefore the instructor, as evidenced by this survey and earlier assessment analysis, had the most effect on student satisfaction.

Students were satisfied with their *student roles and responsibilities as it contributed to a positive experience with an online class*. Although the disrupted context provided limited opportunities for interaction with each other (item 4), it was countered by the blog which formed a repository of activities. This was an effort toward simulated interaction and multiple portals for participation (item 6). As with design and delivery of material, the most significant disagreement (10%) was that online courses did not promote a student's desire to learn in disruptive learning environments.

The course contained sufficient material (item 9) and learner support (item 10) which linked to on/off campus resources. Based upon the help provided by the instructor and the facilitation of numerous process, the students were satisfied due to the *management and support systems in providing services as needed*.

From earlier discussion around student response increasing after the advent of pdf learning material disseminated by WhatsApp and email, students are then satisfied with the *online learning in place of the in-class learning as it offers convenience, individual learning, communicating effectively, sense of community and greater all round participation*. However

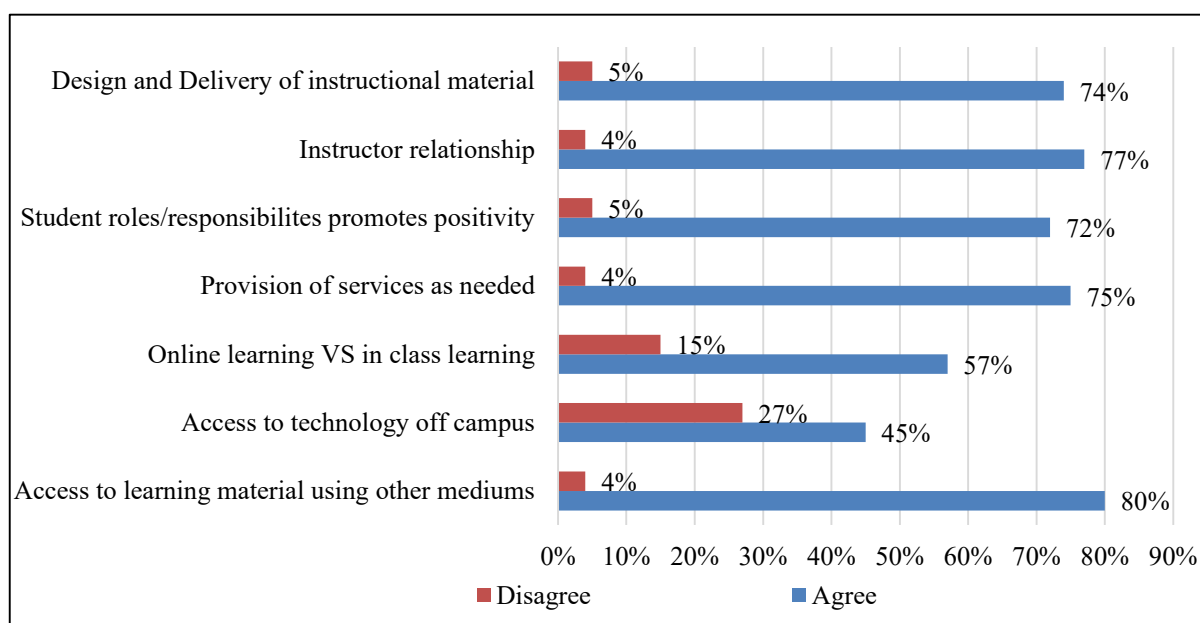


Figure 3 Student Satisfaction

this participation did come at a greater sacrifice for a large proportion of students by way of cost and access hence the significant dissatisfaction here; ranging from 14% to 20%. The most dissatisfying item was noted as individual learning needs not being met through this form of pedagogy (item 18).

Access to opportunity was by far the greatest challenge during this time. Although ultimately students were able to successfully *access technology off campus*, the journey there was more

uncomfortable and laborious than normal as there is a high proportion of students who depend on the on campus resources with a little alternate opportunities. Access to computers (item 22) and access to the free internet portals (item 24) were managed through the disruptive context but there were limits to the free data and ultimately students were out of pocket hence the high dissatisfaction with access to internet at 40% (item 23). Approximately 12 students resumed their academic project after #FMF in the normal way but used the resources as provided to complete their assessments with no in-class support.

Students were satisfied with *instructional material communicated in various mediums on various platforms* (item 25); in particular the advent of learning material on WhatsApp which drastically reduced their time spent online; reducing internet costs.

Thematic Analysis was used to analyse the open ended questions, namely item 27 and item 28 in Table 2 overleaf. The more common benefits identified by students were the better management of resources, a change to traditional teaching methodology and the blog repository of learning activities which reduced repetition. This inspired students toward learning at a consistent pace. This awareness also speaks to the advancement of their technological literacy

Table 2: Thematic Analysis of Benefits and Drawbacks

	Benefits	Drawbacks
Most Common Themes	Better management of resources Change to traditional teaching methodology Repository (reduced redundancy)	Unrealistic Expectations from academia Design/Delivery./Feedback not in balance Extenuating circumstances not considered No Internet Access
Less Common Themes	Enhanced graduate attributes Enhanced motivation Collaborative Learning Technological Literacy	Pace too slow Limited safeguards against plagiarism Perceived increase in workload Learner demotivation

as well as their competency in accepting change to the traditional teaching methodology and enhanced graduate attributes. In contrast the drawbacks seemed focused on Design/Delivery/Feedback of the online learning as well as the unrealistic expectation of the student reciprocally. In particular students cited the structure of posting on the blog as random and not ordered in a manner conducive to the online process supported by an unrealistic expectation of students understanding without adequate feedback or collaboration. To a lesser degree other drawbacks were internet access, slower pace, extenuating circumstances not being considered, no collaborative learning, too much work, demotivation and that the online medium did not work for the student..

Lecturer's reflections

The lecturer's primary objective was to construct learning material and make it easily available to the student and in so doing the students could possibly complete the academic project and achieve their subject outcomes This strategy required a change in the lecturers pedagogy,

namely becoming more open in her pedagogic practice. Although the lecturers practice was not strictly open according to Hegarty, 2015, as it was defined by the use of an LMS platform and a closed WhatsApp group, it successfully served the need created by #FMF. Hegarty (2015) indicates that lecturers immersed in OEP and creating OER will change their practice and develop ‘specific attributes to their open practice’, so the lecturer’s pedagogy is measured against the eight attributes (#) of open practice below (#) below:

- #1 OER material was well used by students and revised according to their contributions and as such can be considered to be *a participatory technology*. The learning material was *freely shared* on multiple platforms as described earlier.
- #2 *Openness* by the lecturer and *trust from the students* was visible by the student’s willingness to learn via the management of the open tools.
- #3 Through literature review and experience, the lecturer identified *educational technologies* and *used them to develop an innovative learning model*.
- #4 There was a high level of comfort by the OEP practitioner as there was a *sharing of ideas* with students and subject moderator and *extensive use of the resource* by the student as evidenced by the positive grade distribution and student satisfaction discussed earlier.
- #5 *Open resource material* developed by the lecturer and contributed to by the student and subject moderator *had meaning to the student* and encouraged an informal *connected community through sharing and collaboration* on the various learning platforms.
- #6 The video material somewhat *reflected learner-generated product* as it was used successfully by the student but also shaped by their contributions and requests for specific video material.
- #7 Reflective practice emerged through *collaboration and sharing* with students and the subject moderator toward *a deeper understanding of open practice* culminating in the lecturers *changing pedagogical approach*.
- # 8 This attribute became applicable when the OER material was placed on the institutional OER platform in early 2017 where the material *is open to peer interactions* (review) and *critique becomes embedded into the learning experience* thus enabling the creator, namely myself, to become accustomed to the input rather than critique of others.

There were other elements which was critical to the success of the online experience, namely

- The Blackboard LMS provided all the tools which allowed for easy housing, dissemination and assessing of the learning material. Specifically tracking, blogging, tests and survey tools which allowed the lecturer to communicate with students and measure their performance afterward.
- Licencing for other programs which develop and capture the learning material
- The lecturer’s body of experience to date which supplemented the competence of the online experience. This included the development of OER as part of an institutional OER project and participating in ongoing discussions on different mediums for presenting learning material and assessment. The lecturer enjoyed a high level of confidence using hardware and software applications and where necessary learned and experimented with technology without compromising the students’ academic project.

- The student's willingness and commitment to work under difficult circumstances to complete their academic project (e.g. threats of violence if students were seen to be studying, working to submission dates although there was no guarantee of meeting them, etc.), their willingness to use their own computers or source computers and cell phones to engage the learning material, their trust in the lecturer and their contributions on the blog, via WhatsApp and email toward developing the learning material.

Conclusions

The instructor's role is the most important element of online learning, particularly in a disrupted context. There must be clear instruction, organisation, learning tools and a variety of ways to communicate. Students responded to online learning with more vigour when access to learning material became less arduous. Similarly the overall grade distribution of students who participated online during #FMF and after were mostly successful with a final pass rate of over 90%. Further the achievement of the subject outcomes provide a very similar trend to previous semesters where the same assessments were undertaken. Students have expressed a high degree of satisfaction with the course design, delivery and feedback as well as provided suggestions to assist in areas of dissatisfaction such as limited internet access. From the online learning methods employed and the data analysed (particularly grade distribution, survey and the measurement of open practice) it is clear that students and the instructor enjoyed a meaningful exchange between pedagogy and technology through the medium of contextual OEP.

Recommendations

Earlier analysis of the survey and attributes of open practice supports the following recommendations toward improving the online learning experience.

- Asking students for their ideas (e.g. survey or specific comments on learning material) toward developing open educational resources with technology will produce resources which is meaningful to the student and part of an effective learning model. Further it can reduce cognitive load in class by being referred to as part of the subject pedagogy and being made accessible on local or external learning platforms. Learning opportunities for peer to peer interaction and communication around these resources can ensure that they are adapted or revised as needed and reissued.
- Learning opportunities such as the use of blogs promote a sense of community between peers but more so when not used anonymously. It can be used as learning tools which promote active learning for both the instructor (by way of instruction), promote active learning for the student by way of independent and peer to peer learning, promoting deeper engagement with the learning material (e.g. videos or text), particularly if the blog is hosted on an external platform, as the external interaction with more learned peers will lend credibility to the students learning and to the open learning material

These are but a few practices which will enable communities of learning and enhance graduate attributes such as communication and self-management.

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APPENDIX: Survey instrument

"Student Perceptions of Online Learning" TRANSPORTATION ENGINEERING III S2-2016

This survey is intended to explore issues of Instructional design and delivery, 2. Assessment and feedback/lecturer roles, 3. Student roles and responsibilities, 4. Management and support systems, 5. Levels of Satisfaction, 6. Benefits/Drawbacks of online learning, 7 Effectiveness, 8. Access and 9. Communication from a student perspective related to online learning in a particular context. Participating graduate students will reflect on the experiences they have had in a particular online course. All students are registered for the course; hence no form of identification is required.

1: How did you know the course was provided online?

2: Ethnicity

(a) White (b) Black (c) mixed race

3: Online courses promote a student's desire to learn in disruptive learning environments.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

4: During *disruptive and unsafe learning environments* students have limited opportunities to interact with one another.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

5: The online course identified clear topics and students are provided with instructions for completing assignments in a timely manner.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

6: The online course provided assistance on how to participate by way of a blog, email and WhatsApp.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

7: The online lecturer provided explanatory feedback which facilitates learning (blog, email & WhatsApp transferred to blog).

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

8: Students have to be self-motivated to be successful in this online program.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

9: This online course contained sufficient course material (course notes, design book, online references) and learner support (video, blog, WhatsApp) which linked to on/off campus resources (course material, computers and access to internet).

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

10: This online course provided sufficient contact information for the lecturer (email, blog, text, WhatsApp)

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

11: Online courses facilitate learning in students of diverse learning styles and personalities.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

12: Online courses utilise a variety of sources which assist student learning (manuals, guide-lines, articles, websites, etc.).

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

13: This online course provides multiple activities for students to develop critical thinking skills.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

14: This online course provides for feedback; formative (test), continuing assessment (blog for project) and feedback on assessment performance (email) to students about their performance throughout the semester (Blackboard)

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

15: Online instruction provides feedback to guide learning in a timely manner.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

16: During online courses, students are able to get help (blog, email, text, WhatsApp) when they have questions.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

Please rank the effectiveness of online learning (blog, videos, emails, notes, tests) compared to meeting regularly in a classroom setting.

17: *It offers convenience.*

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

18: *It meets individual learning needs.*

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

19: *It can contribute to effective communication in the classroom.*

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

20: *It increases your sense of community with the author and fellow students.*

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

21: *It promotes greater student participation and interaction.*

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

22: You have access to a computer off campus?

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

23: You have access to the internet off campus?

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

24 Online assessments are possible via free internet portals.

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

25: Instructional material is provided in other mediums for alternative distribution (e.g. pdf's & audio clips on WhatsApp/blue tooth, blog instruction from course notes circulated by email).

(a) Strongly Agree (b) Agree (c) Neutral

(d) Disagree (e) Strongly Disagree

26: Suggest an alternate instructional medium. E.g. audio recordings, in-depth course notes, Facebook, twitter

27: What do you think is or might be the greatest benefit of online learning?

28: What do you think is or might be the greatest drawback?

29: Is there anything else you would like to add about online learning?

APPENDIX: Survey question groupings and results

Effect of instructional design and delivery of a material on student satisfaction (%'s)

	SA	A	N	D	SD	Un
11: Online courses facilitate learning in students of diverse learning styles and personalities.	44	25	11	6	3	11
12: Online courses utilise a variety of sources which assist student learning (manuals, guidelines, articles, websites, etc.).	40	34	13	2	0	11
13: This online course provides multiple activities for students to develop critical thinking skills.	45	35	7	3	0	10
3: Online courses promote a student's desire to learn in disruptive learning environments.	33	34	13	5	5	10
4: During disruptive and unsafe learning environments students have limited opportunities to interact with one another.	23	54	6	5	1	11
5: The online course identified clear topics and students are provided with instructions for completing assignments in a timely manner.	40	38	9	4	0	10
6: The online course provided assistance on how to participate by way of a blog, email and WhatsApp.	33	47	9	3	1	9
8: Students have to be self-motivated to be successful in this online program	5	59	6	0	0	10

SA (Strongly Agree); A (Agree); N (Neutral); D (Disagree); SD (Strongly Disagree); Unst (Unanswered)

Effect of teacher roles, including feedback and assessment on student satisfaction (%'s)

	SA	A	N	D	SD	Un
7: The online lecturer provided explanatory feedback which facilitates learning (blog, other media transferred to blog).	46	31	7	4	3	9
9: This online course contained sufficient course material (course notes, design book, online references) and learner support (video, blog) which linked to on/off campus resources (course material, computers and access to internet)	48	30	9	3	0	10
12: Online courses utilise a variety of sources which assist student learning (manuals, guidelines, articles, websites, etc.).	34	40	13	2	0	11
13: This online course provides multiple activities for students to develop critical thinking skills.	35	45	7	3	0	10
14: This online course provides for formative (test) or continuing assessment (blog for project) and feedback (assessment performance) to students about their performance throughout the semester (Blackboard)	44	38	8	0	0	10
15: Online instruction provides feedback to guide learning in a timely manner.	38	36	12	3	1	10
16: During online courses, students are able to get help (blog, email, text, WhatsApp) when they have questions.	43	30	11	3	2	11

Effect of student roles and responsibilities are important to a positive experience with an online class (%'s)

	SA	A	N	D	SD	Un
3: Online courses promote a student's desire to learn in disruptive learning environments.	34	33	13	5	5	10
4: During disruptive and unsafe learning environments students have limited opportunities to interact with one another.	54	2	6	5	1	11
6: The online course provided assistance on how to participate by way of a blog, email and WhatsApp.	47	3	9	3	1	9
8: Students have to be self-motivated to be successful in this online program	59	5	6	0	0	10

Effect of management and support systems in providing services as needed (%'s)

	SA	A	N	D	SD	Un
5: The online course identified clear topics and students are provided with instructions for completing assignments in a timely manner.	38	40	9	4	0	10
9: This online course contained sufficient course material (course notes, design book, online references) and learner support (video, blog) which linked to on/off campus resources (course material, computers and access to internet)	48	30	9	3	0	10
10: This online course provided sufficient contact information for the lecturer (email, blog, text, WhatsApp)	40	32	13	3	1	11
16: During online courses, students are able to get help (blog, email, text, WhatsApp) when they have questions.	43	30	11	3	2	11

Effectiveness of online compared to in-class learning (Q19 to Q23) (%'s)

	SA	A	N	D	SD	Un
17: It offers convenience	27	31	14	15	2	11
18: It meets individual learning needs.	23	31	14	15	5	12
19: It can contribute to effective communication in class	31	33	14	7	3	12
20: It increases your sense of community with the lecturer and fellow students.	22	31	20	13	3	11
21: It promotes greater student participation and interaction	23	35	17	10	4	11

Access to technology off campus (Q22 to Q24) (%'s)

	SA	A	N	D	SD	Un
22: You have access to a computer off campus	29	17	11	13	18	12
23: You have access to the internet off campus	21	18	10	16	24	11
24: Online assessments are possible via free internet portals.	20	31	28	6	3	12

Instructional material communicated in various mediums on various platforms (Q25) (%'s)

	SA	A	N	D	SD	Un
25: Instructional material is provided in other mediums for alternative distribution (e.g. pdf's & audio clips on WhatsApp/blue tooth, blog instruction for course notes circulated by email).	33	47	5	2	2	11

Reflections on solving problems: Teaching and learning

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Abstract

This study reports on the experience of developing one's academic competency as a critically reflective lecturer against the backdrop of an educational research project focused at the development of engineering students' problem-solving skills. The context of this study is in teaching and learning environment of a 2nd year engineering mechanics course, where the poor performance of students in assessments was attributed to their poorly developed problem-solving skills. A design-based method was used to plan classroom interventions that address this problem, where an iterative process was used to continually improve the efficacy of the solution. The first iteration of the project design utilised simplistic methods to approach a complex problem. Critical reflection on the scope and limitations of the classroom interventions facilitated the design of more complex, scaffolded learning opportunities that allowed students to translate between different modes of problem representation. It also facilitated the simultaneous development of the lecturer's pedagogical competency, while situating the development within the teaching environment. Throughout the project design process, the lecturer's conceptual understanding of the pedagogical landscape gradually deepened through engagement with theories and research that were appropriate at each stage of the project; this, in turn, resulted in a more appropriate and effective design of the learning environment. The focus of the project changed as problem-solving changed from being seen as skill that was to be acquired, to rather a competency that was to be developed. The effective development of competency relies has a strong temporal and iterative, experiential aspect. The reciprocity of the lecturer-student experience is highlighted as essential in the development of both the lecturer's pedagogical competency as well as the creation of an improved learning environment. The crucial link between teaching practice and learning outcome is critical reflection.

Introduction

One of the core competencies that an engineering student is required to develop is the ability to solve complex, ill-defined problems. This is an Engineering Council of South Africa (ECSA) Exit Level Outcome (ELO) for accredited engineering degree programmes, and as such, the curriculum is designed to lead the students through increasingly more complex and poorly defined problems in order to build this competency (ECSA, 2014). If one looks at the typical engineering curriculum, problem-solving skills are not explicitly taught; rather, students start off solving well-defined, relatively simple problems within foundation level courses, such as mathematics and applied mathematics. As they progress along the degree programme, the course content becomes more integrated, incorporating foundational knowledge and expertise into field specific theories and perspectives. Consequently, the problems that the engineering student are required to solve become increasingly more complex, divergent and ill-defined as they progress through their four year degree.

Similarly, many university lecturers have no formal pedagogical training or at best are given a superficial introduction to teaching and learning strategies that can help to improve the effectiveness of their lecturing (Leibowitz *et al.*, 2015; Boud & Brew, 2017). The result is often that initial approaches for developing improved teaching and learning practice may start off in routine, familiar spaces (teaching how we were taught) with systematic classroom implementations at a technical level, and simplistic interpretation of pedagogical theories and strategies. The results of these interventions may be less than encouraging. Without critical reflection, one runs the risk of superficial explanations and evaluations of the results, and stunting one's development as a teacher (Ashwin *et al.*, 2015).

Both the engineering student who is struggling to solve problems that are assigned in class and the engineering lecturer who is struggling to design an appropriate learning environment benefit from following a systematic approach to solving their respective problems. It is in this context that this particular study is situated. In a 2nd year engineering mechanics module in a South African university degree programme, the pedagogical problem of how to develop students' problem-solving skills was tackled as part of a research project, funded by the institution's teaching and learning development programme. It was over the course of this project, that ran for two consecutive years, that the continual development of new, more effective classroom interventions occurred, and was informed by the assessment of and reflection on the efficacy of the previous classroom interventions.

Methodologies and framework

The concept of evaluating and improving the design of a project, based on reflection of the current progress, whilst still situated within the project is aligned with a design-based research methodology (Hoadley, 2004). Design-based methods are similar to practice theory; practice theory is proposed as a useful lens through which to view the academic development of a lecturer as they learn to teach (Boud & Brew, 2017). The development of lecturer's teaching practice occurs within their teaching and learning environment (their classroom, in their department, in their faculty, in their institution, with their students) through interaction with this environment. In this study, design-based methods are used to model the progression of this educational research project as well as the simultaneous development of the lecturer's teaching practice within the scope of the project.

Critical reflection on the pedagogical value of each design iteration results in broadening the lecturer's understanding of their practice, while simultaneously improving the design of a more suitable solution for the learning environment. Reflection is indicated as an effective method for the development of strong practice, especially when the reflective practice moves beyond a basic, descriptive level of reflection (reporting one's observations and responses) towards a more complex, critical level of reflection (using theory and experience to interrogate and ultimately transform one's practice) (Ryan & Ryan, 2013). Pollard's model of reflective teaching (Pollard, 2014 as cited in Ashwin *et al.*, 2015) describes the dynamic and cyclic process whereby evidence is *collected*, *analysed* and *evaluated*; then, after *reflection*, a *plan* of action is created and *enacted*, as illustrated in Figure 1. If the level of reflection is critical, then the consecutive iterations within Pollard's model transform the practice and move the practitioner up, spiralling through increasing levels of competency in teaching.

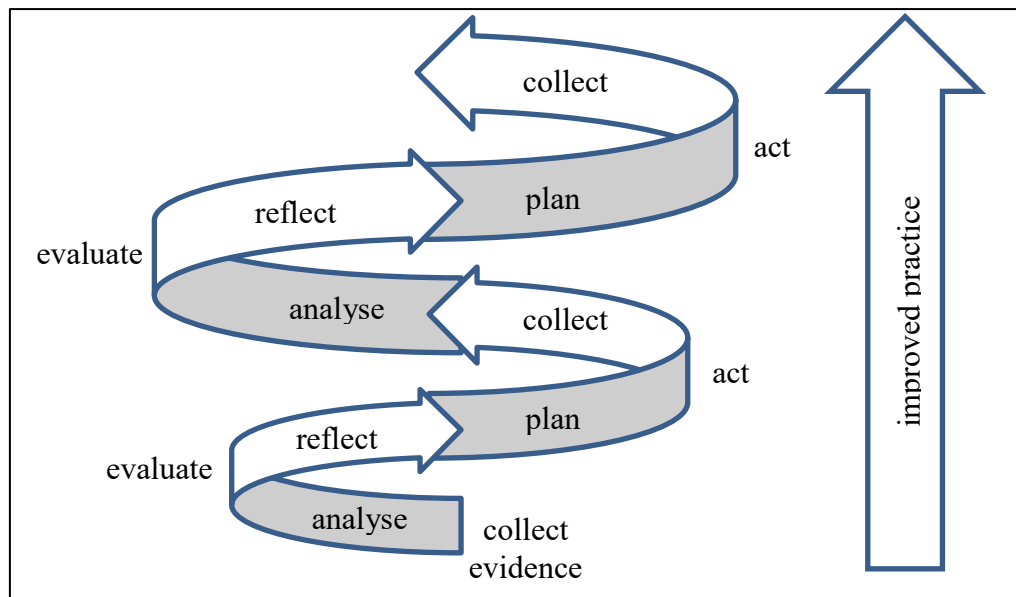


Figure 1. Pollard's model for reflective teaching, adapted from Ashwin *et al*, 2015 to illustrate the effect of transformative, critical reflection on the development of practice.

In order to illustrate how reflective teaching facilitated both the progression of the research project through consecutive design iterations as well as the journey of the lecturer in learning to teach, a variety of data (or 'evidence' in Figure 1) were collected; these included self-reports¹ such as teaching journal entries, anecdotal observations, reflections, literature studies, and project progress reports, as well as student and tutor feedback. This data is presented as an autoethnographic study in this paper, where the author uses their own reflections to inform the research. Ethnography is a research methodology that is emerging in the field of engineering education, and has been used effectively to describe the process of developing a protocol for teaching reflective practice in an academic development environment (Case & Light, 2011; Hains-Wesson & Young, 2017).

The practice of teaching problem-solving

Phase 1. Initial research concept

The impetus for the initial version of the teaching and learning research project started with reflection on the poor performance of some students during formal summative assessment opportunities in a strength of materials course in the 2nd year of an undergraduate mechanical and mechatronic engineering degree programme. A summary of my reflections at this point follows:

Over the few years that I had been lecturing the course, I noticed that students who were struggling to correctly solve the problems presented to them in various assessments were not necessarily struggling to solve the clearly defined problems that were similar to examples that we had covered in class. Rather, they were struggling to recognise the similarity between a more complex, unfamiliar problem and a simpler, more familiar problem that they could confidently solve. In a tutorial session (formative assessment), usually they

¹ In the rest of the paper, any self-report artefacts are presented in the first person as a quote (indented) so as to separate the data from the analysis and interpretation.

can circumvent this hurdle by asking a more competent peer or tutor which theory or strategy should be applied. From this point on, they then progress with relative success. However, in a final assessment scenario, panicked students often jump straight into the problem and apply whichever theory they think may work, whether it was relevant or not, and try to solve the problem. This implied to me that struggling students were not lacking in their ability to implement the theories that we covered in the course, but that they had developed poor problem-solving skills.

Research into assessing the relative competencies of STEM students in solving problems show that students who are able to “connect the dots” usually progress swiftly and develop sound problem-solving skills (Litzinger *et al.*, 2010; Heller *et al.*, 1992). They learn to deconstruct problems in order to clearly *define* the problem and important variables; they are able to *identify* and *implement* the correct theories, methods and algorithms for solving the problems; and (if they are particularly diligent students!) they *check* their solutions for validity and accuracy before presenting their work for assessment. This approach to solving problems is formalised into structured problem-solving strategies that are explicitly taught (Paton, 2010; Polya, 1971), as well as engineering design methods, and even bears similarities to Pollard’s reflective teaching model, introduced earlier. In fact, solving any problem seems pretty simple and obvious when one is presented with a neat and succinct strategy within which to design a solution. But anyone who has any experience in solving problems knows that the space between first reviewing a problem and arriving at a neatly presented solution is vast, even if one has steps to follow.

In order to design a research project with the aim of improving the problem solving skills of the students in the class, a typical engineering problem-solving approach was followed. The problem was *defined*, some time was spent *thinking* about and *analysing* the problem and a solution strategy was *planned*. The result of this process is illustrated in an excerpt from the executive summary of the initial project proposal:

After mechanical and mechatronics engineering students have completed the 2nd year, 2nd semester course in Strength of Materials, they are expected to meet certain course-related outcomes. They should be able to (1) analyse a structural problem, (2) determine which theory should be applied to solve the problem most efficiently, (3) set up the governing equations that describe the mechanical behaviour of the system, and (4) use these equations to calculate a reasonable and accurate solution. At present, the pedagogical approach taken in reaching these outcomes is dominated by epistemological, deductive teaching: lectures of the theory with some worked examples are given in class, after which students are presented with a set of some well-defined, similar problems, as well as some more complex problems to solve in the tutorial session (Prince, 2006). No guidance is given to the student as to how to move from solving well-defined to ill-defined, complex problems; the student is expected to figure this out on their own, by asking questions during the tutorial session and struggling with the content. A common result in tests and examinations is that students struggle to identify and define the problems that they are required to solve when they are presented outside of the structured, guided tutorial session. As such, they apply incorrect theories to problems and arrive at nonsensical, impractical solutions to the problems. The issue is not so much that they cannot use the methods required once they have been identified; it is that they cannot infer which method should be used to start with.

This is typical of a student who has achieved the first three lower levels of Bloom’s educational objectives: acquisition of knowledge, comprehension and then application of content (Stice, 2014). It is essential to the development of engineers that they move to building higher level analytical skills. Engineering educational research has shown that using active learning methods is highly effective in transforming learning into an ontological, inductive learning space (Felder *et al.*, 2000; Prince & Felder, 2006; Dall’Alba, 2007).

This project employs active learning as an intervention strategy in an effort to induct the students into developing their problem solving skills so that they are better equipped to analyse ill-defined, complex problems.

As an important aspect of this study is the concurrent academic development that occurred during the execution of the research project. It should be noted that part of the project design

process was situated within a writing retreat organised explicitly to support lecturers in researching, planning and writing up their project proposals. It was during this retreat that the lecturer was exposed to educational theories and methodologies, and could thus start to approach the solution from a theoretically grounded perspective. The very existence of a supported research programme for teaching and learning, coupled with the creation of spaces for interactions within a community of practice that is focused on educational research, was critical to the initiation and progression of the project. Without this support, it is very unlikely that the lecturer would have delved any further into the problem other than to note that some students were capable problem-solvers and others not.

Finally, the research question for this initial phase of the project was stated as follows:

“Can active learning strategies promote the development of problem-solving skills? (in a 2nd year strength of materials course in mechanical and mechatronics engineering)”

Phase 2. Initial Project Plan, Execution and Results

The first approach employed in order to achieve the goals of these projects, was to use different active learning techniques in order to create more engaging tutorial sessions, and to introduce students to a formal, structured problem-solving strategy in order to improve their problem-solving skills (Stice, 2010; Heller *et al.*, 1992; Felder *et al.*, 2000; Smith *et al.*, 2005, Paton, 2010).

The specific active learning methods used were:

Blended learning: A 5 minute podcast was created that introduced Polya’s strategy for structured problem-solving (Polya, 1971) as advocated by the research of Stice (2014). A second podcast (13 minutes) was created that steps the students through a worked example while using the same structured problem-solving strategy. The podcasts were loaded onto the course website and students were instructed to watch these podcasts on their own outside of class.

TAPPS (Think Aloud Paired Problem Solving): Students were assigned a couple of relatively simple problems to solve before the tutorial session. During the tutorial, the students pair up and explain their solutions to each other in a structured manner. This method is advocated for improving problem-solving skills (Stice, 2014).

Cooperative group learning: Students are required to set up the strategy for solving a more complex problem that is assigned during the tutorial session by working in structured groups. Each of the group members is assigned a specific role, either Manager, Skeptic, Checker and Recorder, and they are instructed to follow a structured problem-solving strategy in arriving at a solution strategy (Heller *et al.*, 1992).

Peer assessment in groups: Students are instructed to solve an assigned problem according to the structured problem-solving strategy in groups. After completing this task, they submit their written solution to a tutor. The written solutions are then redistributed amongst the groups and the students are required to assess each other’s work based on their approach to solving the problem. This activity was designed by the lecturer.

Figure 2 shows a snapshot from the blended learning activity, the podcast of the structured problem-solving strategy that was introduced to the students and that they were expected to follow when solving class problems.

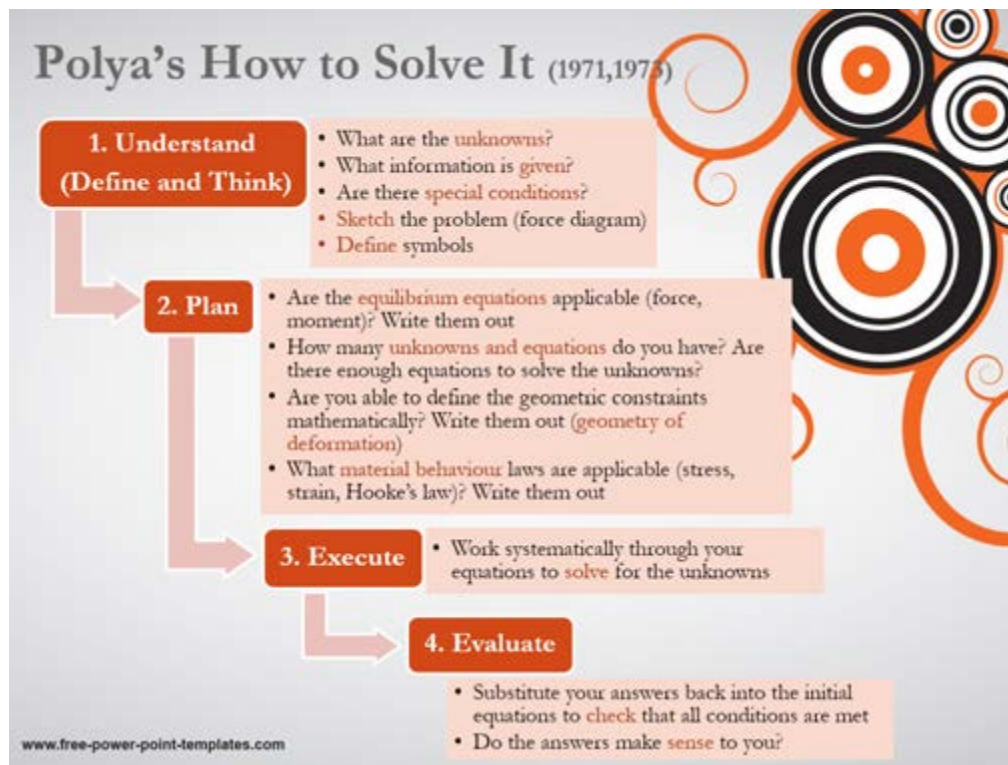


Figure 2 .Snapshot from the podcast used to introduce a structured problem-solving strategy to students

A scaffolded approach was used for introducing problems with varying levels of complexity and difficulty. For the TAPPS activity, the problems were not very complex; the purpose of this exercise was to facilitate a transition from thinking about a problem, to actually verbalising the assumptions and solution strategy. For the cooperative group learning activity, a more complex, unfamiliar (dissimilar to worked examples) problem was assigned that would require the students to think about and discuss the various parameters that would influence the solution (knowns and unknowns).

Tutors roamed the classroom during the activities and were asked to take notes specifically on the types of questions and discussions that the students were having, as well as common errors and misperceptions amongst the students. The tutors were asked to note common errors in the solution strategy as well as how closely the groups followed the instructions.

Comments from tutors indicated that the activities that required verbalisation and discussion of the problems did promote more in-depth analysis of the problems with different student perspectives leading students to have to explain their thoughts clearly. It was interesting to note that students complained that they were “led astray” and “confused” by having to consider different approaches of their peers. Some of the comments from the student evaluation forms, in response to being asked to comment on whether the activity learning influenced their learning and whether they enjoyed the activities, were:

“groupwork (was) enhancing to my understanding of the question”

“approach towards the tutorial was confusing; most probably because we are doing it for the first time”

“Everyone has their own approach to problem-solving; it made it difficult to work together.” (translated from Afrikaans)

There were mixed feelings about being forced to work in groups. Some students noted that they enjoyed getting to know others in the class, others complained that they already had their established work groups and these interventions interrupted their dynamic. Some noted that they prefer to work alone. These are all pretty typical responses to teamwork and were deemed part of the territory (Heller *et al.*, 1992).

Full details of the design, implementation and results of this stage of the project were presented at an institutional conference on the scholarship of teaching and learning (Blaine, 2015).

Phase 3. Critical reflection on the project outcomes

My reflections on the results of the first year of implementing the project were as follows:

From a pedagogical perspective, the fact that students were questioning and interrogating their assumptions seemed to be a triumph. Linking theory to practise is challenging and students frequently resort to memorising solution strategies in lieu of understanding the problem itself, thus fulfilling the goal of answering the question but preventing them from understanding the application of the theory (Case & Marshall, 2004). I felt like the activities achieved their goal of helping students to move out of this comfort zone (rote learning), but an effect that I had not expected was the erosion of student confidence. Students especially did not like it when something had seemed clear to them prior to a discussion of the problem, but after the activity they were unsure of their intuition and application of theories.

The peer assessment activity was more popular, primarily because the students were given the answers in order to assess each other's work. This seemed to remove the confusion and confidence issue, with some students even shouting out in joy when they determined that they had led the group in the right direction for the solution. One confident group even approached me during the peer assessment and questioned the memo as they were so sure of their answer, having discussed it at length in the group. They were delighted when it emerged that they had discovered a calculation error in my worked memo. A common issue that was noted was lack of preparedness of the students.

One of the first lessons learnt during this journey was that, for active learning to be effective in the classroom, instructions have to be succinct and explicit. This requires a significant amount of preparation from the lecturer, as well as briefing of the tutors and the clear instruction for the students. My reflections on things that I could improve in terms of planning were as follows:

The venue did not lend itself to movement of the tutors amongst the students, so data capture was hindered. Very few students had prepared for the activity. I was coordinating small group activities with classes of 100+ students and 4 assistants (tutors) – this leads to a significant amount of chaos if everyone is not well prepared. The amount of time it took to redesign only one 3 hour tutorial was significant (at least 30 hours) and thus further implementation of redesigned tutorials was prohibited within the time available for the semester.

After the first round of implementing the project, it became clear that while active learning had a positive effect on student engagement, there was little tangible success in influencing the approach that students were taking to solving problems or in their performance in assessments. Student engagement does not necessarily translate to improved performance and even when students were “taught” structured problem-solving techniques, very few changed their behaviour when faced with unfamiliar, complex problems. Thus it was from this perspective that I set about to improve the design of the project for a second round of implementation.

Phase 4. Improved project plan

Further review of related educational research indicated that active learning and helping students to develop their problem-solving skills can be effective in promoting deeper learning, but that a critical aspect to the success of these interventions is to simultaneously develop their ability to translate their conceptual knowledge into a conceptual understanding or representation of a problem (Gaigher *et al.*, 2007; Lasry & Aulls, 2007; Litzinger *et al.*, 2010; Prince, 2004). The project was thus expanded to include further classroom and tutorial activities to allow translation between realms of problem conceptualization (Stice, 2014; Heller *et al.*, 1992). The initial research question was therefore expanded in order to address a broader, more encompassing perspective:

Can active learning strategies, that facilitate articulation between different modes of thinking and reasoning, improve the development of problem-solving skills and deepen the conceptual understanding of theories, while improving student engagement in the classroom?

Additionally, more explicit instructions were given during the tutorials, tutors were briefed on the research methodology that was being used before the tutorial sessions, and an open plan venue was secured for the tutorial sessions to enable quick transitions between individual work and group work tasks.

Phase 5. Developing competency

In parallel to the adjustments to the classroom intervention, the methods that were employed to solve the pedagogical problem: “How does one develop students’ problem-solving skills?” were critically reconsidered. Through reviewing theories on the meta-cognitive skill set and its critical influence in building students’ problem-solving skills, the lecturer’s perspective on this problem was broadened (Paton, 2010; Gaigher *et al.*, 2007; Lasry & Aulls, 2007; Litzinger *et al.*, 2010). This perspective was presented as an important project outcome (Blaine, 2016).

Subsequently, it was through the interrogation of the work that a similarity between the approach of novice problem-solvers in engineering classrooms and the novice lecturer’s simplistic approach in designing a solution to a complex pedagogical problem emerged.

Evaluating a classroom learning intervention in terms of whether a student “gets it” or not, is simplistic and misses the progressive aspect in the development of competency. When reviewing how practitioners induct themselves through different levels of skill competency, there are numerous studies that show that this is a gradual, progressive process (Benner, 1984). Procedural and algorithmic approaches have their place in the spectrum of learning (Case & Marshall, 2004); they are part of building the expert’s toolbox of experience, familiarising oneself with different methods and recognising where they are best put to use. Students build their conceptual understanding (comprehension) of theories and the application thereof through both cognitive (knowledge) and affective (confidence) changes (Lasry & Aulls, 2007). Furthermore, meta-cognitive skills, such as time management, logical and systematic thinking, reflection, monitoring progress and asking critical questions, all play critical roles in the development of a skill (Paton, 2010). Expertise is also not built through a series of successful implementations of the “correct” methods. There can be as much, maybe more, experiential value gathered from unsuccessful attempts at solutions as there can be from success.

A typical novice problem solver searches through potential solution approaches or algorithms without defining or understanding the problem fully, and fits the most likely algorithms in the hope that the solution will be found (Paton, 2010). An expert problem solver employs a balance between qualitative and meta-cognitive skills in order to interpret the problem; they identify relevant and related approaches to solve the problem, monitor their progress, and continually adapt their approach until an accurate and realistic solution is found (Paton, 2010). Primary differences between weak and strong problem-solvers, at novice and more competent levels, are the degree to which they use self-explanation when formulating a problem, as well as the degree to which they monitor their progress throughout the solution (Lazinger *et al.*, 2010). Strong novice problem-solvers are better at applying their conceptual knowledge because they follow structured problem-solving strategies that incorporate spending time on analysing a problem, which typically includes some self-explanation of the problem, and they monitor their progress, the applicability and reasonability of their solution, throughout the problem-solving event. Expert problem-solving translates through different levels of “what?” and “how?” moving between procedural approaches, experiential insight, theory and knower insight, as described by the 5P problem-solving model (Wolff, 2015).

When reflecting on these studies, that interrogate the development of strong problem-solving skills, the following thoughts arose:

I realised that I needed to be more patient with my students and nurture their systematic progression from novice problem-solvers, who apply procedural and algorithmic approaches, to more competent problem-solvers, who can build on the novice foundation in order to more easily link theory to practise. Classroom interventions that realise improved, deeper conceptual understanding and stronger problem solving skills need to be structured so as to promote the application of theory during analysis. This can be facilitated by activity learning, such as TAPPS and cooperative group learning, where students are given the opportunity to translate between different modes of representation (visual, mathematical, verbal). Similarly, my expectation, and consequent initial disillusionment, with the effectiveness of the interventions should be seen as a step in the progression of building my competency as an educational practitioner and researcher. Through continual monitoring of the appropriateness and effectiveness of the interventions, I build stronger relations between theory and practise.

Research studies that analyse interventions in terms of meta-cognitive factors are complex and foreign for a lecturer who is only starting the journey of educational research (novice). In fact, it was only after a few years of implementing activity learning in the classroom that discussions at this level started to make sense, that one is able to “connect the dots” and see the relevance of other research studies to one’s own work. Experience, dialogue and reflection, in other words engaging in the practice, are critical in unlocking one’s understanding of these educational theories.

My initial approach was that of a novice practitioner; I fitted solutions to a problem that I did not fully understand, which resulted in misconceptions and ill-guided decisions. However, once I progressed to the monitoring and reflecting stage of the structured problem-solving strategy, and started a second iteration of linking educational theory to my practice, I arrived at better solutions. Reflecting on the current status of the design facilitated the progression of my conceptual understanding and implementation of theories, specifically related to problem-solving in engineering and science. The point here is that it is a journey; it takes time. I am not yet an expert teacher, but the more I practice, the better I’ll get.

Finally, the role of group activities, where practitioners can verbalise their solution strategies and receive feedback from peers is invaluable in building competency.

If it were not for my interaction in engineering education forums (conferences, funded institutional

programmes in teaching and learning, writing workshops and practitioner workshops) I would have been stuck in a classroom practise that I knew was ineffective, but felt powerless to change.

Conclusions

A design-based approach was employed in order to tackle the problem of designing classroom interventions that are targeted at improving engineering students' problem-solving competency, within the context of a 2nd year mechanical and mechatronic engineering strength of materials course. Through a critically reflective practice, situated within the context of the practice of learning to teach, a broader understanding of the pedagogical problem is achieved by the lecturer. A critically reflective practice does not stop at looking back on and assessing one's actions, rather this is where it starts; reflecting on and monitoring the current status of a solution allows one to redesign and imagine a more accurate and useful approach. This is valid whether the problem is calculating the stress in a beam, or teaching students how to effectively approach this problem.

The development of competency in problem-solving is identified as a progressive event, facilitated by the translation between different modes of problem representation and a reflective practice. Activity learning can be effective in helping this translation and in improving student engagement, however there needs to be continual links back to theory during analysis in order to effectively improve competency. The novice typically follows a procedural approach and develops a deeper understanding of theory through practice and experience. Design of an effective learning environment can be facilitated by continual monitoring and reflection on the implementation of educational theories in the classroom, the adjustment of practice, and progressive development of competency. Institutions would do well to provide support to academics in the development of their pedagogical skills if the improvement of teaching and learning is a priority.

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The new engineering curriculum at the Durban University of Technology

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The demand for engineering graduates is increasing as the global economy advances through continuing technological advances. Graduates are required to possess human skills as well as technical competence. They have to cope with technological, organisational and cultural changes at work and in society within legal requirements and a changing global economy. In South Africa, the revision of the Higher Education Qualification Sub-Framework (HEQSF) brought about a curriculum review process wherein all Higher Education Institutions (HEIs) had to review and align their qualification offerings in accordance to the revised framework. For the engineering educational sector at the University of Technologies (UOTs) this process saw the adoption of a new suite of engineering technology qualifications not only aligned to the HEQSF but also to the requirements of the Engineering Council of South Africa (ECSA). ECSA in turn, guided by the requirements of the Sydney (professional engineering technologist) and Dublin (professional engineering technician) Accords sought to align the technology qualifications according to the requirements of our international partners. This alignment process created a paradigm shift in teaching pedagogy for the UOT's from the traditional to that of outcomes based education (OBE). The Faculty of Engineering and the Built Environment at the Durban University of Technology (DUT) chose the option of curricula for the 420 credit Bachelor of Engineering Technology qualification to satisfy the educational base for registration as a professional engineering technologist. The engineering standard (E-02-PT) for this qualification provided the overarching structure for the qualification including the requirements for OBE in the form of Exit Level Outcomes (ELOs). This is a conceptual paper discussion on how the Department of Industrial Engineering undertook to incorporate the ELOs into the curriculum structure of the degree. Subsequent discussions centralise on an understanding of the ELOs, the academic structure of the qualification, the proposed implementation of the ELOs and presents a strategy for the assessment of the ELOs.

Introduction

In recent years the engineering profession and the accreditation bodies have called for change globally. This has sparked a call for the revision of national accreditation criteria for engineering programs in the United States, the United Kingdom and Australia. Engineering programs are now required to demonstrate a set of outcomes and show industry relevance. The Engineering Council of South Africa (ECSA) has specifically encouraged traditional and technology universities to indicate the exit level outcomes of the programs they offer while they have stated generic exit level outcomes for different qualifications in South Africa.

The Higher Education Qualification Sub-Framework (HEQSF) policy revision provided the backdrop to curriculum renewal at all higher education institutions (HEIs). In keeping with this, the engineering faculty at DUT undertook a review of all existing qualifications in order to align to the requirements and criteria of the HEQSF. With this in mind, and having traditionally produced graduates to meet the registration requirements of engineering technologists, it was collectively decided that the engineering disciplines within the faculty would focus on the Bachelor's degree (3 years with 420 credits) qualification offering.

Guided by the HEQSF framework, the Council for Higher Education (CHE) documentation on qualification design and the engineering standard (ECSA, 2012) for the Bachelor of Technology qualification, the department of industrial engineering proceeded to curricularize for the BEngTech in Industrial Engineering. Of note during the curricularization process was the challenge in the incorporation of the ELOs as prescribed by the engineering standard (ECSA, 2012). Whilst achieving the technical outcomes of the qualification remained a relatively easy task, the achievement of the outcomes related to the softer aspects of the qualification required more thought and in-depth examination. The subsequent writing informs on this process and elaborates on how this was achieved.

Background

Curriculum Design

In order to understand the curriculum process, it is necessary to offer a definition of the word "curriculum". Here it is taken to be the formal mechanism through which intended educational aims are achieved. Since educational aims are achieved through learning, the curriculum process is described by those factors that bring about learning. Engineering education is guided by national policy, but there are two main goals which shape the design of the curriculum, viz. the technical and social. In the case of the technical goal, the student is prepared to perform analysis, design or construction, production or operation of the analysis where a full knowledge of the analysis and design of the structure, machine or process is essential.

The second goal, is to develop an understanding of the evolution of society and of the impact of technology on it with an appreciation of the heritage of other cultural fields, the development of personal philosophy which will ensure satisfaction in the pursuit of a productive life, and a sense of moral and ethical values consistent with the career of a professional engineering. Engineering education has attempted to provide within the confines of the traditional four-year period both a general and a broad general education together with a specialised technical education of great and growing complexity (Heywood, 2005).

Outcomes based education

Outcomes based education (OBE) is a comprehensive learning teaching system which focuses on the learner's action-performance and output at the end of learning experiences. In other words, OBE is a method of curriculum design and teaching that focuses on what students can do after they are taught. Research indicates that higher education institutions have increasingly become an integral platform for the development of competences. The perspective on competences in higher education is supported by Rieckmann (2012), Fadeeva and Mochizuki (2010) and Barth *et al* (2007). Their view is that universities should create teaching and learning situations that connect theoretical and practical learning which should be interdisciplinary, transdisciplinary, participative and problem solving in nature, so that it would assist the development of competences through assessment of the learning objectives.

The fundamental theoretical underpinnings of the National Qualifications Framework (NQF) can be identified as human capital theory which is based on the belief that there is a direct link between education and economic growth. Auvinen (2011) quotes Spady *et al* (1991) in describing OBE as an educational paradigm that ensures that each and every student achieves the same outcome but not necessarily at the same speed. The key idea being that students are not allowed to progress before sufficient mastery is acquired. OBE offers the flexibility in demonstrating mastery and is found to be more suitable to fields where students cannot graduate before mastering a specific skill set.

There are various definitions for OBE available, but they are all based on one basic principle in that OBE focuses on learning outcomes (LOs) that prepare students for professional practice and require that programs document evidence of achievement (Yusoff *et al*, 2014). The authors further illustrate some of the immediate effects and advantages such as (1) universities are on always alert and concerned about the quality of the graduates produced; (2) development of more systematic, innovative and flexible teaching methods, for example, project based learning within an integrated learning environment and (3) increase in student exposure to professional practice through industrial training, site visits and industry linked projects.

The Oxford dictionary defines the term *competence* as one's ability to do something successfully or efficiently. In the working world competence is seen as a set of associated abilities, commitments, knowledge and skills that enables an individual or organization to act efficiently in a profession or a situation. Competencies cannot be taught, but they can be acquired through the learning process (Barth *et al*, 2007). Students should be given detailed assessment criteria for the specific leaning outcomes. Rieckmann (2012) believes that competencies are acquired during action, therefore the engagement of the student in the learning process is expected to build the on the skills and competencies.

Lecturers and trainers become facilitators rather than transmitters of knowledge, but the vast majority are underqualified or ill-equipped for the demanding task of successfully implementing the outcomes based education system. It is often considered a loose system which would depend on the skills of the teacher and the availability of resources. This process required a rethink on the role of the teacher and the learner. There was always the danger of

the responsibility of the learning being shifted to the learners (Armstrong, 1999).

Outcome based education has been a strong catalyst for curricular change and improvement in engineering education. The structure provided by the graduate attributes facilitates the transformation process and provides a systematic method to the development of the curriculum (Paul *et al*, 2015). A professional engineering program has a requisite set of outcomes to describe the graduate attributes, e.g. their knowledge, skills and attitudes. A particular course cannot address all the program learning outcomes therefore each course has a set of learning objectives, some of which addresses one or more of the program objectives.

Teaching and learning activities are designed around the learning objective, e.g. teamwork. These activities prepare the students for assessment, which measures certain criteria or standards in a course. This in turn contributes to the summative assessment, that is, whether the student has met the learning outcome specified for the program. Assessment provides the information about the graduate and can be used to review the program. (Uziak *et al*, 2010).

Learning outcomes and objectives

The differences between the learning outcome and the learning objectives have to be clearly understood when designing a program and the individual courses. Learning outcomes are broad goals that describe what the learners are supposed to know or be able to do. Outcomes are different abilities and competencies which students are expected to acquire. These can be specified for the whole program or for the individual but they list knowledge, skills and attitudes expected of the student who passed the program or a course.

There are several pre-defined outcomes which engineering graduates are to achieve which are usually prescribed by an accrediting body. The institution that offers the program has to prove that all of the outcomes have been addressed and achieved in the program. Evidence that each student has singly met all the outcomes of the program would have to be presented during the review or accreditation process. In general learning outcomes cannot be just observed but rather measured and/or evaluated. Therefore, each learning outcome must be linked to one or more specific objectives that are appropriate, measurable, achievable and realistic within the given study period (Paul *et al*, 2015).

The method of instruction or delivery does not define the learning objective which is based on the curriculum. They are merely descriptors of the intended learning outcomes. Learning objectives are statements of students' actions that can be observed, scrutinised and monitored. These objectives will serve as evidence that certain program outcomes (knowledge, skills and attitudes) have been acquired. Program designers need to ensure that statements used in describing the objectives can be observed, measured and assessed. The literature states that to qualify as objective statements, observable action verbs (explain, calculate, derive, design, critique), should be use, whereas observable actions such as learn, know, understand and appreciate can be used for outcomes.

In education environments, learning outcomes and objectives are loosely grouped into three groups or domains which are identified in Bloom's taxonomy. This can be used to create a well-balanced university learning model that covers cognitive, affective and psychomotor domains (Streveler *et al*, 2012).

Assessment

Learning objectives can be assessed for the course by modern classroom techniques, such as tests, quizzes and examinations. The use of a variety of assessment methods and formats aim to enhance the validity and reliability of assessments and to ensure the student's mastery of the course and ultimately the program. Multiple choice and short questions assess comprehension of details and interpretation skills, while tests assess their problem solving skills and written project reports assess their ability to integrate and synthesis.

Multiple and varied assessment methods are called triangulation. Course assessments also assesses the program outcomes, but more tools such as surveys, interviews with graduates, alumni, employers, student portfolios and final year projects are necessary for the assessment of the program. The triangulation process applies to program assessments as well. The design of the assessment tool can become complicated as it requires specifying outcome indicators as well as performance targets. The former assesses levels of attainment and the latter targets criteria for the indicators (Soeiro, n.d.).

LOs are a fundamental requirement for structuring standards and guidelines for quality assessment of (HEIs). In this context, the assessment of LOs becomes a crucial process for the educational system. Measuring the real LO achieved by students, against the intended ones, using assessment strategies that are appropriate should be the main concern for HEIs. The LO of a course should be used to define the teaching and learning activities, ensuring these will address the same LO. The same will apply to the assessment tasks. To ensure the validity of assessment in relation to what is intended from the course, it is necessary that the outcomes measured by the assessment tasks are the same as the intended ones. The initial step to approach the problem was to identify and define the different components of the problem: the two variables, the intended LO in EE and assessment methods; and the link between them that is the alignment question (Soeiro, n.d.).

Quality assurance

Accreditation is the central interest of all engineering professionals working at universities. Programs offered are constantly reviewed internally and externally to ensure that quality standards are maintained and aligned with the professional body. ECSA requires evidence that each graduates have satisfied all outcomes at the required level of performance and therefore record keeping becomes vitally important in the quality assurance cycle.

Case Study: Bachelor of Engineering Technology in Industrial Engineering DUT

Program structure

The department of industrial engineering at Durban University of Technology is situated within the Faculty of Engineering and the Built Environment. The department currently offers the traditional NATED 151 programs i.e. National Diploma and the Bachelor of Technology (BTech). The department has developed a curriculum for the BEngTech program in Industrial Engineering which has been approved by both the CHE and the Department for Higher Education and Training (DHET) for phase-in from January 2018.

The current NATED 151 National Diploma is effectively on a phase-out plan from 2017 and 2018 would see the introduction of the first cohort for the Bachelors program. Table 1 highlights the structure for the intended BEngTech (Industrial) qualification offering.

Table 1. Outline of the curriculum for the BEngTech (Industrial)

Module Title	NQF Level	SAQA Credit Value	Module Title	NQF Level	SAQA Credit Value
YEAR 1 – Semester 1			YEAR 1 – Semester 2		
Engineering Mathematics 1A	5	12	Engineering Mathematics 1B	5	12
Engineering Physics 1A	5	12	Engineering Physics 1B	5	12
Statistics 1	6	12	Financial Accounting for Engineers	5	8
Industrial Drawing and CAD	6	16	Sociology of Work 101	6	8
Cornerstone 101	5	12	Computing & IT	6	8
Technical Literacy	5	8	Electrical Principles 1	5	12
YEAR 2 – Semester 1			YEAR 2 – Semester 2		
Engineering Mathematics 2A	6	12	Engineering Mathematics 2B	6	12
Strengths of Materials 1	5	12	Engineering Work Systems 1	5	12
Mechanics of Machines 1	6	12	Production Engineering 1	5	12
Computer Programming & IT	6	8	Information System Design	7	16
Management Accounting for Engineers	6	8	Manufacturing Engineering 1	6	8
Industrial Design 1	5	16	Industrial Design 2	6	12
YEAR 3 – Semester 1			YEAR 3 – Semester 2		
Facilities Planning	7	12	Engineering Work Systems 3	7	16

Engineering Work Systems 2	6	12	Production Engineering 3	7	16
Production Engineering 2	6	12	Simulation Modelling	7	16
Operations Research	7	12	Principles of Management	6	8
Project Management	7	8	Quality Engineering	6	12
Design Project Part 1	7	12	Design Project Part 2	7	12

As illustrated in Table 1, the fundamental engineering, science and economic knowledge areas are dealt during the first one and a half years of study. Thereafter the qualification becomes more field specific and during the course of the third year the focus of the study trends towards integrating the learnt theory into an application based capstone project namely Design Project Part 1 and Design Project Part 2. Mapped onto this structure was the incorporation of the ELOs.

Exit Level Outcomes (ELOs)

An ELO as described by ECSA (2014) is “a statement of learning outcomes the student must demonstrate at the exit level to qualify for award of a qualification; these actions indicate the student’s capability to fulfil the educational objectives.” For the purposes of engineering work, ECSA has determined that each student must demonstrate competency in each of the ten ELOs (as given in Table 2) in order to fulfil the educational objective of graduating with an engineering technology qualification.

Table 2. Exit Level Outcomes for the BEngTech (E-02-PT, 2012)

Exit Level outcome	Description
1. Problem Solving	Apply engineering principles to systematically diagnose and solve <i>broadly-defined</i> engineering problems.
2. Application of scientific and engineering knowledge	Apply knowledge of mathematics, natural science and engineering sciences to defined and applied engineering procedures, processes, systems and methodologies to solve <i>broadly-defined</i> engineering problems.
3. Engineering Design	Perform procedural and non-procedural design of <i>broadly defined</i> components, systems, works, products or processes to meet desired needs normally within applicable standards, codes of practice and legislation.
4. Investigation	Conduct investigations of <i>broadly-defined</i> problems through locating, searching and selecting relevant data from codes, data bases and literature, designing and conducting experiments, analysing and interpreting results to provide valid conclusions.
5. Engineering methods, skills, tools, including Information technology	Use appropriate techniques, resources, and modern engineering tools, including information technology, prediction and modelling, for the solution of <i>broadly-defined</i> engineering problems, with an understanding of the

	limitations, restrictions, premises, assumptions and constraints.
6. Professional and Technical Communication	Communicate effectively, both orally and in writing, with engineering audiences and the affected parties.
7. Impact of Engineering Activity	Demonstrate knowledge and understanding of the impact of engineering activity on the society, economy, industrial and physical environment, and address issues by analysis and evaluation.
8. Individual and Teamwork	Demonstrate knowledge and understanding of engineering management principles and apply these to one's own work, as a member and leader in a team and to manage projects.
9. Independent Learning	Engage in independent and life-long learning through well-developed learning skills.
10. Engineering Professionalism	Comprehend and apply ethical principles and commit to professional ethics, responsibilities and norms of engineering technology practice.

While the ELOs remain consistent for the three defined engineering categories namely the professional engineer, the professional engineering technologist and the professional engineering technician, the differentiation between each of the categories is within the description for each ELO, the associated range statement and the requirements for the typified assessment. As an example, ELO 6 is given in Table 3 and forms the basis for the subsequent discussions.

Table 3. Exit level outcome 6 (E-02-PT, 2012)

ELO 6 – Professional and Technical Communication:

Communicate effectively, both orally and in writing, with engineering audiences and the affected parties

Range Statement:

Material to be communicated is in an academic or simulated professional context.

1. Audiences range from engineering peers, related engineering personnel and lay persons. Appropriate academic or professional discourse is used.
2. Written reports range from short (300-1000 words plus tables and diagrams) to long (10 000 to 15 000 words plus tables, diagrams and appendices), covering material at exit level.
3. Methods of providing information include the conventional methods of the discipline, for example engineering drawings, as well as subject-specific methods.

Typified assessment criteria:

1. The structure, style and language of written and oral communication are appropriate for the purpose of the communication and the target audience.
2. Graphics used are appropriate and effective in enhancing the meaning of text.
3. Visual materials used enhance oral communications.
4. Accepted methods are used for providing information to others involved in the engineering activity.

5. Oral communication is delivered fluently with the intended meaning being apparent.

Mapping of ELOs onto the Industrial Engineering curriculum

As suggested by Spady (1991) and later by Auvinen (2011), developing a visual map of the outcomes onto the program structure assists in ensuring that the development of the outcomes is scaffolded through the qualification and that the outcome is finally assessed at the exit level. With this in mind the outcome map for the BEngTech (Industrial) was developed. At the lower levels the outcomes are developed gradually building up to the assessment at the exit level.

Table 4. Exit level outcome mapping for the assessment of the BEngTech (Industrial)

	Module Name	Semester	Problem Solving	Scientific & Eng Knowledge	Engineering Design	Investigation	Eng Methods, Skills, Tools & IT	Professional & Technical Communication	Impact of Engineering Activity	Individual & Teamwork	Independent Learning	Engineering Professionalism
			ELO 1	ELO 2	ELO 3	ELO 4	ELO 5	ELO 6	ELO 7	ELO 8	ELO 9	ELO 10
FIRST YEAR	Engineering Mathematics 1A	1	D									
	Engineering Physics 1A	1		D								
	Statistics 1	1		D		D						
	Industrial Drawing and CAD	1			D		D	D	D		D	
	Cornerstone 101	1								D		D
	Technical Literacy	1						D			D	
	Engineering Mathematics 1B	2	D									
	Engineering Physics 1B	2		D								
	Financial Accounting for Engineers	2										
	Sociology	2						D	D			
	Computing & IT	2					D					
SECOND YEAR	Electrical Principles 1	2	D	D		D						
	Engineering Mathematics 2A	1	D									
	Strengths of Materials 1	1	D	D							D	
	Mechanics of Machines 1	1	D	D								
	Computer programming & IT	1	D				D					
	Management Accounting for Engineers	1							D			
	Industrial Design 1	1		D	D			D		D	D	D
	Engineering Mathematics 2B	2	D									
	Engineering Work Systems 1	2										
	Production Engineering 1	2										
	Information System Design	2	D				D					D
THIRD YEAR	Manufacturing Engineering 1	2					D		D			
	Industrial Design 2	2	D	D	D			D		D	D	
	Facilities Planning	1										
	Engineering Work Systems 2	1		D			D					
	Production Engineering 2	1					D		D			
	Operations Research	1	D								A	
	Project Management	1								D		A
	Design Project Part 1	1	D		D	D		A				
	Engineering Work Systems 3	2		A								
	Production Engineering 3	2					A		A			
	Simulation Modelling	2										
	Principles of Management	2								A		
	Quality Engineering	2										
	Design Project Part 2	2	A		A	A						

In instances where the outcome is being developed the letter “D” is used and where it is being assessed the letter “A” is used. In order to simplify the process of assessment and record keeping it was agreed within the faculty to utilise a system whereby the outcomes are only assessed at the exit level in the final year of study. This was a matter of convenience and departments are allowed to change as they deem appropriate.

Progression of ELO 6 towards exit level and assessment

As indicated earlier, ELO 6 was taken as an example to illustrate the process of development of the outcome through to the final assessment.

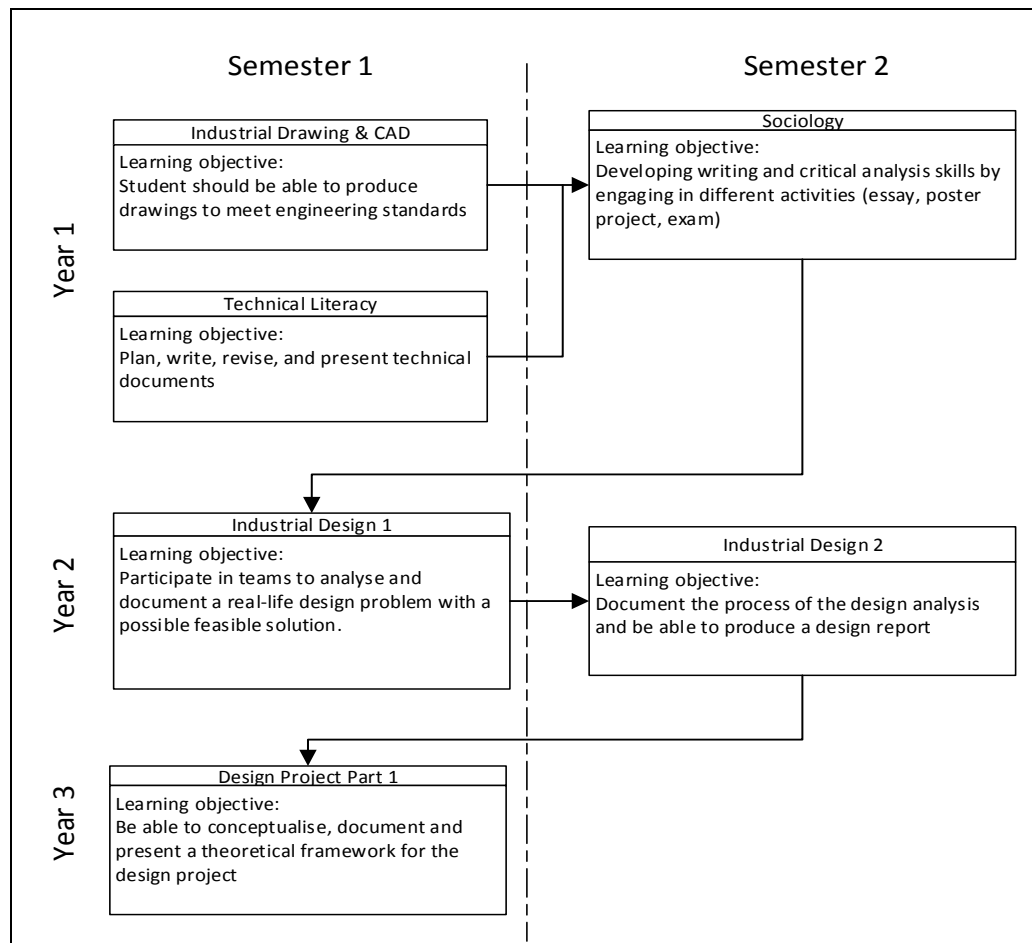


Figure 1. Illustration of the development of ELO 6 through to assessment at the final level

Learning outcome 6 was broken into 6 distinctive learning objectives which the student would need to fulfil as they progressed through the levels of study. Upon successful completion of the relevant module it would be taken that the student was able to fulfil that learning objective and therefore have acquired the necessary skill, knowledge and competency to attempt and fulfil the outcome at the Exit Level. Content for each module would take into consideration the knowledge and skills required in order to build the required competency to fulfil the learning objective required in that module.

Assessment of ELOs

Assessment of the learning objective for each module would be designed in accordance with requirements of the overarching outcome that is being fulfilled. Using the module Industrial Drawing and CAD as an example, one of the assessments of the module would be for the student to be able to produce an engineering drawing for an idea that would meet engineering standards i.e. a visual and graphical representation of the student's idea for an engineered component. During the assessment phase the lecturer would need to determine if the

submission has fulfilled the requirements of the learning objective. This can be achieved through the use of an assessment rubric which could incorporate an oral presentation as well. The focal thrust of the assessment would be to determine if the student is able to communicate effectively with an engineering audience and other affected parties.

This methodology would be repeated through the curriculum culminating in the module Design Project Part 1 where the final assessment of the ELO would be held. Each assessment related to the achievement of the learning objective would be compulsory wherein the student would not be allowed to progress to the next level if the learning objective has not been met.

Conclusion

This paper aimed to deliver a simplified explanation and demonstration of how the ELOs would be incorporated into the new qualification offering in the Faculty of Engineering and Built Environment using the BEngTech (Industrial) as a case study example. The methodology and process described through the preceding sections is an attempt to illustrate the process and methodology that would be duplicated for all ten ELOs across all engineering disciplines. As ELOs represent a marked departure from the previous NATED 151 qualification offerings, the implementation thereof represents a paradigm shift in pedagogy of educating and training future engineering technologists and technicians. The quality assurance procedures that follow would guide the process of continued evaluation of how the implementation of the ELOs proceed highlighting possible challenges that would need to be overcome. Ultimately it is seen as a step in the right direction to produce graduates who are socially and technical competent to compete in a global economy.

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The uneasy role of proof in teaching engineering mathematics

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When teaching mathematics to engineering students, just how much proof should one include? Include too little and you weaken the heart of mathematics, that of logical reasoning from axiomatic principles. Include too much and you take up time necessary for much needed practical application and risk alienating students who see no need for such work. Anecdotal evidence suggests that each individual lecturer makes the decision of how much proof to include idiosyncratically. As lecturers of engineering mathematics, we need a sound theoretical argument on this question, not simply personal opinion. In this paper I take a first step on this journey and argue that the deciding factor for the inclusion or exclusion of any proof in an engineering maths course should be whether the proof constitutes a warrant, that is whether it truly secures knowledge and convinces the reader of mathematical truth.

Introduction

The decision taken by lecturers of mathematics of what proofs to include in introductory mathematics classes to engineering students is often made idiosyncratically. Sadly, these decisions are influenced by time, given that such courses are often loaded with content which takes a lot of time to teach and proofs can get side lined. Omission of all forms of proof from an engineering mathematics course would weaken the course immeasurably and would not provide a sound mathematical education to the students. Inclusion of too much proof would require omitting some other content (some integration techniques? Lagrange multipliers? Taylor series?), which would be problematic and would also risk boring students who, while mathematically proficient, frequently do not enjoy the more theoretical side of formal mathematics. Clearly there is a need for a deciding factor in whether any one proof should be included or not.

In this paper I briefly discuss five reasons for teaching or demonstrating proof as foregrounded in the mathematics education literature and consider them in the context of an engineering mathematics class. I pull out one reason in particular, that of warranting, as being of primary importance and suggest that the capacity of any one proof to constitute a warrant should be the deciding factor to include or exclude in the classroom. It is important to make clear what this paper is and what it is not. It is not a theoretically grounded argument, but it is the beginning of a conversation about how we can draw on the theoretical literature to influence pedagogical choices in engineering mathematics classrooms. This paper is unapologetically an opinion piece, aiming to generate fruitful discussion amongst South Africa's engineering educators. Much of what I suggest can be argued with and I welcome such argument in the quest to better inform our teaching choices and make our teaching less based on personal whim and more based on choices we can defend.

What Is A Proof?

The Merriam Webster dictionary defines a proof as “the process or an instance of establishing the validity of a statement especially by derivation from other statements in accordance with principles of reasoning” (Merriam Webster online). Grabiner (2012) says that “in the simplest

sense, a logical proof deduces that something is a logical consequence of something else already believed to be true” (p. 148) and Zaslavsky et al. (2012) similarly say that “historically, a proof is a rhetorical device for convincing someone else that a mathematical statement is true” (p. 217). Hanna and Jahnke (1993) define modern formal logical proof as “a finite sequence of formulae within a given system, each formula being either an axiom or derivable from an earlier formula by a rule of the system” (p. 423). Cabassut et al (2012), however caution that while mathematicians all know a good proof when they see one, “no explicit general definition of a proof is shared by the entire mathematical community” (p. 169).

There are a variety of reasons for teaching proof or demonstrating proof in the mathematics classroom foregrounded in the mathematics education literature. I argue that the needs of engineering students overlap with those of pure mathematics students, but are not exactly the same. Much of the literature (and I fear I am also guilty) conflates teaching students how to prove with demonstrating proofs. The catch all term “teaching proof” includes both meanings. A sizable amount of mathematics education literature exists on the role of proof in mathematics and the reasons to teach proof, however there is very little of this literature which pertains to engineering students. The reasons to teach proof, discussed below, reflect this focus on the needs of pure mathematics students.

Why Teach Proofs?

In this section I briefly describe five reasons for teaching proof, as put forward by the literature. Many such lists exist (Zaslavsky, 2012; Hanna, 2014; Leron and Zaslavsky, 2013); the one presented here is my union of those lists, presented in my own words. These reasons are: developing skill at proof creation, problem solving, connecting concepts and clarifying assumptions, teaching logical reasoning, and convincing someone that a statement is true. These five reasons are present to greater or lesser extent in much of the mathematics education literature, which, unfortunately, largely does not consider engineering students. I leave what I argue is the most important reason in our context until last and then elaborate on my argument in the next section.

To learn how proofs are developed so that you can create your own

Students who are studying mathematics with the intention of continuing to advanced undergraduate pure mathematics or continuing into postgraduate mathematics degrees need to develop the skill to create proofs of their own. It is therefore a responsibility of their early undergraduate lecturers to use proofs as a teaching tool to develop those argumentative and discursive skills, itself a demanding task (Selden and Selden, 1995). For example, Fukawa-Connelly (2014), in the context of “proof-based courses” such as algebra, explicitly recognises proof teaching as “opportunities for learning about writing proofs” and “how students learn proof writing” (p. 75). I argue that this need for teaching proof is the least valuable for engineering students.

To demonstrate problem solving

Zaslavsky et al. (2012) suggests that problem solving could potentially be demonstrated by providing multiple different proof methods for the same theorem. This reason for teaching proof is not commonly provided in the literature, unlike the other four reasons discussed here, but problem solving definitely could be demonstrated with certain carefully chosen exemplar proofs.

To show how concepts are linked and what assumptions underlie rules/statements/results.

A human intellectual need for proof is the “need for causality” (Zaslavsky et al., 2012, p. 221), frequently driven by “knowing” that something is true and wanting to know why or, alternately, discovering something is not true and wanting to know why. This “need for causality” moves closer to what I recognise as the primary driver to teach (well chosen) proofs in undergraduate engineering mathematics classes. Often students wilt at the appearance of a derivation and request we, the lecturers, simply give them the final result, the mathematical “rule”, and omit the derivation, yet the derivation is key to showing the links between concepts and the reasons why a certain rule can be regarded as true. For example, the calculation of the area of a parallelogram by the vector cross product is used in deriving the conversion factor used in calculating surface integrals. Without derivations such as this and others, using the cross product to find area remains a cute trick used in first-year and its power goes unrecognised.

Redish and Smith (2008) consider the type of teaching which only presents rules as facts as dangerous.

Often what our students learn in our classes about the practice of science and engineering is implicit and may not be what we want them to learn. For example, a student in an introductory engineering physics class may learn that memorizing equations is important but that it is not important to learn the derivation of those equations or the conditions under which those equations are valid. This metamessage may be sent unintentionally.

(Redish and Smith, 2008, p. 297)

If rules or algorithms are taught without derivation, Redish and Smith are concerned that the students learn that the assumptions and scientific principles underlying the rules are treated as irrelevant at the cost of developing associations between concepts and recognising when certain rules or concepts are relevant.

When we teach algorithms without derivation, we send our students the message that “only the rule matters” and that the connection between the equation we use in practice and the assumptions and scientific principles that are responsible for the rule are irrelevant. Such practices may help students produce results quickly and efficiently, but at the cost of developing general and productive associations and epistemic games that help them know how their new knowledge relates to other things they know and when to use it.

(Redish and Smith, 2008, p. 303)

To teach logic

Grabiner (2012) eloquently argues for the need to teach logic in mathematics classes. In her essay on the history of mathematical proof, she demonstrates how the discourse of logical reasoning and the methodological processes of mathematical proof teach skills which have immense power not only within mathematics itself, but in many realms outside of mathematics both historically and today. “The historical function of proof in geometry has not been just to prove theorems in geometry, although of course it did that, but to exemplify and teach logical argument in every field from philosophy to politics to religion.” (Grabiner, 2012, p. 153)

To convince that something is true – to provide a warrant

I have left for last the need for demonstrating and teaching proof which I argue is the most important in the context for teaching engineering students, that of convincing the student that a statement is true, what Rodd (2000) calls a warrant: “that which secures knowledge” (p. 222). The Oxford English Dictionary includes amongst its definitions for warrant: “A guarantor; a conclusive proof; a token or evidence of authorisation; justifying reason or ground for an action, belief or feeling” (Oxford English Dictionary)

Toulmin’s (2003) model of argument (applicable to many different forms of argument, not only mathematical) proposes six elements of an argument: the data, the qualifier, the claim or

conclusion, the rebuttal, the warrant and the backing (Toulmin, 2003; Simpson, 2015; Hanna, 2014). The “warrant” of an argument is the part of an argument answering the question “how do you get from the data to the conclusion?” It is the part of an argument which would appear after the word “since”, as in “the conclusion follows from the data *since* we understand such and such to be true”. Toulmin’s model of argument is influential in mathematics education (Simpson, 2015; Fukawa-Connelly, 2014), however Rodd’s and Toulmin’s definitions of “warrant” are not identical, although similar. It is Rodd’s definition which I am using here.

We have to ask whether the mere presentation of a proof, on the board or on a screen, does achieve that aim of the students recognising a validation of a statement (Jones, 2000), that is determining the truth of the statement. Selden and Selden (1995) have found that sometimes students accept proofs as valid, but still like to see empirical evidence, suggesting that more justification than a formal proof is needed. What one is really after, as a teacher of and learner of mathematics, is to *know* that something is true. The hard truth is that, for the novice mathematician, a proof is neither a necessary nor sufficient condition for such a warrant.

I may justify a proposition by reproducing a proof of it, but this may not warrant my knowledge of the proposition because the proof is not my own reasoning. Moreover, it may be possible to know without being able to justify in terms of reasons (visualization, for example, may warrant).
(Rodd, 2000, p. 222).

One of the intellectual needs (Zaslavsky, 2012) met by proof is the need for certainty. Studies have shown that students do experience a need for certainty in mathematics, but that need is frequently not met by formal logical proofs and comes about by worked examples, or examination of special cases, or diagrams. Furthermore, if the need for certainty is met by examples or diagrams, there is no further drive to require a formal, general proof (Almeida, 2000). In certain key cases, however, a formal logical proof is completely convincing of the truth of the result and thereby does constitute a warrant, in that it “secures knowledge” (Rodd, 2000, p. 222).

The Primary Role of Proof In An Engineering Mathematics Class

In this paper, I suggest that “warranting” is the primary role which mathematical proof should serve in an engineering mathematics class. The first reason for teaching proof listed above, that of inculcating the student into the discipline of pure mathematics so that they can learn to develop and create formal mathematics proofs is largely unneeded in engineering. A small number of students proceed into postgraduate studies and an even smaller number proceed into sufficiently mathematical branches of engineering that they need to develop anything resembling original theorem proofs. Given that there are great demands on time in a typical mathematics class, spending time on developing original proof development skills is poor use of time.

The second reason listed above, that of teaching problem solving by demonstrating multiple proving methodologies for a single theorem statement, is harder to achieve through formal proofs than it is through problem solving one’s way through a demonstrated exercise. It is hard to see proof as the best vehicle for teaching problem solving skills.

The third reason, that of showing how concepts are linked and what assumptions are at play in any particular mathematical result or statement is certainly valuable. Deriving all the standard differentiation rules in first-year calculus is an obvious example of where such a process is very visible. Another example in first-year calculus is that it is quick and obvious to formally and symbolically show that differentiability implies continuity.

The fourth reason for teaching proof, that of teaching logic and logical reasoning, is extremely important. “In the systems of secondary education in most countries, if

mathematics teachers do not teach logic, logic doesn't get taught" (Grabiner, 2012, p. 153) While it is clearly true that formal logical proof does teach logical reasoning, this skill is arguably also demonstrated in other areas within a mathematics class. I argue that rigour, strictly correct use of algebraic symbolic language and adherence to mathematical register and discourse throughout the course continually demonstrates logical reasoning.

That brings us to my last listed reason to teach or demonstrate proof, that of convincing the student that a mathematical statement is true. I argue that the purpose of proof in an engineering mathematics class is warranting, that is, securing knowledge. When considering the inclusion of a formal proof in class, the lecturer should ask herself whether it constitutes a warrant and only if it does should it be included. Sufficient proofs will meet that criterion that the other purposes of teaching proof will be fulfilled. Proofs that are unlikely to constitute a warrant will only serve a negative purpose by supporting any preconceived notions the student may have that mathematical proof is boring and unhelpful, notions that students not studying mathematics for mathematics' sake can tend to have. To illustrate my point, I include below two proofs, one which I suggest does constitute a warrant for students who make the effort to follow it and one which does not, by employing mathematical techniques that are valuable in themselves but which are not obviously valuable (nor familiar) to a first- or second-year student of engineering.

Example of a proof which does constitute a warrant:

Clairaut's Theorem on equality of mixed partials: Suppose f is a real-valued function of two variables x and y and $f(x, y)$ is defined on an open subset U of $\mathbf{R}^2$. Suppose further that both the second-order mixed partial derivatives $f_{xy}(x, y)$ and $f_{yx}(x, y)$ exist and are continuous on U . Then we have $f_{xy}(x, y) = f_{yx}(x, y)$ on all of U .

Proof

For any point (a, b) in U

$$\begin{aligned} f_{xy}(a, b) &= \frac{\partial}{\partial y} f_x(a, b) = \lim_{k \rightarrow 0} \frac{f_x(a, b+k) - f_x(a, b)}{k} \\ &= \lim_{k \rightarrow 0} \frac{\lim_{h \rightarrow 0} \frac{f(a+h, b+k) - f(a, b+k)}{h} - \lim_{h \rightarrow 0} \frac{f(a+h, b) - f(a, b)}{h}}{k} \\ &= \lim_{k \rightarrow 0} \frac{\lim_{h \rightarrow 0} \left(\frac{f(a+h, b+k) - f(a, b+k)}{h} - \frac{f(a+h, b) - f(a, b)}{h} \right)}{k} \\ &= \lim_{k \rightarrow 0} \lim_{h \rightarrow 0} \frac{f(a+h, b+k) - f(a, b+k) - f(a+h, b) + f(a, b)}{hk} \end{aligned}$$

Similarly we can find

$$f_{yx}(a, b) = \frac{\partial}{\partial x} f_y(a, b) = \lim_{h \rightarrow 0} \lim_{k \rightarrow 0} \frac{f(a+h, b+k) - f(a+h, b) - f(a, b+k) + f(a, b)}{hk}$$

The expression whose limit is being computed is the same in both cases, therefore

$$f_{xy}(x, y) = f_{yx}(x, y)$$

for all (x, y) in U .

Example of a proof which is unlikely to constitute a warrant

Epsilon delta proof of the limit law "the limit of a sum is the sum of the limits", that is

$$\lim_{x \rightarrow a} [f(x) + g(x)] = \lim_{x \rightarrow a} f(x) + \lim_{x \rightarrow a} g(x)$$

Proof

Let $\varepsilon > 0$ and let $\lim_{x \rightarrow a} f(x) = K$ and $\lim_{x \rightarrow a} g(x) = L$.

Since the limits of f and g exist, there exist $\delta_1 > 0$ and $\delta_2 > 0$ such that

$$|f(x) - K| < \frac{\varepsilon}{2} \text{ whenever } 0 < |x - a| < \delta_1$$

$$|g(x) - L| < \frac{\varepsilon}{2} \text{ whenever } 0 < |x - a| < \delta_2$$

Now choose $\delta = \min\{\delta_1, \delta_2\}$. We need to show that

$$|f(x) + g(x) - (K + L)| < \varepsilon \text{ whenever } 0 < |x - a| < \delta.$$

Assume that $0 < |x - a| < \delta$. Using the Triangle Inequality, we then have

$$\begin{aligned} |f(x) + g(x) - (K + L)| &= |(f(x) - K) + (g(x) - L)| \\ &\leq |f(x) - K| + |g(x) - L| \\ &< \frac{\varepsilon}{2} + \frac{\varepsilon}{2} \\ &= \varepsilon \end{aligned}$$

Thus

$$\lim_{x \rightarrow a} [f(x) + g(x)] = \lim_{x \rightarrow a} f(x) + \lim_{x \rightarrow a} g(x).$$

Naturally, my choice of proofs shown above is influenced by my opinion of how convincing of truth they are. A fruitful further research project would be to survey students on which proofs they do indeed find convincing.

Conclusion

The challenge we face as educators of mathematics is to teach a wide range of rules and algorithms with sufficient derivation to give depth to the students' knowledge, allowing them to make connections within their knowledge networks and understand the constraints on and applicability of knowledge and concepts within context. The derivations, whether formal proof or not, need to constitute a warrant, where "warrants are for truth, and justifications are reasons" (Rodd, 2000, p. 223). Ideally, a formal proof with its careful deductive reasoning from axiomatic principles should constitute such a warrant, but often it does not. Proof therefore plays an uneasy role in an engineering mathematics classroom, both very necessary for warranting yet frequently not good enough.

Engineering students are different from students majoring in mathematics. Their reasons for studying mathematics are different and the uses to which they will put mathematics are different (Redish and Smith, 2008). While much of the content taught to engineering students and to mathematics majors is the same, different considerations need to drive pedagogical choices on how the curriculum is presented. One area where different needs drive choices is in the teaching of formal logical proof. The literature on proof foregrounds a number of reasons to teach proof which I have summarised here as developing skill at proof creation, problem solving, connecting concepts and clarifying assumptions, teaching logical reasoning, and convincing someone that a statement is true. I argue that the last of these reasons is the most important role proof has to play in an engineering mathematics classroom. A clearly

demonstrated proof can be unequalled in its capacity to convince the reader of mathematical truth.

Questions which remain to be asked in future research include: Are there any theorems or otherwise provable statements in the undergraduate engineering mathematics curriculum which “secure knowledge” reliably for a majority of the class? If so, which are they? Is it possible to rank theorem proofs by their “warranting likelihood” and, if so, where do we draw the line between teaching or omitting the proof? Do students from different educational backgrounds, or languages, or nationalities have different propensities to be convinced by any one formal proof? I hope to seek answers to some of these questions in future research.

Much of what I have opined in this paper is controversial. Some of my colleagues may argue that proof creation skills are as valuable for engineering students as for mathematics majors. Some might argue that all proofs are equally constitutive of warrants. I call for further research to enrich this discussion. While the mathematics education literature has much to say about proof, there is little which pertains to engineering students.

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MOOCs and transitions: Pathways in and out of learning and work

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Understanding and supporting transition pathways - in and out of learning and work - is increasingly important for universities aiming to support graduates in ongoing professional development. People making such transitions eagerly seek out information to learn about and understand current topics and develop new skills. Information not thoughtfully curated in support of learning may lead to misunderstanding or lost opportunities. Appropriately conceived Massive Open Online Courses (MOOCs) can help support people in such transitions. Understanding how people make use of MOOCs, especially in developing country contexts, should inform universities' responses and provide insights into how they can support transition pathways. Our research explores the experience of people taking MOOCs offered by the University of Cape Town (UCT). We focus on their experiences of these less visible online transitional spaces. Focusing on transitions helps frame the MOOC audience research on those seeking this specific value from courses. It also informs tools used to analyse survey data more systematically. The data from the UCT MOOCs Project consists of course enrolments from throughout the world, and includes a significant proportion of graduates, students and aspiring students from the African region. Investigating MOOC learner experiences becomes especially important for universities aiming to reach a wider audience regionally and beyond. The initial analysis of data from an engineering faculty MOOC illuminates the ways in which MOOCs help people make choices and transition, especially among working graduates.

Introduction

We conceptualise transitions broadly as occurring when people move between work and learning, between different disciplines of knowledge and between different levels of learning. There is much reflection in higher education about how to be more responsive to such transitions. People intending to make such transitions eagerly seek out information to learn about and understand current topics and develop new skills. Here we investigate stories of transitions of Massive Open Online Courses (MOOCs) takers, who have enrolled in a MOOC in an Engineering-related field: Climate Change Mitigation in Developing Countries (CCM-MOOC) offered by the University of Cape Town (UCT). We focus specifically on MOOC takers in developing countries, as one of the goals of the UCT MOOCs Project is to offer support to this constituency.

Since MOOCs have no entry requirements, anyone can enrol, including people with no formal qualifications, those with a general interest and retired persons. It is more likely, however, that people with some academic or work background relating to the topic will be interested given that typically a relatively high proportion of MOOC takers already have degrees (Glass *et al.* 2016). Whereas students who register for degrees would have the explicit intention of completing a course for credit, people engaging in MOOCs are better described as 'volunteer learners' with a range of intentions. In lieu of needing formal qualifications, these 'volunteer learners' may want to become more aware of new fields, to develop specific skills or to acquire additional knowledge required for interdisciplinary opportunities. We are specifically interested in what ways MOOCs are being used as opportunities for transitions for these learners. Here getting value from taking a MOOCs need not require actually completing the

whole course (Howarth *et al.* 2016, Walji *et al.*, 2016). This contrasts with other MOOC related research which aims to ascertain how or what people learn (Veletsianos *et al.*, 2015) or which focusses on why people do not complete a course (Onah, Sinclair & Boyatt, 2014).

Since MOOCs are not designed in the same way as traditional formal online courses, the MOOC format provides the opportunity to question existing assumptions about online learning. MOOCs provide far less direct learning support, rather relying on features such as peer assessments, auto-graded quizzes and peer engagement. MOOC takers have a great deal of choice with regards to a pathway through a MOOC, and understanding what they choose and wish to do in a MOOC has been an active area of inquiry.

We first consider the roles of MOOCs in the higher education landscape before introducing the research question which is to understand what MOOC takers find of value. This study uses the CCM-MOOC as a case study. We analyse the survey and platform data available from this MOOC. Naturally there are limitations with using such an opportunistic collection of data. However the intention of this analysis is to inform the planning of a more systematic study on understanding transition pathways in and out of work and learning.

Higher education and MOOC takers

In response to changing learner needs, many universities have been exploring different course formats through experimentation with modes of delivery, entry requirements, assessment practices and flexible provision resulting in a diverse landscape of higher education provision. Figure 1 represents this landscape as having three bands, namely, ‘formal’, ‘semi-formal’ and ‘non-formal’ (Czerniewicz *et al.*, 2014, Walji *et al.*, 2016). In this landscape, a MOOC is positioned as a flexible non-formal or semi-formal course that, in relation to a traditional formal course, is expanding the breadth and access of university course provision. In the past ‘semi-formal’ and ‘non-formal’ courses tended to be small and did not attract much attention, but with large diverse enrolments and global access, MOOCs have been increasingly the subject of research.

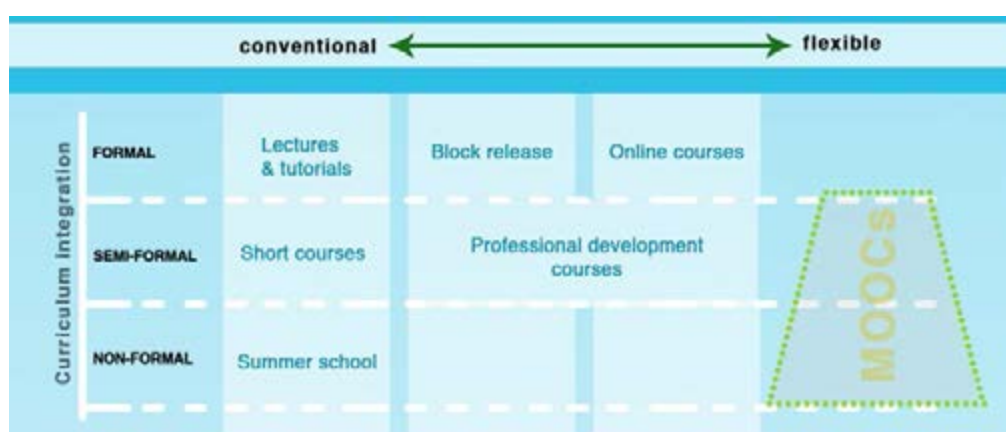


Figure 1: The landscape of higher education course provision.

To innovate with MOOCs and other flexible course formats, universities have partnered with companies that build infrastructure to host these courses. UCT has partnered with Coursera, which now has 24 million registered learners globally, over two thousand courses and rich platform features (Coursera 2017). Coursera’s mission statement states that it aims to ‘provide

universal access to the world's best education' and describes its course design as being developed through mastery learning, peer assessments and blended learning.

Coursera, along with many other MOOC platforms, is exploring a range of business models to fund and sustain platform development including considerable experimentation around the forms of certification and where to place the paywall on open learning. To cater for developing country learners and weak exchange rates, the UCT MOOCs are priced at the lowest certificate level in all cases. Coursera also allows learners to request fee waivers for certificates.

The university partners take responsibility for identifying topic areas and creating courses. The UCT MOOCs Project received funding from the UCT Vice Chancellor's strategic fund to create twelve MOOCs over three years. The UCT MOOCs Project goals included developing the institution's online capacity, showcasing teaching and research as well as supporting students in introductory or gateway courses. UCT academics were invited to submit proposals that required a motivation for the likely value of the course to people in the region. For example the 'Understanding Clinical Research' MOOC has explicit goals to support postgraduates transitioning into research, while 'Writing Your World' aims to help undergraduates transitioning into higher education and develop an academic writing voice. The other UCT MOOCs include opportunities for students to transition into a new or interdisciplinary field of study and to support continued professional development.

In imagining intended MOOC takers, one can distinguish between inward and outward facing courses (Czerniewicz *et al.*, 2014). While most MOOCs are open to anyone to enrol, inward facing MOOCs are more aligned with supporting students and curricula within the university. In contrast outward facing MOOCs are generally conceived to help showcase the university's teaching, professional development or research. CCM-MOOC is primarily an outward facing course showcasing research at post-graduate level.

Research question

To identify what MOOCs can offer within the course landscape requires a better understanding of the particular value people see from the MOOCs they have taken. Not having direct contact with MOOC takers requires asking more focused strategies to help understand what people have valued as well as ascertaining the nature of transitions - as those pathways in and out of learning and work – which are useful to MOOC takers. Such transitions are described using a range of related terms in the literature, including life-course changes, turning points and branching points (Rönkä *et al.*, 2003). Common to these understandings of transitions is the idea that events or opportunities can result in people reassessing priorities leading to changes or seeking goals which can impact people's lives and careers.

We wish to understand how MOOC takers are being assisted by their MOOC experiences to move between work and learning, between different disciplines of knowledge, and between different levels of learning. We wish to understand the expectations for open online courses offered by universities and the difficulties experienced with this type of learning. The main question for this paper is: What are the types of transitions people from developing countries describe and value?

Literature Review

While there is a wide range of research on transitions (Gale & Parker 2014, Holmegaard *et al.*, 2016, O'Shea 2014), this research tends to be very contextual. From their extensive research in Australia, Gale & Parker (2014) observe that transition tends to be conceived in three ways – as induction, development and becoming – each of which is associated with different

transition policies, course offerings and research outputs. The three transitions thus broadly correspond to those stages of an individual's life before, during and after (formal) studying, although this division is not quite as clearly delineated in practice. Takers of the CCM-MOOC are those most likely to be supported in the act of 'becoming' with regards to their chosen profession given the relatively high proportion of graduate MOOC takers, although opportunities for 'induction' and 'development' remain, given the diverse audiences MOOCs attract.

However, comparatively little research relates to the diverse participants found in MOOCs and various forms of transitions (e.g., Garrido *et al.*, 2016), in part because of difficulties collecting data. More frequently, research on MOOCs and transitions tends to focus on how universities respond to perceived needs of people in transitions in relation to market or industry-wide pressures (e.g., Clow 2013; Howarth *et al.*, 2016) or focus on the granular learning experiences of people taking MOOCs (e.g., Veletsianos *et al.*, 2015). Literature from marketing and technology adoption has been used to describe both MOOCs models and learners' uptake. Clow (2013) and Howarth *et al.* (2016) use the metaphor of a funnel of participation to describe how MOOCs are used as 'tasters', where completion may not be the goal of everyone, to differentiate this from formal courses. The notion of 'tasters' describes how MOOCs can attract enrolment into postgraduate study as well as for developing basic skills, especially for people with existing qualifications.

MOOCs are often cast as a new or disruptive technology that has attracted attention of both MOOC takers and makers. MOOC platforms can be seen marketing new educational technologies and interest in seeing how this might address some of the complex problems of Higher Education provision underpins much MOOC discourses. There has been close scrutiny of how universities have responded, made choices and innovated around open and flexible formats (de Freitas *et al.*, 2015). There is, as Calonge & Shah (2016) note, also long standing scepticism about whether or when online, flexible and affordable courses will reduce the challenges facing students and universities.

Many of the MOOC platforms do certainly make use of the discourse of technology marketing and link ideas of educational achievement with access. The Coursera mission statement states 'anyone, anywhere can transform their life by accessing the world's best learning experience' which implicitly suggests that access to education might address all educational problems being faced. Furthermore Coursera suggests that '[w]ith flexible start dates, adjustable due dates, and easy to use mobile apps, you can learn when and where you want.' (Coursera 2017). While a mission statement and promotional material are expected to be inspirational and motivating, learning does not easily happen anytime, anywhere and flexibly. Sheail's (2015) work on critical temporalities and online education is one possible way in which to understand MOOC takers' experiences by recognising how someone's time invested in learning is something shared, limited and not easily managed.

Research design

Coursera, like all other MOOC platforms, collects usage data that is typically presented in aggregate forms to monitor and evaluate courses (Chapman *et al.*, 2016). These enrolment, engagement, assessment and quality measures are shared with university partners. Some of this can be related to the research question, by looking at who enrolled in CCM-MOOC and why. While comparatively little of this data relates to quality and the experiences of learners beyond the course the Coursera 'Learner stories' have provided the most useful text for analysis, as they are reflections on the course experience.

We have adopted a mixed-methods research design, using quantitative and qualitative approaches in a coordinated manner in the same research study (Jensen & Laurie 2016). As there are some limitations to both the quantitative and qualitative data that is available for analysis, a mixed-methods research design can help mitigate some of the weaknesses of the available data. Our intention in this paper is to also critically assess what we have and to identify better ways to collect more informative data with the goal to inform the creation of improved instruments for a larger study involving creating a set of survey questions followed by a selection of interviews.

Case study: Climate Change Mitigation

The CCM-MOOC considers how one might lift societies out of poverty while also mitigating greenhouse gas emissions. It explores the inherent complexity of developing country governments wanting to grow their economies in a climate friendly way (Reubenheimer *et al.*, 2015). Weekly topics include facilitation process techniques, energy modelling, scenario building, innovation and policy making. While primarily showcasing research, offering the course was seen as an opportunity for MOOC takers to transition into a multidisciplinary postgraduate programme from related fields, as well as for those transitioning within a field of work. Drawing on one and a half years' worth of available data we consider who has taken the CCM-MOOC, and what types of transitions are apparent.

Who enrolls on the CCM-MOOC and why?

The Coursera platform collects country data based on the IP address of each participant who makes their browser location visible (85%). The CCM-MOOC attracted a higher proportion of enrolments from developing countries when compared to the mean for all Coursera courses, i.e. 18% African enrolments compared to the Coursera mean of 5%. While the CCM-MOOC course emphasises cases from developing countries, all UCT MOOCs have similarly attracted higher proportions of South African and African enrolments, suggesting the university location is important for attracting enrolment from the continent.

Certificate sales are an indicator of an interest to receive recognition for completing the course. While CCM-MOOC is a free course, one can opt for certification, either by purchasing or applying for financial aid. Of the 12,368 who enrolled in the first year and a half of the course running, 508 requested a certificate (4.1%), which is similar to the uptake on other courses. As might be expected, applications for financial aid are much higher for people from developing countries.

We had administered pre and post course surveys to supplement data from the Coursera platform and to obtain further information about the people participating in the course. Generally MOOC learners are well-educated (Glass *et al.*, 2016) and this is reflected in CCM-MOOC. Of those surveyed (n=242), a high proportion (95%) have a degree qualification and the remaining 5% are in school or have school level qualifications. Of those with degrees, 60% have Masters or higher degrees and 35% undergraduate degrees, suggesting that few learners need to seek further formal qualifications. A similar pattern is seen in Coursera survey data for a different sample of people on the course.

Responses to a pre-course survey question on the reason for enrolling on the course (n=258), show 68% indicating it would be of value to their current job, 81% for their future career, 79% for future studies and 21% for returning to study (see Figure 2). This might suggest that a high proportion of MOOC takers intend to transition in some way.

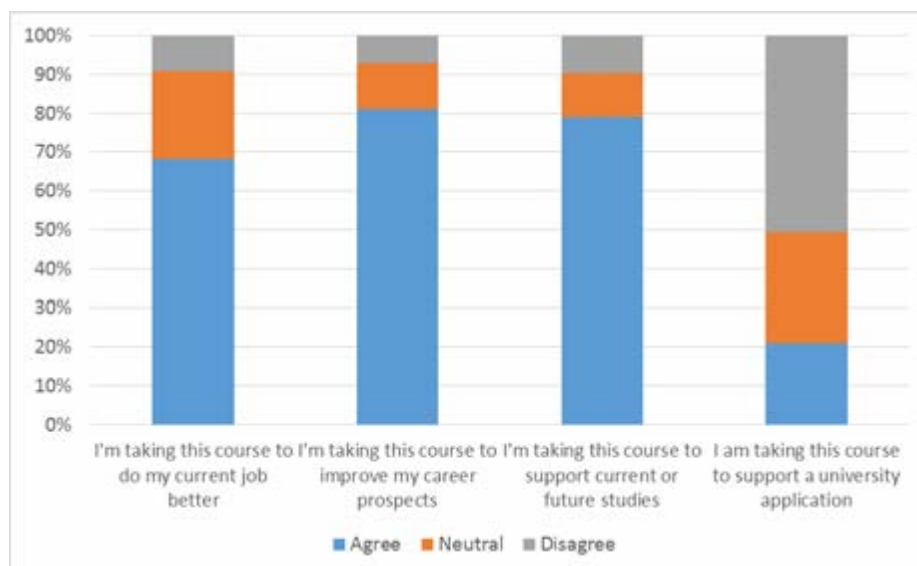


Figure 2: Responses to CCM-MOOC pre-course survey asking reasons for doing the course (n=258).

In what ways has the CCM-MOOC been valued?

For those completing the course and opting for certification, a certificate is added to the 'Accomplishments page' of the Coursera platform. On this page people are invited to share their experiences, referred to as a 'Learner story' (see Figure 3) which only the course instructors and teaching team can see. On the Coursera platform there are also course reviews, discussions and other places where people have opportunities to describe their experiences and indicate the value gained from the course.



Figure 3: Prompt on the Coursera 'Accomplishments page' encouraging people to submit their stories.

In total 71 'Learner stories' were analysed. We identified information about the participant location, profession and the value they found from the MOOC, including how the MOOC might be supporting transitions in their lives. With respect to location, 36 stories revealed no specific information. The remaining 35 were heavily skewed towards countries in Asia (13), Africa (11) and South America (6). Two other participants said they were from developing countries. Only one learner story identified as being from South Africa.

Of the total, 34 learner stories revealed information about the MOOC takers' profession. These professions included engineers, researchers and government officials as well as people working in NGOs and education institutions. There were also two post-graduate students and two individuals who were retired.

Nearly a quarter of the learner stories (17) made clear reference to how they had been able to apply what they had learnt in the MOOC directly to their work:

“I am an Energy Engineer working on... Uganda's Green Growth Development Strategy.... I noticed sharp contestations on data and methods amongst the different members of the scenario building team... What started as an exciting 'scientific' assignment seemed to be turning into a political contest of sorts... It was then that I started looking out for countries that have gone through these processes before, and that is how I came across this course. I feel empowered now. I am confident that I can play a significant part in the processes.”

“I have been part of the climate change policy setting process in my country Rwanda in a senior position in the Ministry of Natural Resources I took this course in order to get insights on how mitigation is being handled in developing countries.”

“The material and contacts made through this course helps my work as a freelance environmental journalist.”

“Being from a developing country (India) and working in a sector (urban transport) which is a major contributor to the problem, I will be able to take the learnings from the course towards making some positive impacts.”

“As staff in the planning office of the province of Rizal Philippines, it gave me added awareness on my environment and how our actions lead to devastation of our resources. Presently, we are updating our provincial physical framework plan and big part of it involves the disaster preparedness and climate change affect integration to various sectors.”

The data revealed people from different backgrounds being exposed to interdisciplinary perspectives:

“It has help me learn how to engage with other colleagues outside my field of work.”

“I have been able to incorporate the climate component into my academic context.”

People who are not necessarily directly involved in climate change professional activity but might work in ancillary fields also valued being able to understand processes such as mitigation and issues impacting developing countries. Some MOOC takers included explanations of how they had taken the course to help them with specific challenges in their work:

“I was preparing a strategic environmental assessment at the time of undertaking the course and found there were lessons that could be drawn from [it].”

“As an environmental activist member of an NGO ... in the DRC, I will apply this course through the idea of a project to create a cooperative of agroforestry of 126 members.”

“With my academic background in Mechanical Engineering, Masters in Development Studies and MBA in Executive Program, this course ... will help me to develop climate change project and strategy especially for GCF project submission and to implement ongoing projects as well.”

Some learners were anticipating transitions in careers pathways and induction into the field of study:

“This course has truly shaped how I plan to pursue my career and gave me a much better understanding of the current ecosystem of climate change in developing countries.”

“Being a Physics student [in Nepal] I always have a deeper insight to the interrelationship between physics and environment so I have specialized in Atmospheric Physics in the final year of my master's study. This course has added another brick in my educational career.”

“Yours is the type of educational structure I need to be practical about my ideas to set up a Sustainable Development and Environment initiative agency in Guinea.”

Others spoke of how the course experience encouraged them to consider further study, research and teaching:

“I was not certain what I was going to do next. Thanks ...for providing such a good opportunity to keep myself within my areas of study and interest.”

“It will help me a lot in my career as an assistant lecturer at university.”

There were two that specifically mentioned studying further at UCT:

“I’ve seen you offer an MPhil in Energy & Development Studies and I was thinking about maybe following this master in 2018 after the project here will be finished. This course gave me a good introduction to your university and the masters.”

Both the retired learner stories reflected a transition from being in retirement back into studying. Only one person made explicit reference to the value of the Coursera certificate, although over 500 had sought to get certification:

“I really appreciated the course especially because I have been working on Climate Change issues without certificate.”

This is a self-selected group of people who specifically chose to share something about what they valued and intended to do in future. They are not sharing their problems or difficulties but their intentions and experiences. More developed countries with many opportunities appear underrepresented. Although each learner story is very different and cannot be neatly categorised, we see transitions within professions, across interdisciplinary fields, into study, and further study. These are addressing gaps for working people whose needs are not catered for through formal university study.

Discussion and further research

The CCM-MOOC learner stories have given insights into people’s lives that are otherwise invisible. The question we posed was whether and how people in developing countries used CCM-MOOC to support transitioning in and out of work and learning. Following the Gale & Parker (2014) characteristics of transitions, these were mostly about becoming rather than induction or development. This suggests transitions in identity rather than the acquiring of skills. This mirrors the course design which helps learners think through the inherent complexity of developing countries needing to grow their economies in a climate friendly way. While workplace transitions were most frequently described, there were also cases of people seeing CCM-MOOC as a taster and induction into further study.

MOOC platforms such as Coursera emphasise access and suggest that ‘you can learn when and where you want’ (Coursera 2017). Although there was no specific mention by learners of access issues we conjecture that while people were likely to have faced challenges they made little reference to these in the Learner stories, despite clearly having invested considerable time in the course watching videos, reading articles and completing assessments. The brevity of the learner stories and lack of follow up questions leaves open further lines of enquiry. Implicit in the research question is to find out more about how people value MOOCs. As part of the post course survey we asked people if they were willing to be interviewed; the high positive response (68%) suggests we are likely to find people willing to be interviewed. Interviewing MOOC takers is planned for the next stage of the study.

Simply observing and recording what people say about transitions has limitations, in part because we have not been able to establish more detail about the participants’ context, intentions and specific applications of the MOOC learning. As Tedlock (1991) argues for adopting a narrative ethnography, one needs to have a more subjective perspective, a move from participant observation to the observation of participation. The narratives from participant interviews will allow us to further unpack the research question to understand the relationship

between the university and the phenomenon of transitioning in and out of work and learning. We have received research funding to conduct narrative interviews with UCT MOOC takers.

Conclusion

We conceptualised transitions broadly to include those changes which occur as people take action to move between work and learning, between different disciplines of knowledge and between different levels of learning. Stories shared provided examples of such transitions and an interest in more opportunities. The majority were from people in work that ranged from those applying what they learned immediately to those seeking insights into the wider field as it intersected with their work. Another smaller group of learners saw value from the MOOC to enable transitions into study, mostly from other disciplinary fields.

Higher education commentaries have presented diametrically opposed views on MOOCs, suggesting both that they are solutions and distractions to challenges facing the sector (Howarth *et al.*, 2016; de Freitas *et al.*, 2015). Our research has sought to explore how MOOC takers are making use of MOOCs and MOOC materials, including to assist them make transitions. We are in the process of conducting further interviews to enhance our understanding of what people value in MOOCs. Elaborating on these learning experiences is important for improving strategies to support people making transitions in and out of learning and work that extends beyond the traditional university's reach.

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A web-based learning platform for remote engineering laboratories

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In an era of soaring costs, increasing student numbers and industry demands, it is becoming more challenging for institutions to offer a balanced engineering education that provides students with theoretical knowledge integrated with real-world problem solving exposure, essential to instil a “design oriented thinking” (Dym, Agogino, Eris, Frey, & Leifer, 2005). Engineering programmes at an undergraduate level also need to ensure learners meet their required exit level outcomes. To be successful this needs to take place within a simulated real-world setting. Learners need more self-opportunity and time to experimentally engage with subject matter (Toth, 2016). More efficient laboratory strategies are thus required within engineering education that will be simple and flexible for staff and students alike and still give students a self-paced, stimulating and high quality learning experience. Due to Industry 4.0 there is a growing implementation of interconnected sensors, actuators and digital computing across all engineering fields as well as an increased need for access, connectivity and human-machine interaction (Hermann, Pentek, & Otto, 2016). It is therefore important for engineering laboratories to offer a broad-spectrum mechatronic approach that remains problem-centred, product design oriented and project-team organized (Wikander, Torngren, and Hanson (2001). Such an approach should ideally include ‘real-world’ problems that better prepare students for industry without drastically affecting implementation costs.

This paper details some of the challenges faced within engineering education and how they are being tackled at the Nelson Mandela Metropolitan University (NMMU) within the Advanced Mechatronic Technology Centre (AMTC). Of about nine industry standard laboratory systems that were developed, five are in the process of being converted into remote e-learning systems that will allow students to perform tasks remotely yet still gain maximum practical benefit. An additional novel e-learning system that has been developed, implemented and tested as an undergraduate control systems laboratory makes use of actual industrial hardware and software components. The lab allows learners to control a selection of virtual, model-based plants that can be re-configured and expanded upon without having to purchase additional components. Results and deductions collected from the systems implementation are detailed. All of the developed e-learning systems are readily accessible via an online portal that also features a laboratory scheduling system, an automatic practical guide generator and a feedback and comments section.

Teaching and Learning within Engineering Education

Traditionally, technical content has been learned through a process of deduction where learners are presented with the theoretical content beginning with fundamentals followed by a section of practical application. It is intended through this method that learners will be able to apply and hence solidify their understanding of underlying principles taught in class (Prince & Felder, 2006). Arguably, a better approach to deductive learning is inductive or student-centred learning in which learners have to determine for themselves, based on a combination

of research and interpretation of results, the best approach to solving a particular problem. Inductive teaching and learning encompasses a number of instructional methods that have many similarities and include inquiry learning, problem-based learning, project-based learning, case-based teaching, discovery learning and just-in-time teaching (Felder & Silverman, 1988; Godrich, Nehorai, Tajer, Greco, & Zhang, 2017; Prince & Felder, 2006). These methods of learning are “active” learning methods and usually include a mixture of formal lecturing, tutorials, group laboratories and individual design projects. (Prince & Felder, 2006). College and university faculties around the world are finding themselves leaning more towards active learning strategies that require greater engagement and interaction of students in the learning process (Hall, Waitz, Brodeur, Soderholm, & Nasr, 2002).

Based on 15 years of teaching practice, Wikander et al. (2001), suggest that engineering curriculums should be problem-based, product design oriented, and project-team organized in a form similar to professional industrial product development and should include as many real-life situations as possible. They further suggest that engineering courses, at least as far as laboratory work goes, should focus on bridging the gap between individual course components. For an advanced engineering course such as Control Systems, individual course components including software design, control theory, dynamic systems modelling and real-time implementation would need to seamlessly integrate. The development of communication skills and teamwork experience among the students must also not be overlooked when learning is evaluated. Group projects that are structured such that they still allow individual assessment to be conducted are highly recommended. Additionally, since ‘design work’ is considered to be the central activity within engineering, there is need to develop design skills in students through project based learning that entails a significant research and design aspect (Dym et al., 2005).

Motivation for an Industrial Approach in Engineering Education

In light of the above mentioned points, countless industry based lab systems have been developed by technical colleges and engineering institutions around the world. Common systems include transfer systems such as conveyors and Automated Guided Vehicles (AGVs) for materiel handling, process and instrumentation systems, robotic arms with grippers, stacking systems and steering applications just to name a few. The aim of most of these laboratories is to give students maximum exposure to modern electrical and computing technologies whilst taking up the least amount of laboratory space (Bassily, Sekhon, Butts, & Wagner, 2007; Craig, 1999). The widespread use of Programmable Logic Controller’s (PLCs) in industrial processes has motivated their use in many current mechatronic educational systems. PLCs are usually performance graded and offer a rugged yet simple industrial solution to monitoring and control problems. The cost of PLCs generally increases with performance. Nevertheless, even lower performance PLCs are capable of performing relatively complex tasks including demanding maths functions, interrupt requests and data acquisition. They also usually come with a wide choice of graphical or text based programming languages that relate closely to mainstream programming languages. Network connectivity for remote access and control is also a possibility with most standard PLCs (Saygin & Kahraman, 2004). A major drawback is that the cost of PLCs compared to other programmable devices such as microcontrollers is significantly higher (up to 8 times for the lower performance range). Despite this, as industrial processes grow in size and complexity the need for engineers with strong skills and knowledge in this area, who can propel industry in to the future, is great (Hsieh & Yeehsieh, 2004). In most 3rd world regions of the world

including South Africa, a definite skill gap exists when it comes to digitization, automation, process control and instrumentation. Engineering courses that adequately prepare students not only to fit in to industry but also to make meaningful contributions thereafter are therefore of utmost importance. At an advanced engineering level this would imply exposing students to industrial technology and practices and subsequently to more complex real-world problems that would direct them in thinking and solving problems in a systematic way just as engineers would in the real world. Throughout this process, strong emphasis must be placed on current and futuristic technological trends such as the Internet of Things (IoT) and Industry 4.0 which envision the possibilities of highly available and connected systems.

Grooming Engineering Students for the Future: Internet of Things and Industry 4.0

Advances in the manufacturing and process industry have paved the way for Cyber-Physical-Systems (CPS) that seek to integrate computational algorithms, controllers, networks and physical processes in order to bring virtual and physical worlds together. Such systems have vast social and economic potential and are thus gaining widespread international attention (Lee, 2012). CPS forms the basis of IoT which makes smart services and products possible by interconnecting and promoting interaction of everyday objects with one another and with humans via the internet (Xia, Yang, Wang, & Vinel, 2012). Industry is gradually also moving towards fully integrated and connected systems in what has been named the fourth industrial revolution or Industry 4.0. It is a collective term consisting of a number of different technologies used in the 21st century (e.g. contemporary automation, data exchange and manufacturing technologies). It includes the operation, monitoring and modification of plants, processes and machines through the Internet (remote access). The rise of Industry 4.0 will undoubtedly be accompanied by a corresponding change in human activity and involvement in the factory (Gorecky, Schmitt, Loskyll, & Zühlke, 2014).

Beyond simply gaining an understanding of the coming changes, engineering students would need to be prepared to meet the demands of working in a highly connected environment. To this end, a shift away from the conventional teaching methods to a more interactive and collaborative approach that encourages virtual learning would be necessary (Schuster, Groß, Vossen, Richert, & Jeschke, 2016). In the virtual world, simulation has been used extensively to provide illustrations of systems that can't easily be visualized or accessed due to their size, hazardous nature, complexity or cost. It also has the benefit of allowing a wide range of tests to be performed and has often been used as a pre-lab experience to give students an idea of what they will experience in an actual experiment. Although there has already been a significant move towards e-learning and virtual laboratories within higher engineering education, proponents of hands-on laboratories argue that the best way to prepare students for industry is to give them real practical exposure. Through this methodology, the senses are stimulated and engagement takes place through what is seen, heard and touched. To somewhat reinforce this argument, a body of research has proven that simulation alone is not sufficient to give students a strong sense of confidence in solving real-world problems (Kappers & Cutler, 2016; Saco, 2002).

Remote laboratories have thus emerged and seem to fit in somewhere between the traditional hands-on laboratory approach and the virtual laboratory approach. Remote laboratories are similar to simulation techniques in that physical presence is not a requirement and they require minimal space and time since the experiments can be rapidly configured and run over the Internet. But unlike simulations, they provide real data and sometimes a live audio/ visual link to view the physical laboratory equipment (Nickerson, Corter, Esche, & Chassapis, 2007). It is difficult to measure the effectiveness of remote laboratories in comparison to

hands-on laboratories, however results from a study carried out by Nickerson et al. (2007) suggest that students learned laboratory content equally well from both types of activities and were able to obtain a realistic understanding of the practical advantages of remote laboratories.

Challenges in Providing Quality Practical Engineering Education

Engineers are increasingly under pressure to work innovatively while dealing with changing workplaces. An underlying need therefore exists to educate engineering students so that they are able to Conceive, Design, Implement, and Operate complex processes and systems in a modern environment (Crawley, Malmqvist, Ostlund, & Brodeur, 2007). Furthermore, industries, governments and professional bodies alike have called on educators to better prepare engineering students for the real-world by emphasizing professional competencies other than technical skills. These include communication skills, teamwork skills, business skills and problem solving skills (Brunhaver, Korte, Barley, & Sheppard, 2016).

In South Africa numerous challenges hinder engineering education. Many of these are highly complex social, political or historical obstacles that are not easily resolved. In this work, attention is therefore rather attributed those challenges that can be confronted and solved at a local level by the institutions of higher learning themselves. The following challenges have been identified in practical engineering education in South Africa but are also common to most institutions of higher learning around the world (Brunhaver et al., 2016):

1. It is becoming increasingly difficult to cater for the rapidly growing student numbers due to a shortage of lecturing and laboratory staff who can give students the needed attention. There is also a shortage of laboratory equipment. This results in the students getting a shorter time to use the facilities which often have to be shared amongst big classes.
2. Engineering programs are often based on out-dated engineering norms that lack forward thinking and don't prepare students adequately for solving real-world problems such as the implications of Industry 4.0 and the Internet of Things.
3. In many cases it is impractical for institutions to purchase and maintain certain laboratory equipment due to high costs, general lack of space or complexity of the setup.
4. In the interest of safety, certain laboratories require students to work under supervision. This could become burdensome for teaching staff to manage especially if the same piece of equipment is to be shared by an entire class.
5. Originality of submitted work cannot be guaranteed especially if all students are required to perform the same practical tasks on the same equipment.

Development of an E-learning laboratory (hub) at NMMU

Formed in 2006, the Advanced Mechatronic Technology Centre (AMTC) is a unit within the NMMU that focuses upon engineering skills development in the Eastern Cape region. To date, in excess of 1000 industry engineering practitioners have received accredited training in different fields ranging from automation to renewable energy. Owing to well established partnerships with large technology players such as Siemens and Festo, the AMTC has been able to set up three state of the art laboratories that are fully equipped with current industrial automation technology. One of these laboratories is devoted to teaching and learning within the disciplines of control systems, process control and instrumentation. The laboratory houses

nine educational systems that were designed and built in-house by electrical, mechanical and mechatronic students in order to facilitate advanced training. All of these systems make use of industry standard hardware and software components. The facility not only benefits delegates coming from industry but also main stream university students who get to work on certain systems as compulsory parts of their curriculums. In attempting to deal with some of the above mentioned challenges faced by universities, five of the nine educational systems are in the process of being upgraded to allow students to remotely access them and safely conduct practical tasks using their personal computers or mobile devices. Live camera feeds as well as real-time embedded and sensor based monitoring and control systems allow learners to work on the systems as though they were physically present in the lab (May, Ortelt, & Tekkaya, 2016). They include:

1. Multi-Disciplinary Process Control System

This process system, shown in Figure 1 gives learners from multiple engineering backgrounds a chance to experiment with actual industrial field sensors, actuators and process monitoring and control devices (such as Human Machine Interfaces (HMI's) and PLC's). The system furthermore offers team based learning where learners are required to get different sections of the plant to interact in order to adequately control certain parameters. The following modes of control are possible and find numerous real-world applications in different sectors: fluid temperature control (heating and cooling through a heat exchange mechanism), flow control, pressure control and 2nd order tank-level control.

When operated remotely, learners will be able to perform the following tasks in real time: Level, temperature and flow sensor calibration, valve and pump calibration, PID loop tuning (temperature, level or pressure), master-to-master communication between the systems controllers, statistical analysis through real-time data capture (accuracy, repeatability, hysteresis etc.).



Figure 1: Multi-Disciplinary process control system

2. Dual-Tank System

The dual-tank system shown in Figure 2 is a simpler process system. It is composed of two Perspex tanks coupled together by means of two manually actuated valves. Each tank also has its own manual drain valves as well as overflow outlets that allow the water to be released in to the stainless steel reservoir beneath the tanks.

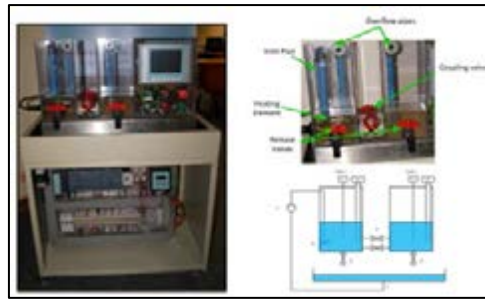


Figure 2: Dual-tank process control system

The following modes of control are possible: on-off control, flow control and 2nd order tank level control. When operated remotely, learners will be able to perform the following tasks in real time: Level and flow sensor calibration, pump calibration, PID loop tuning (level control of either the 1st or 2nd tank) and statistical analysis through real-time data capture (accuracy, repeatability, hysteresis etc.).

3. Sensor Station

In preparing engineering students for the real-world, it is important that they learn about the different types of sensors that are available as well as their functional principle. The sensor station shown in **Figure 3** displays various industrial sensors including five digital proximity sensors and an analogue ultrasonic distance sensor. When operated remotely, students can perform the following tasks in real-time: Analogue sensor calibration, accurate positioning of piston using basic feedback control, statistical analysis through real-time data capture (accuracy, repeatability etc.).



Figure 3: Sensor station

4. Active Heave-Control System

The heave of waves generates undesirable motions and tension within the cables of cranes carrying loads at sea. However this problem can be solved using a control system called Active Heave Compensation (AHC). AHC is a mechatronic system that cancels out the effect of heave and sway, thus preventing unwanted movement and increasing the lifting effectiveness. The developed AHC demonstrator system is shown in Figure 4. When operated remotely, students can perform the following tasks: accelerometer sensor calibration, load stabilization at different depths (using closed loop control) and statistical analysis through real-time data capture (accuracy, repeatability etc.).

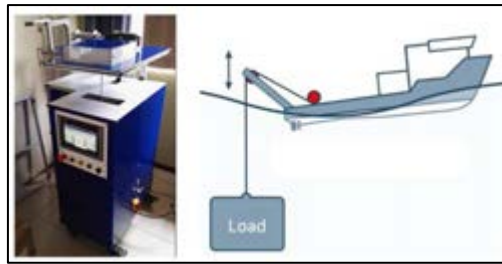


Figure 4: Active heave control system

5. Temperature control system

The temperature control system (Figure 5) consists of a solid aluminium block with an integrated heating element. Attached to the aluminium block are two fans that direct air flow towards the aluminium block. By adjusting the speed of the fans, the temperature of the aluminium block can be regulated. When operated remotely, students can perform the following tasks in real-time: on-off control (by turning on and off the element), PID loop tuning (temperature) and statistical analysis.



Figure 5: Temperature control unit

An Effective Approach to Laboratories within Engineering Education

An online process control simulation platform that makes use of an industry standard controller (Siemens S7-1200 PLC) as well as an industry standard monitoring and visualization system interfaced via TCP/IP with a reconfigurable Matlab/ Simulink based plant model has been developed and implemented as an undergraduate 3rd year control systems laboratory. Figure 6 shows the system architecture and physical components used.



Figure 6: Online process control simulation platform integrated with real industrial hardware components

The online platform was designed to allow learners to actively participate in the learning process and in so doing be able to:

1. Understand one or more, reconfigurable simulated processes based on actual plant models running in Matlab/ Simulink
2. Use industry standard visualization and control software tools

3. Engage with industry standard hardware (sensors, controllers etc.)
4. Remotely access the laboratory at their leisure and retrieve data in real-time
5. Access study material and practical guides easily
6. Leave comments, ask questions and give feedback on their experience

Two simulators have been implemented and tested thus far, a dual-tank system and a ballast control system for a submarine. The monitoring and control interfaces for the two systems are shown in Figure 7 and operate and react based on actual system models. This means they run as though they were interfaced with an actual plant. Therefore, although students won't see any literal plant, it does not diminish their learning experience. In fact, in many real world applications, the larger processes in particular are rarely visualized physically. They are much better visualized and controlled by means of a software interface which is able to give more complete impressions of large or concatenated systems in operation. In this manner, this online learning platform works well in preparing engineering students for the real world.

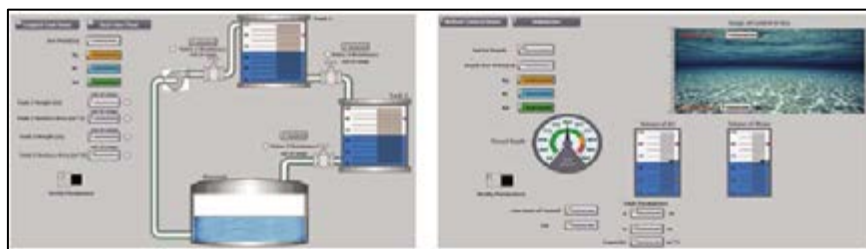


Figure 7: Real-Time SCADA access to dual tank process (left) and submarine system (right)

Learning tasks include:

1. Determining the time constants of the systems
2. Determining (and plotting) the systems response parameters
3. Deriving system differential equations
4. Designing and implementing a variety of controllers (e.g. PD, PI, PID, Intelligent controllers)
5. Using tuning methods such as the Zeigler-Nichols method
6. Performing statistical analysis
7. Drawing conclusions from gathered results

Students can capture plant data in real-time and save it in ".csv" format for further statistical analysis in MS Excel or Matlab. Apart from being entirely reconfigurable, the system also incorporates automated session scheduling where students can book sessions 24 hours a day and complete practical's at their convenience without unfairly taking up too many slots. Also, in an attempt to promote originality of submitted work the online system has the ability to generate unique practical guides in which model parameters are adjusted for each student that logs in. In other words, each student gets a slightly different control problem and therefore achieves unique results. The developed online platform also gives lecturers the advantage of being able to remotely manage and record student activity, assignments and marks.

Though still under development, the online platform will soon also allow lecturers to give live classes from remote locations and log student attendance while also giving the students a chance to send feedback and questions directly to the lecturer through an instant messaging

application.

Feedback from Learners engaging with Simulated Plant through Remote Access

Twenty students within the third year Control Systems course at NMMU performed the modelling, analysis and PID Control of a Dual-Tank System laboratory through a remote access site. These students have been exposed to Control Systems laboratories through direct engagement of similar mechanical plant simulators. Therefore they were exposed to both hands-on engagement and remote access engagement to real-world plant simulators. They could therefore give feedback to the advantages or disadvantages of on-line laboratories. A comprehensive questionnaire was provided for the evaluation of their experience in terms of hardware and software technology use and performance, computer aided teaching and learning through the representation of real-world systems simulators. The feedback answers were simplified and placed into the following categories, namely: Strongly Disagree (Dark Blue), Disagree (RED), Neutral (Green), Agree (Purple), Strongly Agree (Blue).

Figure 8 (a) represents feedback received on the graphical representation and real-time interaction of the Dual-Tank Simulation Control System. The learners agreed (87%) that the remote access model represents and responds favourably when compared to direct engagement. They found performing the laboratory very motivating as it brought the theoretical modelling and real-time calculation and analysis more into context. Figure 8 (b) represents feedback on actual laboratory engagement. Several users (20%) felt it was more challenging to do the laboratory via the Internet and felt more engaged with implementing and operating the physical real-world simulator.



Figure 8: Feedback received on the graphical representation and real-time interaction

Figure 9 represents feedback received on (a) the support material provided in which the learner had to record results, engage with theory represented online to perform subsequent analysis and (b) hence evaluate the learners overall learning experience. The learners agreed (90%) that the support documents were sufficient to access and engage with the system within a relatively short period of time. They also found that the theory correlated well with the classroom. Given their field of study they (88%) found that through this laboratory they had a better understanding of the application possibilities of control systems within their overall programme.

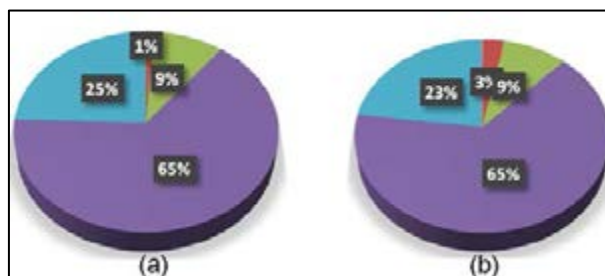


Figure 9: Feedback received on the support material and overall learning experience

An integral part of the research was for users to evaluate several system features and functionalities. Figure 10 reports on the verification and testing. Most learners (75%) found that it was not a huge challenge to access and browse the website (registration, login, practical implementation) as well as perform tasks such as data logging procedure for real-time analysis.



Figure 10: Online System Functionalities

Conclusion

In this paper, some of the challenges faced in providing engineering education at an advanced level have been discussed as well as how they are being overcome at the NMMU. The developed laboratory systems allow learners to participate actively in the learning process and offer the following benefits for students and lecturers:

- There is greater coherence with concepts and principles taught in class
- No need for lecturers or students to physically be in the lab which is only accessible for a limited number of hours a day
- Limited lab space is no longer an issue as all of the practical systems discussed fit in a relatively small area.
- Students cannot tamper or misuse the costly equipment
- Safety concerns while using the equipment are eliminated
- Students do not need to be monitored by lab technicians or lecturers
- Students complete practical's in their own time by booking slots that they find convenient
- All information and material is readily available on the site
- There is less duplication of work
- Students receive exposure to industry standard equipment and norms

The simulation based process control system which was implemented as an actual lab offers numerous further benefits. The model based virtual plants can be re-configured and expanded at will without having to make additional software or hardware purchases. Results from the student feedback show that the implemented system is successful in reinforcing concepts taught in class and in bridging the gap between individual course components such as software design, control, dynamic systems modelling and real-time implementation.

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The night before the test: Electrical engineering students' use of online resources to prepare for assessment

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This paper presents a study in an electrical engineering programme at a Southern African university where online resources are used to support student learning. The research analysed student engagement with a range of learning support materials hosted on the institutional Learner Management System. The key focus of the research is the relationship between the electronic availability of all the resources designed to support understanding and assessment on a so-called 24/7 basis (systemic), student sleep patterns (affective) and academic performance (cognitive). As such, students' performance in the assessments were correlated against data collected from access logs for the online course material on the course website. Results were obtained by analysing the login behaviour of two cohorts in the hours preceding an examination, using a cognitive-affective-systemic learning support framework. The findings suggest a complex and symbiotic relationship between cognitive, affective and systemic factors. A contention in this research is that improved use of a particular educational technology can be achieved through a learning-orientated analysis of how students access and utilise the available resources, and the impact of this engagement on their academic performance.

Introduction

Tertiary education institutions, worldwide, face unprecedented challenges in the education of 21st century engineering professionals. International literature abounds with statistics on falling engineering enrolment and completion rates (UNESCO, 2010), poor retention rates (Bernold, Spurlin, and Anson, 2007), and chronic industry complaints about skill deficiencies in engineering graduates (Felder, 2012). In South Africa, the focus of the study, there is an average non-completion/dropout rate on engineering programmes of 50% (Council on Higher Education, 2015; Fisher, 2011), which is comparable to rates across Europe (Andersson, Chronholm, and Gelin, 2011) and the USA (Bernold, Spurlin, and Anson, 2007).

Studies to determine the cause of low retention and high attrition, both locally and internationally, reveal that key factors are content overload, inadequate study skills, misconceptions about the nature of the engineering profession, and the disjuncture between science and engineering (Bernold et al., 2007; Andersson et al., 2011). Additionally, increasing number of students are regarded as underprepared with respect to their mathematics and science capabilities (Council on Higher Education, 2015), threatening to worsen the already 'critical shortage of science and engineering graduates in South Africa (Wolmarans, Smit, Collier-reed, and Leather, 2010).

The national priority to address these challenges (Case, Fraser, Kumar, and Itika, 2016) has seen significant changes to engineering education approaches, from the redesign and alignment of curricula to the provision of additional time and support through extended curriculum programmes. The rapid evolution of information communication technologies has opened new spaces for learning support in engineering. Through the provision of virtual environments and

computer simulations (Badjou and Dahmani, 2013) to the ubiquitous practice of making available online learning resources in any format from anywhere at any time. Attempts to evaluate the effectiveness of such interventions led to numerous studies investigating the (1) impact of online learning environments, (2) their relationship to students' academic performance (Perera and Richardson, 2010) and (3) time spent online. There has been little focus on how and when students access and use different forms of online learning support resources from the perspective of what kind of learning the resources enable.

Given that (1) the second key factor impacting on student success in engineering studies is inadequate study skills and, (2) (increasingly) technology is used to augment forms of learning support, an examination of current student study habits in the context of online support is warranted if technology is to be more effectively harnessed in appropriately designed student learning support systems. This paper reports on a study investigating how two 2nd year electrical engineering student groups engaged with a range of online support materials in the 24 hours prior to examination. Drawing on online login data, the time and method students interacted with specific course content was observed and compared to their assessment outcomes. Through this analysis of student study habits, the research hopes to contribute to the growing body of knowledge on technology-supported student learning which takes us beyond the typical endorsement of a technology resource (Laurillard, 2007) and enables a more refined understanding of the educational problem being addressed.

Conceptual Framework

The conceptual framework for this study is informed by three complementary perspectives (Figure 1). In its White Paper on Post-School Education and Training (Department for Higher Education and Training, 2013), the South African Department of Education establishes clearly that higher education's mandate is to enable the development of knowledge, skills and citizenship.

These aspects of our 21st century educational duty echo Barnett's (2000) characterisation of curriculum for a super-complex world as entailing epistemological, ontological and praxis dimensions. In similar fashion, the learning support model proposed for Open Distance Learning institutions features three core functions: the cognitive, systemic and affective (Tait, 2000). These three different characterisations of curriculum and learning are based on the centuries-old philosophy of the education of the whole person (Brühlmeier, 2010) the so-called head, heart and hand dimensions. For the purpose of this paper, the terms cognitive, systemic and affective are used as an organising framework through which to, firstly, review existing studies on student study habits, their use of online resources and the impact on performance; and secondly, provide analytical categories against which to interrogate the research data.

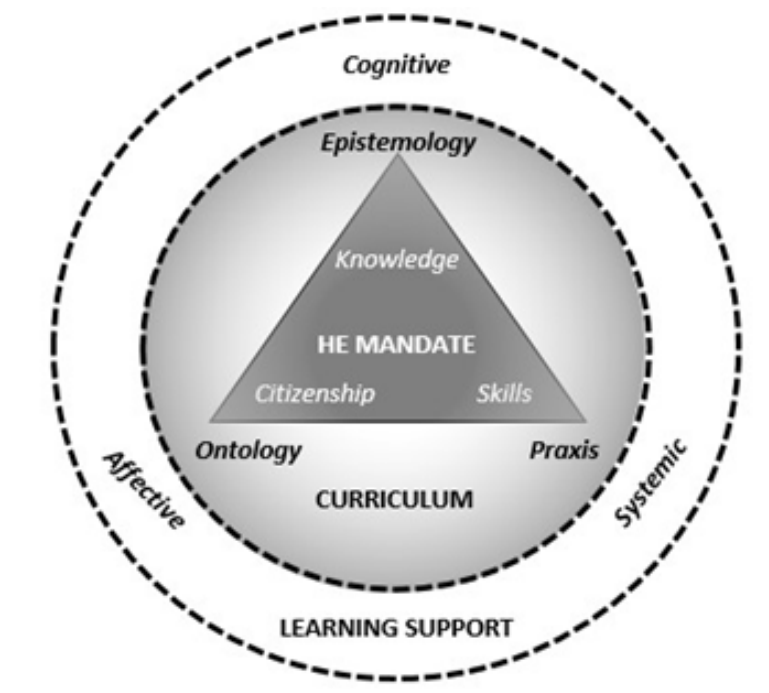


Figure 1. Conceptual organising framework: Enhancing the cognitive through the systemic

With the engineering curriculum stretching backwards to consolidate the fundamentals and forwards to meet the demands of globalisation, complexity and relevance (Shay, Wolff, and Clarence-Fincham, 2016), the workload for engineering students has steadily increased. In an engineering thermodynamics course study the authors researched the impact of lecturers' use of technology to expand the possibilities for instruction (Taraban, Hayes, Anderson and Sharma, 2004, p. 205). Students were asked to keep an activity log of their engagement with course notes, supplemental tutorial materials, interactive homework problems, virtual learning labs and a host of additional resources. These logs were analysed in relation to course performance. Key findings indicate a strong correlation between online homework problems and course grades. An important observation by the researchers was the "good student" syndrome, i.e. the student draws on several learning resources in order to learn the course material even though the amount of time spent on these multiple resources impacts on course performance.

In a study on the use of virtual learning environments (VLE) at a British school of engineering lecturers intentions were primarily to provide resources which clarify their students' misconceptions in their own time and space (Limniou and Smith, 2010, p. 651) given the common challenge of too little class time and the students' background level of knowledge. The level of expected self-regulated learning in this context is challenged by student feedback on the VLE experience, stating they preferred their learning to be focused on collaborative learning and the technology to afford opportunity for discussion and participation.

Many of the studies on the relationship between the affordances of technology and engineering student learning focus on student perceptions, and suggest a technological panacea for the woes in engineering education. There is little interrogation into how and when students use what kind of resources and what kind of learning this enables. The question of time is a crucial one. Technology has offered a way for lecturers to avoid the too little class time issue and shift the

responsibility of learning to the students in their own time. However, what are students doing in their own time?

The personal systemic becomes the affective

Much of the literature on the use of technology to support learning appears to assume that the accessibility of materials and nature of the net generation (Limniou and Smith, 2010) means students are engaging in learning at their own time and place. This has led to increased interest in researching how students are learning under these new conditions. In other words, what are the affective manifestations of new systemic mechanisms? Already in 2004, Taraban et al. examined student logs detailing their learning activity and found that the length of time students spent online actively working on solving subject-related problems translated into improved academic performance. However, Perera and Richardson (2010) found no relationship between performance and the time spent online during exposure to a range of online learning support materials. In fact it was active student participation (such as online discussion fora) that had a more significant impact on student performance. Laurillard (2008) points out that a more informed perspective on the nature of educational problems is necessary in order to make effective use of learning technologies.

If technologies are being used to solve the problem of overfull curricula or the need for more support, and the additional/support material is being provided in alternative sites (such as VLEs), then the question is who, how and when are students accessing these forms of learning support and what kind of impact are these having on student grading outcomes? One of the key observations that drove the study reported in this paper was based on access to student login records which demonstrated significant peaks in online behaviour in the early hours of the night before examinations. Concerned about academic performance patterns, the researchers looked into existing studies on the relationship between hours of sleep and academic success.

One study conducted to determine the possible relationship between sleep quality, academic performance and workload demonstrated a significant relationship between academic performance and sleep quality for those students carrying a greater workload (Howell, Jahrig, and Powell, 2004). A more recent study on medical students found no correlations between examination performance and sleep duration and quality (Genzel, Ahrberg, Roselli, Niedermaier, Steiger, Dresler, and Roenneberg, 2013), rather it appears sleep timing was most significant. In other words, when participants actually go to sleep. This confirms an earlier study which found medical student academic performance improved with a more regular sleep-wake cycle and longer sleep length (Medeiros, Mendes, Lima, and Araujo, 2001). Studies support the finding that early to bed, early to rise leads to better academic performance for example Ahrberg, Dresler, Niedermaier, Steiger, and Genzel, (2012) report that an important factor in the relationship between sleep and academic performance is stress,. The latter gives rise to poor sleep and subsequently poor performance. In yet another study on academic performance and student study habits, an unexpected factor emerged that having access to a good set of notes while spending time studying is shown to be more effective for those who use the time efficiently (Nonis and Hudson, 2010). This latter suggests students who performed better know how to manage their time effectively, signifying a relationship between the cognitive and the personal systemic. However, the study does not detail factors that could be

interpreted from an affective perspective.

Methodology in the Research Context

The University of Stellenbosch a contact-based, research intensive institution in South Africa) has increasingly expanded its use of various technologies to support student learning. The learning management system is reliable, accessible and widely used. Examples of course material made available online in addition to the hard copy textbook include mainly PDF versions of the course framework, detailed lecture notes, tutorials with memoranda and practical assignments - the latter accompanied by instructional videos. From a systemic perspective, it can be argued that the institution is more than fulfilling its mandate to provide an enabling system. However, given the particular challenges in STEM-based qualifications (Science, Technology, Engineering and Mathematics) in South African Higher Education (SA HE), and a pervasive digital divide based on socio-economic and historical inequities, there is little research that looks at the relationship between accessing such systems and materials, and the issue of student success. The high dropout and low retention rates in engineering education in particular, and the assumed affordances of technology-supported learning warrant an examination of the relationship between these materials, student behaviour and key academic success factors.

The initial impetus for the study reported in this paper was the simple observation that some students appeared to be more tired than others during the relevant assessments. The institutional context being a sensitive one in the South African higher education landscape, with respect to questions of transformation and 'access', meant this observation warranted deeper investigation. The subsequent review of assessment performance did not suggest any noticeable gender, race or age relationship. However, it is the responsibility of the academic to ensure the best possible 'learning support' conditions for all students, and given the availability of data within the institutional LMS, the question evolved from 'why are they tired?' to the relationship between possible levels of fatigue and performance. These observations, questions and access to actual time-stamped student login data led to the deductive application of the Cognitive-Affective-Systemic (CAS) framework in order to develop a better understanding of the cognitive and affective implications of having a well-established LMS.

The methodology applied in this research could broadly be defined as a mixed methods case-study approach, including quantitative (n=190) and qualitative data (i.e. a priori analysis of logs), with the latter consisting of the purposive sampling of 30 cases representing low, middle and top performers in the course assessment in question. The a priori analysis was done keeping in mind the various materials made available to support the three levels of learning (see discussion further on). The data themes have been pre-selected according to the course aims and objectives. Internal verification was achieved by using two second-year registered cohorts (n=160) for the years 2015 and 2016. The main difference between the cohorts is that the assessment discussed was taken on different days of the faculty assessment week.

The systems and signals course was the focus content area for the study. This course is a compulsory module for all second year electrical and electronic engineering students and introduces various key concepts in electrical and electronic engineering. As a result, the module is also a prerequisite module for a further three second year modules. No changes were made

to the course content, available resources and the lecturer for the duration of the project. From a cognitive support perspective, the course material made available to the students in this study include a module framework, textbook, lecture notes, tutorials, tutorial tests, practical assignments and memoranda for the tutorials and tutorial tests. These materials have been grouped into three categories according to the type of learning facilitated by the material. The study was based on the assumption that students with high workloads will have developed personalised study habits (i.e. good time management skills). To ensure deep, strategic and surface learning, access to the full range of materials is readily available. The responsibility rests with the student to make the necessary choices to support their learning (Marton and Säljö, 1976):

1. Deep learning, i.e. students search for meaning and underlying meanings and implications; the information gets internalised and made his/her own by the student; examples include notes, referring to lecture notes, course framework and test instructions;
2. Strategic learning, i.e. students learn to please authority; they stand loose from the information. Examples include problems, referring to tutorials and practical assignments and
3. Surface learning, i.e. students experience the information as a collection of discrete units which should be memorised to be able to answer anticipated questions – examples include memos, which refer to the memos of the tutorials and the tutorial tests

Midway through the semester, the first assessments for all engineering modules at Stellenbosch University are written over a period of one week. Students write one test a day for five consecutive days under strict examination conditions. For this study, the 2015 cohort wrote their test at 08:00 on the morning of the first day of test week (the Monday) while the 2016 cohort wrote their test at 08:00 on the fourth day of test week (the Thursday). Since the assessments for the 2016 cohort towards the end of the test week, fatigue becomes a consideration when evaluating test performance data in relation to sleep patterns. The difficulty level of the tests for both cohorts was similar.

The key focus of the research is the relationship between the electronic availability of all the resources designed to support understanding and assessment on a so-called 24/7 basis (systemic), student sleep patterns (affective) and academic performance (cognitive). As such, students' performance in the assessments mentioned above were correlated against data collected from access logs for the online course material on the course website. A timestamped log item is created for every item the user clicks on when signed onto the course website. The latest log item for each student was used to generate two assumptions (a) student went to bed/rest, or (b) student got involved in other activities except in the following cases:

1. If there were multiple log items for a variety of course items timed within the space of a few minutes, it was assumed that the student either printed the course material or downloaded it for offline use. These students were excluded from the sleep vs test performance study since it cannot be reliably determined whether they were awake at a certain time. These students were considered under the printed notes category.
2. If regular online activity was recorded over a space of time, followed by a gap of a few hours, followed by more regular online activity, the student was considered under the

‘irregular sleep pattern’ category.

3. Students for which no online data was available were excluded from the study, except where the general class average for the test is considered.

Findings and Discussion

Affective behaviour, i.e. student sleep patterns

The initial impetus for the study was the relationship between sleep and academic performance. To begin with the latter, at face value it may appear that there is nothing disconcerting about the academic performance patterns on this course, given that it falls within the 50 - 60% internationally normative pass rate (Fisher, 2011). However, the institution in question draws top-achieving students both nationally and internationally. The combined academic performance for the two groups as demonstrated in Figure 2 shows 44% of students failing the assessments, which is a problematic result in this context.

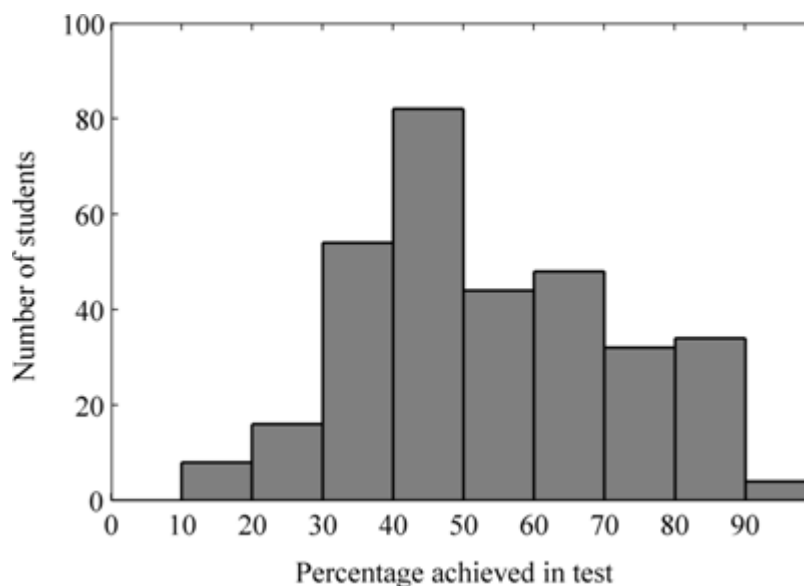


Figure 2. Combined assessment performance histogram for both 2015 and 2016 cohorts, n=160.

When combining the overall assessment performance with the time of last access to the course website data vs test performance graph shown in Figure 2, it can be seen that students who went to bed after 02:00 all fall in the category of students who failed the assessment. In this case the time of last access to the course website is considered the most reliable indication of sleep patterns. Figure 3 therefore suggests that there is a relationship between the number of hours a student slept the night before the assessment, and academic performance. This suggested relationship is however not reciprocal. Students for whom online activity after 02:00 has been logged all failed the test, but all students whose activity stopped before 02:00 varied, i.e. they did not all pass. This unidirectional relationship confirms common belief that a variety of factors influence academic performance. The next section takes this observation further.

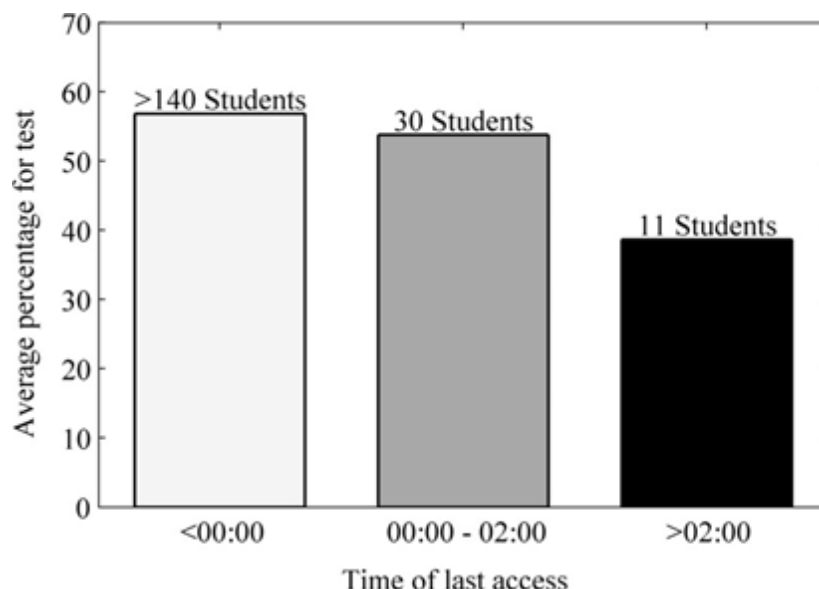


Figure 3. Average assessment performance per sleep category Cognitive behaviour, i.e. student learning focus

Phase two of the research involved the purposive sampling of 30 students selected according to their academic performance levels. Figure 4 shows a comparison of the general online access behaviour of the top 10, middle 10, and bottom 10 students. The average number of times a specific category of document was accessed by each of the performance groups is given as a function of the average performance of the specific group in the assessment. The three categories of course materials were considered to enable three different forms of learning: Deep, strategic and surface. Ideally, the notes represent materials intended to facilitate deeper learning, while the problems represent materials meant to encourage strategic learning, and the memos are more likely to encourage surface learning. What is noticeable about the phase 2 analysis as represented in Figure 3 is that the middle group is shown to be the most strategic learners who seem to be drawing on focused problem resources in order to pass the exam. It is believed that the middle group may well be attempting to rather memorize methods of solving particular types of problems without necessarily understanding the work.

The top and bottom groups have similar deep/surface/strategic ratios but how the resources are being used (systemic) is not shown. Section 4.3 offers more insight into this aspect, but the results in Figure 3 are beginning to confirm our intuition that blindly emulating “successful student” content access behaviour is not enough to ensure academic success.

Systemic Agency

In the previous two sections discussing the affective and cognitive behaviour of students as an indication of academic success, relationships suggestive of a causal link were observed. These relationships were, however not reciprocal, indicating that other factors are also influencing academic success. It was also argued in Section 3 that given the availability and wide scope of study materials being made available, the institution is fulfilling its mandate to provide an enabling system. How students make use of the available resources is therefore considered to be the deciding factor of the systemic characterization in this study.

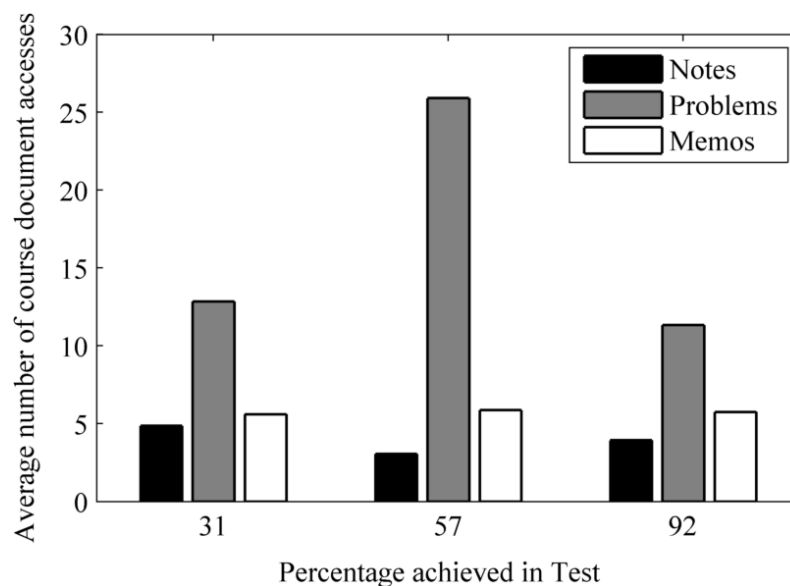


Figure 4. Course document type access behaviour vs average assessment performance for top 10, middle 10 and bottom 10 students.

Figure 4 offers a view into how the top 10, middle 10, and bottom 10 students make use of the online resources described above in the 24 hours leading up to the assessment. It can be seen that the highest achievers are more inclined to print their notes and do not go online after 00:00, while the low achievers manifest erratic patterns in relation to how they engage with the online material. The behaviour of the middle coincides with that of the top group to a larger extent, except that there are also students who display irregular sleep patterns.

This is in line with the strategic mind-set of the middle group discussed in Section 4.2. Faced with a time-constrained assessment timetable, the data suggest that students are optimising their sleep/study schedule by combining the rest-period following the previous test and their daily rest period. The same strategy is followed by students in the bottom group, but without success. This suggests that success of this strategic approach is also dependent on other factors that could not be empirically measured with the available objective data.

Concluding remarks

The research set out to examine the relationship between student behaviour, the use of technology-based resources and academic performance in a 2nd year electrical engineering course at a South African university. Using a conceptually layered framework which sees the role of HE as providing learning support in the cognitive, affective and systemic domains, the study investigated the connection between student online login behaviour ‘the night before the test’ and their test scores afterwards. Findings suggest a complex and symbiotic relationship between cognitive, affective and systemic factors:

1. The negative impact of student behaviour from an *affective* perspective manifests *cognitively* in a 100% failure rate for all the students who demonstrate poor sleep hygiene (those whose online activity only ceased after 02:00). Further investigation into students time management skills in a highly complex and dense knowledge environment (engineering) is recommended

2. For struggling students - for whom the learning management system (LMS, i.e. Moodle), from a *systemic* perspective is seemingly ideal given the 24/7 provision of a range of materials to support deep learning - it gives the impression that gaining proper understanding of the concepts is not a priority. Further research on students' perceptions of their quality and quantity of learning using LMS is necessary. Top performing students study habits suggest an ideal *cognitive-affective-systemic* synergy. Their personal systemic is evident through a multimodal approach to the learning support materials (offline and online), and this appears to enable or, indeed, be as a result of the positive *affective* behaviour evident in their sleep hygiene. Comparison between modes of learning and learning outcomes in an engineering context is envisaged.

On the one hand, the question of enabling and encouraging 24/7 access to all manner of materials runs the risk of shifting the responsibility of learning entirely to the student. Lecturers may more easily feel indemnified when all the materials have been provided. On the other hand, a key 'graduate attribute' as determined by the engineering standards is indeed 'self-regulated learning'. This study suggests that academic success is significantly linked to evidence of 'responsible' (or self-regulated learning), but that this is not the reality for the majority of the students in the study. The question of appropriacy of materials and platforms in relation to learning outcomes or objectives is a significant one, given the proliferation of technology-supported learning initiatives. One clear advantage of an LMS which enables student behaviour tracking is that it enables a richer possible view of the complex relationships between the cognitive, affective and systemic domains of student learning support. This understanding, however, needs to be accompanied by a deeper interrogation of how the actual learning materials facilitate deep, strategic and surface learning, and a more focused study of how the 24/7 availability actually influences study behaviour. The current study suggests that students are lured into a false sense of security by believing they can access materials 'at the last minute' and that this might be sufficient to pass. This clearly is not the case, and the study in question hopes to make a contribution to a more refined understanding of the affordances and constraints evident in the use of technology-based learning support.

Acknowledgements

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Using epistemic justice as a framework for underpinning articulation between technical and vocational education and training colleges and higher education engineering programmes

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This conceptual paper describes the theoretical framework that is being used to guide a research project, in which the articulation processes between Technical and Vocational Education and Training (TVET) Colleges and Higher Education Institutions (HEIs) in the field of engineering, are being explored. The paper will briefly describe, challenges faced by the TVET Colleges, as well as some of the issues facing students wishing to articulate from TVETs to HEIs. Epistemic injustice will be described, along with how it will be used as a lens that, together with other allied theories, will form the framework guiding the enquiry.

Introduction

One of the key objectives of the National Qualifications Framework is to facilitate access, articulation, mobility and progression between qualifications (Mukora, 2008). Articulation of students between TVET Colleges and HEIs should be a straightforward and common occurrence but this is not necessarily the case. Previous initiatives to improve these articulation pathways have proven to be challenging (HRDC, 2014). In addition HEIs are currently developing curricula for, and/or implementing new programmes, aligned to the Higher Education Qualification Sub Framework (HEQSF) that may exacerbate these challenges (DHET, 2013). A number of engineering programmes will soon be offering, or are currently offering, programmes that differ substantially from what was offered in the past. Substantial effort may have been spent developing these qualifications, but this process has, overall, been undertaken without significant consultation with the TVETs, and also with little regard being given to articulation pathways for their students. With a number of Universities of Technology (UoTs) ceasing to offer diplomas, the primary articulation pathway for engineering students, at TVETs, may disappear.

In the light of the above there is a need to explore factors that mitigate or promote articulation, as removing obstacles that hinder access, articulation, mobility and progression of students can only positively contribute to the development of a more socially just society. The Durban University of Technology (DUT), in partnership with the South African Qualifications Authority (SAQA), has recently undertaken a research project entitled *Developing an understanding of the enablers of student transitioning between TVET Colleges and Higher Education Institutions*, which intends to build upon the work carried out in previous SAQA projects. This project intends to address gaps in the understanding of articulation and learning pathways, specifically to improve articulation between the TVET Colleges and UoTs and to understand the factors that promote such successful articulated learning pathways where they exist. The project will attempt to answer the broad question “How can collaborative relationships between TVET Colleges and HEIs be developed, which will enable, enhance, and

promote student transitioning between TVET Colleges and HEIs?

A case study of student articulation between TVETs and HEI's in Electrical, Electronic and Mechanical Engineering programmes nationally, will form part of the larger research project described above. Preliminary work, as described in the National Articulation Baseline Study (NABS) indicates that there may be misalignment between the National Certificate Vocational (NCV) curriculum and the entrance requirements of engineering programmes, such that it seriously hinders articulation (Lortan, Maistry, Bolton, & Surtee, 2017). Communication of HEI entrance requirements to TVET students may also be problematic. Results of the NABS indicate that issues relating to articulation are viewed as low priority by HEI staff in that they are seen as being 'outside of core business' with more pressing issues occupying staff's time.

A key preliminary outcome of the NABS is the prevalence of epistemic injustice within the Post School Education and Training (PSET) sector. It pervades the sector in systemic, institutional and individual terms, insofar as relating to student transitions between TVETs and HEIs in engineering programmes is concerned. This paper will describe articulation in general, as well as in relation to engineering programmes. It will also introduce the notion of epistemic injustice, and finally conceptualise how epistemic justice may be used as part of a framework to describe and investigate, amongst others, the issues highlighted above.

Articulation

As mentioned previously, the primary objectives of the NQF are to increase access to education as well as to facilitate articulation, mobility and progression between qualifications. In this light, articulation must be seen as a tool to broaden the pathways leading to higher education (RSA, 1995). Simply put, articulation relates to both student transitions, from one qualification to another, (either within or between institutions) and the curriculum structures put in place to facilitate such transitions. The inclusion of intra or inter institutions agreements for Credit Accumulation and Transfer (CAT) in these structures is considered to be a form of articulation, however the absence of CAT does not imply the absence of articulation.

The authors have previously defined articulation as it relates to this study as "the enabling of mobility within and between the various learning programmes and institutions (including colleges, universities and workplaces) that comprise the post-school education and training system" (Graham, Lortan, Maistry, & Walker, 2017). Articulation of students between TVET Colleges and HEIs should be a routine occurrence, but it will be shown that this is often not the case. That the majority of school leavers are under-prepared for higher education, is one critical reason we should improve articulation, for it is here that the TVETs can play a critical bridging role (Oosthuizen, Garrod, & Macfarlane, 2009).

Prior to 2007 TVET Colleges offered a series of National Certificates commonly known as 'Nated certificates' or 'N courses'. The N1, N2 and N3 certificates were offered at a secondary school level and the N4, N5, N6 certificates were offered at post-secondary school level. The certificates were originally offered such that students would complete a trimester at college and the remainder of the year in the workplace.

The NCV, which was designed to replace the N courses, is offered as three one-year courses at levels 2, 3 and 4 of the NQF. Although it includes considerably more content, which in terms of level and cognitive demand, is in better alignment to the NQF (Matshoba & Burroughs, 2013), it has faced significant resistance from industry, particularly in the engineering sector, with regards to the relevance of its content and its inability to accommodate part time or block release students (Marock, 2011). Further its capability to create the priority skills required by the economy has been questioned (Allais, 2012; McGrath & Akoojee, 2009), as has been its

ability to be implemented effectively by the TVETs (Wedekind, 2013). This led to the current situation, where the phase out of the N1-N3 engineering programmes was halted in 2010, and they are now offered concurrently with the NCV at many TVETs.

Students completing the NCV or the N-diploma should form the backbone of student transitions from TVETs to HEI degree or diploma programmes. Although the pathway from NCV to HEI programmes is laid out clearly on the NQF, as shown in figure 1, in reality it is often hindered by a lack of curriculum alignment, at a program level. The lack of alignment is often of such a magnitude that it actually blocks the pathway, preventing NCV student access to an HEI programme in the same field as his/her NCV (Branson, Hofmeyr, Papier, & Needham, 2015; Malale & Gomba, 2016). There are specific instances, highlighted by both Malale (op.cit) and Powell, where students pursued the NCV, specifically to gain access to an HEI, and were later denied access precisely because of this curriculum disjuncture, causing both student (Powell & McGrath, 2013) and staff frustration (Blom, 2016).

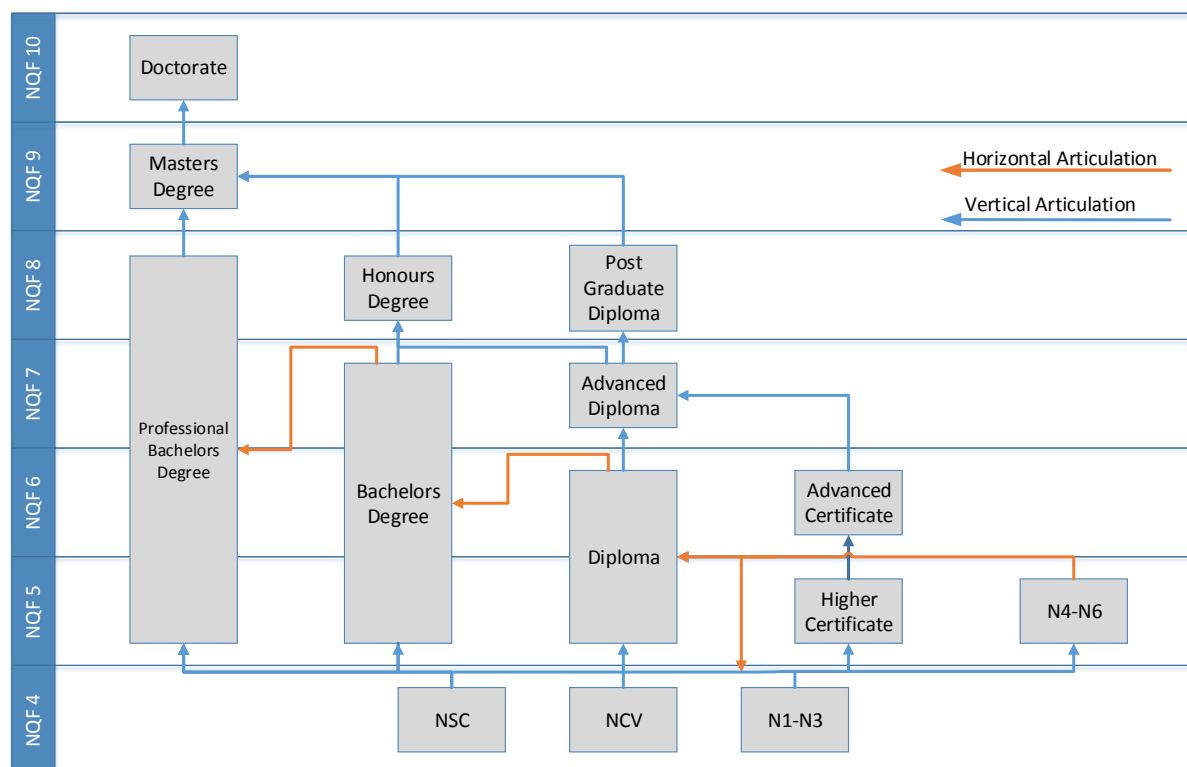


Figure 1. Some of the Articulation Pathways Available on the NQF

Articulation from N-courses into university degrees is largely non-existent (Mbanguta, 2002), and although some University of Technology (UoT) programmes recognise the N courses for articulation purposes, this is not the norm (Perold, Cloete, & Papier, 2012; Simkins, 2013). Engineering programmes at UoTs, generally have better developed pathways that often include credit transfer, for students wishing to articulate into diploma programmes. Articulation into engineering programmes is still far from optimal with ‘hidden boundaries’ often in place.

The ‘hidden boundaries’, as described by Lotz-Sisitka, are in the conditions that permit admission, but preclude credit transfer (Lotz-Sisitka, 2015). An example of such a boundary is the requirements for credit exemptions given by UoTs to students completing N4, N5 and N6 Mathematics. Typically a student needs to get at least 50% for N4 and N5 Mathematics in order to be given a credit for the entry level maths course (S1) in an engineering diploma. To get a credit for the second level maths course (S2) a student would need to obtain a minimum

of 50% for both N5 and N6 Mathematics. Thus a learner who obtains 80% for N4, 49% for N5 and 81% for N6 (averaging 70%) will neither receive credit for Mathematics S1 nor S2, and would therefore have to register for S1 in spite of having a significantly higher average than his/her counterpart who obtained 50% for each. Such boundaries need to be identified and incorporated into any discussion regarding articulation.

Epistemic Justice

To conduct our epistemic practices as fairly and rationally as possible, in other words in an epistemically just manner, we should first understand the factors likely to negatively affect them (Fricker, 2008). One category of injustices that, until recently, did not feature prominently in South African discourse, and appears to be completely absent from both local and international engineering education discourse is that of epistemic injustice. Although the concept originates from feminism studies, as described in Miranda Fricker's seminal work 'Epistemic Injustice: Power and the Ethics of Knowing' (Fricker, 2007), it's relevance is far wider. Epistemic, derived from the Greek 'episteme', means knowledge, so simply put epistemic injustice relates to injustices pertaining to knowledge. Fricker describes two dysfunctions prevalent in epistemic practices, namely testimonial injustice and hermeneutical injustice.

Testimonial injustice relates to the unfair diminishment of a speaker's capacity, as a source of knowledge, due to an identity prejudice held by the listener. This prejudice becomes an impediment to the full and accurate transmission of knowledge from the speaker to the listener as the speaker suffers a 'credibility deficit'. It is important to note that ascribing a credibility deficit alone does constitute testimonial injustice, it is the ascribing of said deficit, due to the prejudice held by the listener that categorises the injustice as testimonial. Fricker cites, by way of example, a scene from the film *The Talented Mr. Ripley*, where Herbert Greenleaf, an older man, responds to a younger woman, Marge Sherwood, 'Marge, there's female intuition, and then there are facts'. Greenleaf does not take Marge seriously due to his prejudice-induced stereotype that women are prone to emotional rather than rational response.

Fricker and Medina expand on testimonial epistemic injustice to describe a version thereof as *pre-emptive testimonial injustice* or *silencing* (Fricker, 2007; Medina, 2012). This form is a structural prejudice where, for example, members of certain groups may simply not be asked their opinions, as they are deemed invalid.

Hermeneutical injustice relates to the inability of individuals to express their experience or knowledge claims owing to a lacuna, or gap, in the collective understanding. The existence of this lacuna is due to the relative powerlessness of the social group, to which the individual belongs, and its inability to fully articulate its experience of being disadvantaged. Fricker, in 'Powerlessness and Social Interpretation' (Fricker, 2006) describes the case of Carmita Wood, an administrator at Cornell University's department of nuclear physics, who was subjected to sexual harassment by a professor. But this took place in the 1970's so 'sexual harassment', as a term, did not yet exist. Wood, after enduring long-term stalking and molestation left her job, and was denied unemployment benefits as she could not sufficiently describe her reasons for doing so. When Woods approached colleagues, they debated how best to describe what happened to her, so as to take action. Once they coined the term "sexual harassment", something that had occurred for as long as women had worked with men, now had a name, and could be fought.

Fricker's focus on the individual's experience of epistemic injustice can be used to identify and break down some of the structural prejudices prevalent in our society. She posits that once

individuals are capable of recognising their own prejudices they can contribute to the amelioration of epistemic harm. Anderson, (Anderson, 2012) takes a contrary position, arguing that some epistemic injustices are best ameliorated at the collective, rather than individual, level, implying a need for structural or policy change. This is not to say that structural responses should be put in place in lieu of attempts to promote individual value changes, but rather that the structural response should also encourage an individual response, because without individual support the public policy will ultimately lack effectiveness (Christman, 2012). The definition of epistemic injustice should be broadened to include all areas of knowledge production (Beeby, 2011; McKaiser, 2016) and it is this broader definition that will be utilised in this project.

Social struggles, especially post-colonial ones have been described recently in terms of epistemic struggles, epistemic justice or epistemic othering (Icaza & Vázquez, 2013; Keet, 2014; Restrepo, 2014). The apartheid construct itself is described as a structurally self-reproducing hermeneutical injustice, with the black consciousness movement evolving as a necessary response to overcome this hermeneutical injustice (Hull, 2016). Considering our colonial and apartheid histories, the ‘fallist’ movement, and calls to decolonise the curriculum, the relevance of epistemic justice to South African educators should be apparent.

Speaking, in relation to feminism, Fricker states “the powerful have an unfair advantage in structuring collective social understandings”(Fricker, 2007). The result is that epistemic benefits are distributed unevenly. This is equally applicable to the academic environment, where epistemic injustice is inherent in the formation of the academic disciplines but remains largely invisible to the academy itself (Keet, 2014).

Mc Kaiser speaks of the need for academics to be aware that “groups like ‘women’ and ‘black people’ suffer multiple forms of epistemic injustices, routinely. As an individual member of these groups you are less believable than white men, typically; and as a group you are structurally assaulted in terms of the skewed social epistemologies that consequently are produced in our society and especially within the academy under the uncritical guise of academic freedom” (McKaiser, 2016). Changing content, curricula and academic structures will not decolonise higher education, rather the recognition of the power imbalances inherent in the production and validation of knowledge is required. If that is achieved the former can follow.

By recognising epistemic injustice and implementing principles and practices to ameliorate it we may achieve epistemic justice (Maistry & Lortan, 2017). The work by Fricker and by Anderson, whilst attempting to further epistemic justice, views individuals from outside the academy as research subjects only. Academia should not hold hegemony of the production of knowledge and individuals outside the academy, when appropriate, should be involved, in partnership, in all stages of research.

Epistemic Injustice in the National Articulation Baseline Study

Preliminary results of the NABS conducted by the SAQA-DUT research partnership, as mentioned earlier, describes epistemic injustice in the relationships between TVETs and HEIs at a sectoral level. It is believed that similar scenarios may be found within engineering programmes, and the extent, or lack thereof, will be investigated in the engineering case study. The NABS forms a useful starting point, indicating a poor understanding of articulation by both TVETs and HEIs, as well as unfurling evidence of epistemic injustice in their relationships governing the management of articulation (Lortan et al., 2017). The lack of a common understanding regarding the implementation of policies for access to qualifications

offered by HEIs was also highlighted as an area needing attention. The TVETs tend to offer advice to their students on possible articulation pathways based on Government Gazette minimum admission rules and SAQA 'bands', whereas many HEIs' entrance qualifications exceed these, meaning students are often given false expectations. Further, TVETs report that HEI frontline staff are often unfamiliar with the NCV and the particular programmes' entrance requirements for TVET students in general.

The HEIs' lack of understanding of, or indifference to, TVET College qualifications and standards, as described in the NABS, points to a diminishment of the TVETs in their capacity as a source of knowledge. Closely intertwined with the aforementioned diminishment is the issue of a lack of parity of esteem, with the TVET Colleges being widely regarded as inferior to the HEIs, not just by the HEIs but also by TVET staff and students (Blom & South African Qualifications Authority, 2006). The diminishing of the TVETs in their capacity as a source of knowledge, coupled with the prejudice held (the lack of parity of esteem) accurately describes both testimonial and pre-emptive testimonial injustice.

Although the NABS was undertaken at a sectoral level and the injustices described are mainly institutional or systemic in nature, epistemic injustice may also be of an individual nature. Relationships between HEI staff and TVET staff and students could be a possible source of individual epistemic injustice. An example of this would be the differential treatment of individual applicants to HEIs based on differing qualifications, such as NSC, NCV or N courses, which is also reported in the NABS.

Conceptualising an Epistemically Just Framework

Although Epistemic Justice will form the overarching lens or framework through which this investigation is pursued, Participatory Action Research (PAR), relational agency and ecosystems theory will also contribute to this framework and so will be briefly discussed below.

PAR, as the name suggests, is an approach to action research where a collective or collaborative approach is utilised to effect individual, collective or societal change. Kindon et al describe PAR simply as "research by, with, and for people affected by a particular problem, which takes place in collaboration with academic researchers" (Kindon, Pain, & Kesby, 2008). It reframes research such that research is carried out with people as opposed to on or for them. Thus the participant is not viewed merely as a subject of the research, but rather as a participant in the co-construction of knowledge in all stages of the research (McIntyre, 2007). In addition to the identification of good practices as well as barriers to articulation, the theoretical framework utilised should be capable of contributing towards a relationship building process as per one of the main aims of the broader SAQA project. Such a process needs to ensure that relationships for improving the articulation imperative are formed, maintained and sustained. PAR satisfies these criteria by providing a robust framework to guide the research portion of the project, as well as to contributing to the secondary objective of developing relationships between TVET Colleges and HEIs.

Glass (Glass & Newman, 2015) advocates that collaborative community-based research methodologies such as PAR, which emerged as a means to empower marginalised peoples (Tandon, 2002), be implemented, together with a lens of epistemic injustice, to achieve epistemic justice in scholarly research. We intend to test Glass's theoretical standpoint by utilising PAR together with a philosophy of epistemic justice in this project. This combination will ensure that the voices of TVET staff, students and other participants are not marginalised with respect to decisions and processes relating to the determination of enablers of articulation. Further, by applying it in practice and demonstrating its applicability and limitations, albeit in

an engineering education context, we believe it will be of relevance to the research community in general.

Bronfenbrenner's ecosystems theory is used to study the complex relationships between individuals, communities and wider society. It is well suited to research multifaceted, dynamic systems with multidirectional linkages and processes such as educational systems (Bronfenbrenner, 1992; Johnson, 2008). The complex relationships involved in the transactional interactions within, and between, TVET Colleges and HEIs at an institutional, staff, and student level may require an ecosystems theory approach when attempting to implement measures to engender epistemic justice. Mattaini suggests a collaborative application of ecosystems theory to "bring power to bear for the vulnerable, who often have little access to other sources of power" (Mattaini, 2008) which appears to talk directly towards ameliorating epistemic injustice which, as discussed earlier, may easily present in situations where there are power differentials.

Relational agency theory is used to understand and engage with the motives of 'others' (Edwards, 2005) and the existence thereof implies that all parties, or partners, recognise the contribution of others individual expertise and resources to the partnership (Albertyn & Frick, 2016). In addition, relational agency is the capacity to work with others to 'strengthen purposeful responses to complex problems' (Edwards, 2011). Although relational agency and PAR both deal with collaborative relationships, it is in the recognition and the use of the support of others, as well as the ability to respond to the need for support from the same that sets it apart (Edwards & D'arcy, 2004). If we are to assess the extent to which motives of the institutions, staff and students promote or hinder articulation, integration, and joint work by utilising a PAR framework, we should further develop these relationships so that they display the support, described by relational agency. By doing so we will be moving towards our goal of achieving epistemic justice.

The development of epistemically just, collaborative relationships between TVET Colleges and HEIs offering Engineering programmes, is viewed as one of the key measures to improving articulation. The conceptualisation of the challenges faced, primarily in terms of epistemic justice, but supported by relational agency theory, ecosystems theory and PAR will suitably frame the investigation, as well as to contribute the relationship building process.

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An exploratory study on science and engineering student experiences at UCT

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There are ongoing concerns about students' access to and success in university level science and engineering studies. There has been a particular interest in exploring students' persistence in these degrees which are often considering challenging. A key issue is the interaction between students' agency and the challenges provided by the curriculum and the broader context. These issues are of particular interest in post-apartheid South Africa, where access to and success in the STEM area remains racially stratified.

This study explores the student experiences of science and engineering students who began their undergraduate studies in 2009 at the University of Cape Town (UCT). The students were categorised into four trajectories: the smooth trajectory, the passionate few, the struggling and the seeker of advice. Though the student narratives corresponded with many of the findings from prior survey data in this context, there were a few interesting contradictions. Considering the dynamic and tumultuous climate within the higher education system at present, this study calls for more detailed research into the perceptions, opinions and experiences of students at institutions of higher learning; for the underlying causes that these findings might illuminate.

Introduction

STEM (Science, Technology, Engineering and Mathematics) graduates are considered important contributors to society and the economy. Post-apartheid South Africa has had a strong focus on increasing participation and success in these disciplines. However, these are also considered challenging areas for study especially in a country with a mixed quality of schooling outcomes. Thus, there is particular significance in research that seeks to understand where students experience challenges in order to design teaching and curricula that can better facilitate student success.

Students' access to and experiences of higher education in South Africa continue to be influenced by race and class, despite twenty years of post-apartheid policy making (Badat, 2009). According to Scott (2009), in 2009, only 5% of young black people succeeded the programmes they enrolled in. This "vastly unequal levels of readiness for studies in higher education" makes the research to comprehend student learning and student success of continual significance (Fraser & Killen, 2005:2).

Many people hold the view that science and engineering students are already autonomous and independent people who know what they are doing. However, not all students enter university with these dispositions. It is challenging to learn new ideas and concepts and select subjects to study. On top of that, students often suffer from limited free time. Many students are not sure of their interests and passions at the time of choosing their degree. Research in these areas has started to offer important understandings about these challenges (Mogashana, 2015; Case et al., 2015a; Fraser & Killen, 2005; Lea & Street, 1998). Following Barnett's

(2007) call for further research in student persistence, this study explores student experiences and persistence in the fields of science and engineering.

Most research on student persistence makes use of the student integration model theorised by Vincent Tinto in 1986. This model postulates that the students bring a set of traits and expectations that influences their initial commitment and their goal to graduate. According to Tinto (1986), there lies a direct relationship between the integration of the individual into the academic and social community of the institution they attend and the degree of their individual commitment to graduating when all factors are considered equal. The initial commitment and the development of other commitments influences student persistence directly.

Drawing from the works of Tinto (1986, 1997), Jama et al. (2008:994,998) developed the Circle of Progression model, which focuses on the “non-traditional students” within South Africa who are “mostly black from disadvantaged family and school backgrounds”. This model conceptualises the student’s persistence to complete their initial commitment to graduate by exploring the influence of the teaching-learning experience followed by the ongoing social and academic integration. This model was used to shape the structure of the interview protocol.

The work on student persistence has made a significant impact on the field, yet Ashwin (2009:5) argues that research in the existing higher education literature focuses on the academics or the students and little understanding on the “dynamic interplay” between academics and students within specific teaching-learning interactions. Hence, the use of Archer’s (1995, 2003, 2007) morphogenetic approach which conceptualises this dynamic interplay by categorising personal emergent properties.

Background

In 2012, an institution-wide survey was sent out to the undergraduates at UCT. The engineering student sample consisted of 443 engineering students with 31% being females and the remaining 69% males. The science student sample consisted of 287 students with 47% females and 53% males. Basic descriptive statistics were performed on the responses obtained to this survey.

With regards to the coursework and schedule, the survey analysis observed that engineering students had less sleep, spent more time in lectures and tutorials and spent more time studying outside of class. Table 1 gives some detail of the survey results in this regard.

Table 1. Hours per week relating to academic activities – lectures, tutorials, studying, etc.

Hours per week attending lectures, tutorials, practicals, workshops and discussions								
Hours	0.00	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	>30
Engineering (%)	0.2	4.8	5.5	9.2	11.0	17.6	23.6	28.1
Science (%)	0.0	9.5	11.2	14.7	19.6	15.4	15.4	14.0
Hours per week studying and other academic activities outside of class								
Hours	0.00	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	>30
Engineering (%)	1.1	13.5	22.7	18.0	17.3	9.9	9.9	7.4
Science (%)	1.1	20.4	24.3	18.6	12.1	8.6	5.7	9.3

Furthermore, the survey analysis showed that more engineering students incorporated information from other courses into their assignments, which were often longer than the assignments given to science students. Also, engineering students were less inclined to choose a hard course that might lower their marks. Engineering students studied in a group outside of class and helped each other more often than science students. The survey analysis also observed that engineering students approached a lecturer more often than science students. However, it was also observed that engineering students were more likely to find UCT to be impersonal.

There were however many dimensions of this survey where science and engineering students had similar responses. With regards to participation and student engagement, it was observed that science and engineering students similarly contribute to class discussions, bring up information from different courses during discussions, asked questions in class, found a course interesting and did more than the required work. They similarly submitted assignments of similar page lengths, used more than five references in a paper, applied information from a class to understand something outside of class, raised their academic standard due to high lecturer expectations and extensively revised a paper before submitting it.

Finally, the survey analysis observed that when applying to study at UCT engineering students found it more important that the degree led to a higher paying job. Moreover, the survey observed that science students found it more important that the degree prepared them for postgraduate studies.

The present study aimed to uncover more detail on student experiences in science and engineering at UCT, with a view to better understanding student persistence in these disciplines.

Methodology

The purpose of the present study is to compare the student experiences of science (BSc.) and engineering (BSc. Eng) students who began their undergraduate studies in 2009 at UCT. This comparison may shed light on the areas of concerns within the current higher education system that often go unnoticed or attributed to an incorrect cause. Furthermore, as noted above, undergraduate student experiences are often linked to a wide-range of outcomes, such as student engagement, quality of education and academic success and persistence (Benckendorff et al., 2009).

The study adopted a qualitative methodology using student interviews. The science students' narratives were analysed from transcriptions collected by Case et al. (2015a); whereas the engineering participants were selected from the 2009 cohort of first year chemical engineering students and were interviewed during this study. Hence, interviews with the science students were conducted in 2015 and interviews with the engineering students in 2016.

An e-mail invitation was sent to the full 2009 cohort of students using the e-mail addresses from the university records. Upon acceptance from the voluntary participants and ethical clearance, the in-depth interviews were conducted either face-to-face or via Skype, and were audio-taped for transcriptions. Interviews were guided by a semi-structured protocol, but all participants were encouraged to share their narrative in detail, particularly their background, choice of study, perceptions of higher education and life after their studies. The transcriptions were followed by the individual narratives, which were analysed following Polkinghorne's

(1995) concept of narrative analysis. Each narrative was explored individually before being analysed across narratives.

Findings

Narrative analysis of the interviews resulted in the identification of four distinct themes that will outlined in the sections that follow.

Table 2. Summary of participants involved in study.

Participants	Name	Discipline
Keni	Female	Geology
Jessica	Female	Chemistry, Math
Taku	Male	Computer Science
Lynda	Female	Computer Science
Hanna	Female	Chemical Engineering
Travis	Male	Chemical Engineering
Resa	Female	Chemical Engineering
Sipho	Male	Chemical Engineering

The smooth trajectory

Taku had a seamless career trajectory with a strong support structure from his Zimbabwean family. Despite the financial struggle his family underwent to pay for his studies, he managed to complete his undergraduate degree. During Honours, he secured an overseas job as a software developer with hopes of pursuing his Masters in due time.

Much like Taku, Resa and Hanna also had a seamless trajectory regarding their education. Both women are currently pursuing their PhD. Resa plans to return to the engineering industry upon completion whilst Hanna has no plans at all. Additionally, both women struggled in the first two years of their undergraduate studies and found it difficult studying in countries far away from their origin. However, they each believe that the experience has made them more mature and independent.

Struggling and then making an alternative career choice

Sipho was raised in a rural community and unlike the previous three participants, who were academically successful and had a healthy support structure, Sipho grew up in an unstable home with most of his high school curriculum being self-taught. Because of his inadequate secondary education, the unfamiliar territory and demands of university and the decline in his maternal relationship, he failed many of his courses. Despite losing his bursary funding and failing a few of his courses, he completed his degree in six years. He claims this persistence is due to the family pressure to succeed and the shame associated with failure especially since he is the first in the family to attend university.

Just like Sipho, Travis desired a career in commerce. This realisation came in his third year of study through interest developed via networking with friends and acquaintances. He did not

choose to do any business-related courses and was continually persuaded by his parents to not change degree programmes. He describes his university experience as “the best and worst four years” of his life. The best part was the friendships and networks that he built and the worst was studying a field of study he did not particularly enjoy.

Upon graduation, both young men re-evaluated their life-goals and chose to pursue a career in commerce. They believe that the set of tools and skills learnt during their chemical engineering degree programme is advantageous in their current line of work.

The seeker of advice

Jessica has been born, raised and educated in Cape Town. Rejected from the extended degree programme for Medicine, she studied chemistry, biology and microbiology. Because she was unsuccessful with her biology courses, her degree was extended by one year and she changed her major to mathematics. Upon the completion of her BSc., she applied for an Honours degree in Material Science which she did not enjoy. During her studies, she partook in a number of societies and held a variety of part-time jobs which exposed her to different environments. Even though she sought out a full-time job, she rejected a full-time prestigious graduate programme because her mother did not want her to leave Cape Town.

Now, based on the advice by a friend, she wishes to pursue a qualification in education. She claims that if had she known about the other courses offered in other faculties, she would have completed a different degree. She believes this lack of knowledge comes from her school education’s focus on science-related courses and her BSc. programme not offering better opportunities. She finds that her life would have been different had she been informed of different career pathways – an indication that her knowledge was limited by what she heard and not what she sought to know.

The passionate few

Lynda grew up in a small South African town where she was inspired to pursue computer science by a retired UCT professor. After overcoming the thought of dropping out of school due to consistent bullying, she was accepted for the computer science degree programme with funding. This was the beginning of a progressive career as a software developer. When asked if Honours was a necessity, she claimed that in industry it was more about who she knew than what you knew – a contrasting perspective to Taku, another computer science student interviewed. Lynda expresses her confidence and passion for her field of study and emphasises her desire to improve herself at every turn. Despite her field of study being male dominated, she did not encounter any form of aggressive sexism. In fact, she says that her male peers were essential in her academic excellence and student persistence.

Similarly to Lynda, Keni has a deep passion for her field of study, geographical information systems (GIS). Unlike the other participants, Keni was initially part of the General Entry Programme for Science (GEPS), which she found more intensive than the mainstream curriculum because of the extra help and tutorial sessions. Upon completing her Honours, she worked as an intern researching and collecting data for GIS. Disappointed by this experience, she returned to pursue her Masters. She admits that this was not her initial plan but is now determined to complete her PhD part-time.

Both women claim that attending university is beneficial as it prevents narrow-mindedness and expands a vast range of skills other than technical skills, such as networking and presentation skills.

Discussion

In this section, we now bring the findings from the interview analysis into conversation with the background survey presented earlier.

Coursework and schedule

The survey analysis observed that engineering students had less sleep, spent more time in lectures and tutorials and spent more time studying outside of class. This aligns with a general perspective supported by the engineering interviewees who claimed that the engineering programme was tough and time-consuming. However, Keni, a GEPS student, felt that she did twice as much work as the mainstream science students.

The survey analysis observed that more engineering students incorporated information from other courses into their assignments. This is in a sense supported by the narratives of Siphon and Travis, who believe that the courses taken and skills developed during their chemical engineering degree were advantageous to their careers in finance. Ultimately, the method of thinking instilled during their studies and the exposure to multi-disciplinary courses caused the expansion of skills and a broadened world-view. Jessica, a science student, felt she could have benefited from this type of exposure during her studies.

The survey showed that science students were more likely to choose more challenging courses despite the effects this would have on their marks. This may be supported by Lynda and Taku's narratives, who each chose and excelled at what were considered difficult fields of study at the time. Thus, it may be deduced that 'challenging courses' would rely on the individual's perception, preference and ability (Bitzer & Troskie-De Bruin, 2004; Jama et al., 2008). Furthermore, when considering the engineering students, this observation is supported by the narratives of Siphon and Travis. Even though they each wanted to pursue a career in commerce, when given the opportunity to register for a commerce-related course, they declined and chose a course 'less challenging'.

Student engagement

The survey analysis observed that engineering students studied in a group outside of class and helped each other more often than science students. Each engineering students' narratives affirms this observation and explicitly mentions the benefits of studying in a group, such as academic success, confidence boosts and diversifying ideas. Hanna and Siphon mention the maintenance of relationships upon graduation. The science students' narratives do not explicitly state any involvement in group work or teamwork, which alludes to the perspective that science students are particularly independent during their studies. The only science student to mention any benefits from relationships from her peers was Lynda.

Furthermore, the survey analysis observed that engineering students approached a lecturer more often than science students. During the science students' narratives, there is no explicit mention of their relationships with their lecturers. On the other hand, the engineering students' narratives refer to the approachability and consideration of their lecturers; particularly Hanna who was encouraged to finish her degree by an engineering lecturer. Additionally, according to the survey analysis, engineering students were more likely to find UCT to be impersonal. Due to the limitation of only interviewing chemical engineering students, it cannot be argued extensively. It is recommended that a study consisting of a variety of engineering students take place in order to identify issues or concerns across departments.

Motivation to study

The survey analysis observed that when applying to study at UCT engineering students found it more important that the degree led to a higher paying job. This observation contradicts the narratives of Hanna and Resa, who are both currently pursuing their doctorates with the interests of research at heart rather than money. This may be inherent in their choice to study further. It is suggested that engineering graduates that entered engineering careers are interviewed to shed further light on the choice of an engineering degree for a high salary. Siphon and Travis hope to climb the proverbial career ladder, but whether it is for skills development or higher pay is unknown.

Furthermore, the survey analysis observed that science students found it more important that the degree prepared them for postgraduate studies. Though this may be true considering the current job markets, there is the contrasting perspective of Lynda, a software developer. She felt that postgraduate studies (Honours) was not required and that her degree was beneficial but inessential. She attributes this perspective to the fast-paced, dynamic industry of software development; which she has experienced since graduation. This opinion was not shared by Taku, another computer science graduate, who believes the reverse. This variation of opinion may depend on the cultures and social structures that conditioned each response. Unfortunately, the lack of contact details for the science students prevented further analysis. With regards to the engineering students' narratives, all participants believed in the need for postgraduate studies, whether it be engineering or another field of study entirely.

In each narrative; it was evident that some form of support structure was required to achieve success, whether it be family, friends or lecturers. This indicates the extent support plays in the commitment to graduate. Additionally, the stress of financial concerns also played a major part in the ensuing decisions. If one considers the narrative of Siphon, a non-traditional South African student who lacked maternal support, had constant financial concern and experienced family pressure to succeed, one may argue that student persistence is a dynamic process that requires an inherent sense of self to overcome these constraints.

Conclusions

Ultimately, this study shows that a variety of factors affect student persistence and a student's commitment to graduate. Though the majority of the participants who partook in this study were successful, more detailed research is required to understand those who were unsuccessful. This study set out to explore the student experience of science and engineering students and found interesting perspectives that break the mould of the traditional perception of students, particularly in the case of non-traditional students (defined as black South African students from disadvantaged backgrounds).

Furthermore, it must be noted that the survey analysis data took place in 2012. Firstly, the current climate within the higher education system has been dynamic when considering the strides taken towards more inclusive and advanced teaching-learning methodologies. Secondly, it has also been tumultuous when considering the strive towards a decolonised curricula and accounting for #feesmustfall protests; some of the major underlying causes can be found in the opinions and perception of 'non-traditional students'. These views, opinions, perceptions and experiences are obtained during their stay at institutions of higher learning and may provide a platform that could, and can, initiate change.

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Using YouTube as a reflection tool for a service-learning module

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Visual media, such as videos, provide a medium for authentic self-reflective feedback by students. They facilitate knowledge of performance and improve students' understanding of their learning. Uploading such videos on YouTube provides a new forum for interaction to a broader community. Expecting students to use YouTube for reflective assignments in a service-learning module gives the students the opportunity to provide feedback to campus-community partners and the public on their projects. The study examines students, enrolled in the compulsory undergraduate Community-based Project Module of the Faculty of Engineering, the Built Environment and Information Technology of the University of Pretoria in South Africa, perceptions of the level of difficulty involved in making YouTube videos for reflective assessment purposes are. It aims to establish if they learnt any additional skills through such an assignment. It also aims to establish what impact the assignment had on the students, including the impact on the module's allocated notional hours. Feedback from the students was positive, and they found it relatively easy to make a YouTube video for reflection. They learnt how to design, develop and edit audiovisual footage. Students were encouraged to develop quality YouTube videos and share them with their friends and relatives. YouTube can be used as a reflective tool in a service-learning module, as it provides students with an opportunity to showcase their service-learning project. Its added value is the possible marketing of the University, service-learning and campus-community partnerships.

Background

As part of the undergraduate curriculum, the Faculty of Engineering, Built Environment and Information Technology includes a compulsory module, Community-based Project Module. This module centralises and coordinates the Faculty's community service initiatives.

The objectives of the service-learning project that forms part of the module are that it must achieve a beneficial impact on a chosen section of society and expose engineering students to real-life issues. If the students are involved in the communities, they develop an awareness of their citizenship and how they can utilise their acquired knowledge to the benefit of the community. Students seem to prefer projects such as teaching computer skills, designing, developing and uploading websites for non-profit organisations, helping secondary school learners with Mathematics and Science, serving at shelters and children's homes, renovating buildings and participating in animal-related projects (Jordaan, 2014).

The students must reflect on their service experience to gain a deeper understanding of how the curriculum content and community dynamics relate to each other. They deliver a presentation about their projects to the lecturer. During this presentation, they reflect on the outcomes of their service-learning engagement, the skills acquired in the execution of the project and lessons learnt during and upon completion of their projects (Jordaan, 2013).

In the past, students were required to complete a reflection report in the form of a blog that could be accessed via a link on the University's website. The aim was to expose the public to the projects and present the students' reflections on their learning experience. The blog function

on the University's website was made inactive, and the development of a virtual blog in the form of a YouTube video has been used since 2013. The students are required to make a video of three to five minutes. The video must include the students' text or vocal reflection on what they learnt from their service-learning experience. Students usually use their smartphones to take photographs or short videos to include in their final YouTube.

Written permission and evaluation documents from a representative in the community where the students completed their field work must be submitted as part of the final assessment. The lecturer approves the change of the video status from "unlisted" to "public" on YouTube after evaluating not only the content but also the permission documents. The students are instructed not to add faces of vulnerable children or patients. They are also instructed to be careful with sensitive issues relating to animal shelters, for example, and the enclosures of rhinoceros at various sanctuaries.

There is a YouTube channel for the module, but the students must use their personal YouTube account details so that they can manage the video link for personal curriculum vitae purposes.

Literature review

Service-learning teaches and connects community service and academic study (Colby, Bercaw, Clark & Galiardi, 2009). Students must, therefore, reflect on their community service activity in such a way that their understanding of the course content and sense of civic responsibility are enhanced, and they achieve a broader appreciation of the discipline (Bringle, Hatcher & Jones, 2011).

Service-learning modules enable different types of reflective activities. These activities may include journals, experiential research papers, ethical case studies, class presentations or electronic reflections (Bringle & Hatcher, 1999; Bringle, Hatcher & Jones, 2011). These assessment modalities have been proven to be efficient, but the possibility of using YouTube as an online video broadcasting technology and as a reflection tool in a service-learning course is not yet standard practice.

Technology tools such as blogs, reflective journals, online discussions, self-report surveys and "vlogging" or digital storytelling can engage students in reflection (Zhang, Olfman & Ractham, 2007). Video also provides a medium for critical thinking and gives the students the opportunity to understand and improve their learning (Hattie & Timperley, 2007; Issenberg, McGaghie, Petrusa, Gordon & Scalese, 2005).

The launch of YouTube in 2005 provided a new platform for students to produce, share and contribute to visual knowledge (YouTube, 2009). The development of Web 2.0 has facilitated the use of video for meaning representation and has provided new possibilities for educational materials (O'Reilly, 2005; Franklin & Van Harmelen, 2007). The term *Web 2.0* generally describes how users interact on the Internet and the participative and social elements of the World Wide Web (Rogers-Estable, 2011). Online video use in education has become global following the widespread availability of production technologies. Ubiquitous technologies, such as smartphones with video recording capabilities, video production software, photo and video-sharing applications as well as social networking services, contribute to the growth in new ways to disseminate information. It may also allow raising funds, promote community engagement and enhance citizen participation (Mogull, 2014; Jacob, Sutin, Weidman & Yeager, 2015). Through integrating these affordances in teaching and learning, education acknowledges its alignment with changes in society and integrates it due to the educational value.

Web 2.0 technologies provide more opportunities for online social interaction (Harley & Fitzpatrick, 2009). YouTube as an extension of these Web 2.0 technologies (Duffy, 2007), has its popularity among young adults, as one of many virtual communities. YouTube not only became a place to post, view and share music videos, but it is also a platform for daily video uploads like video blogs (Workman, 2008). This led to a generation with a creative outlet, a global audience, immediate satisfaction and responses, as well as the possibility of instant fame (Kavoori, 2015). YouTube videos that are produced by students may support communities to gain marketing value and allow students to take ownership of their experiences (Cheng & Chau, 2009).

Cheng and Chau (2009) found that digital video encourages students to improve their showcases and that digital videos created for reflection were relevant to student's learning needs, especially for developing soft skills like listening and speaking.

Theoretical and conceptual framework

The integration of media in higher education assignments has many benefits, as is evident in the research literature. It can support student inquiry by expanding the range of questions to ask and the expectation of the collection of different types of information (Winnie, 2010). Prensky's understanding of digital natives (2001) opened up a debate about how students learn and how technology has changed their learning. Margaryan, Littlejohn and Vojt (2011) found that students of a technical discipline are more inclined to use technology tools. Keller's attention, relevance, confidence, satisfaction and volition (ARCS-V) model (2016) provides a framework to understand the success of the integration of the development of a YouTube video as a reflective assignment. The model suggests that the main categories that comprise the model should promote motivation. Figure 1 illustrates the ARCS-V model that is used as a theoretical framework for the integration of video-based reflection in this study and to support the hypothesis that video will be the preferred medium of student assessment.

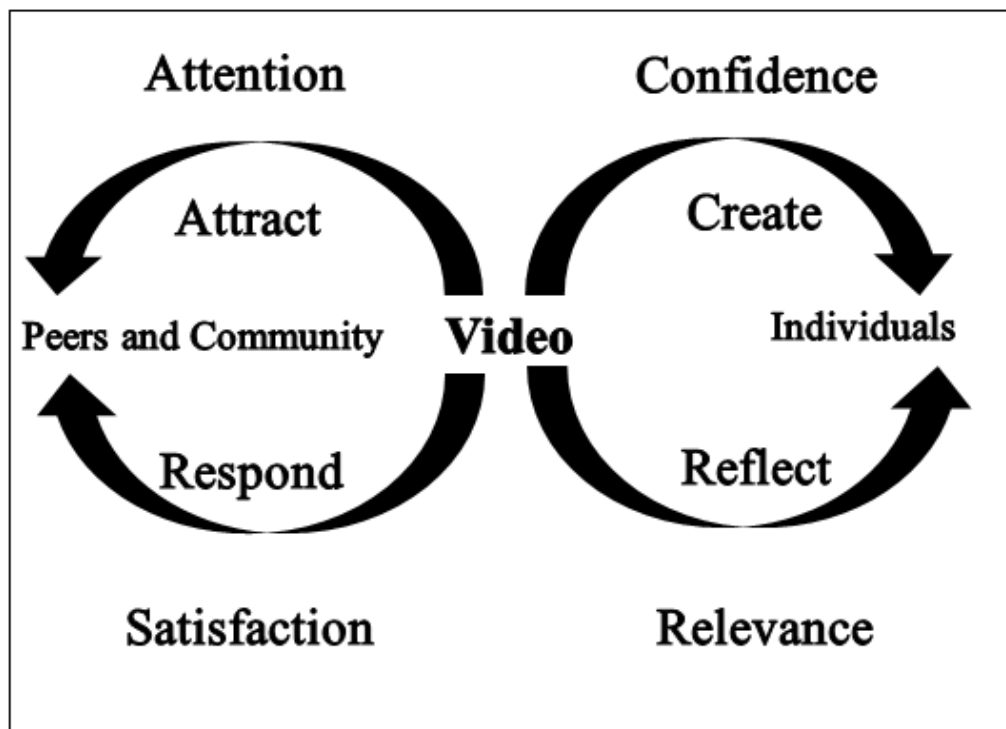


Figure 1. The ARCS-V theoretical framework.

The students' **attention** is immediately drawn to the novelty of the assignment, as it is challenging to develop a YouTube video. They may also find it **relevant** to reflect on their project through a video where they can showcase their project to their peers and the community. The students also show **volition**, as they are motivated to complete the YouTube. **Confidence** can, with the possibility of "instant fame" via the YouTube video or the number of "likes" on YouTube, lead to a feeling of **satisfaction**. The motivational components of the ARCS-V model consolidate the interactions between the YouTube video, individuals, peers and campus-community partners. All these stakeholders have a shared, but unique motivational interest in the outcome of the development of the video as linked to the interactions of the broader community and the possibility of "instant fame" via YouTube.

The conceptual framework, as illustrated in Figure 2, was adapted from the ARCS-V model by the authors. It shows the impact (relevance, confidence and satisfaction) and input from stakeholders (attention) in the development of the YouTube video. It aims to provide a holistic overview of the video impact and the relationship between the different stakeholders. The stakeholders are the students, the University, the lecturer and the community.

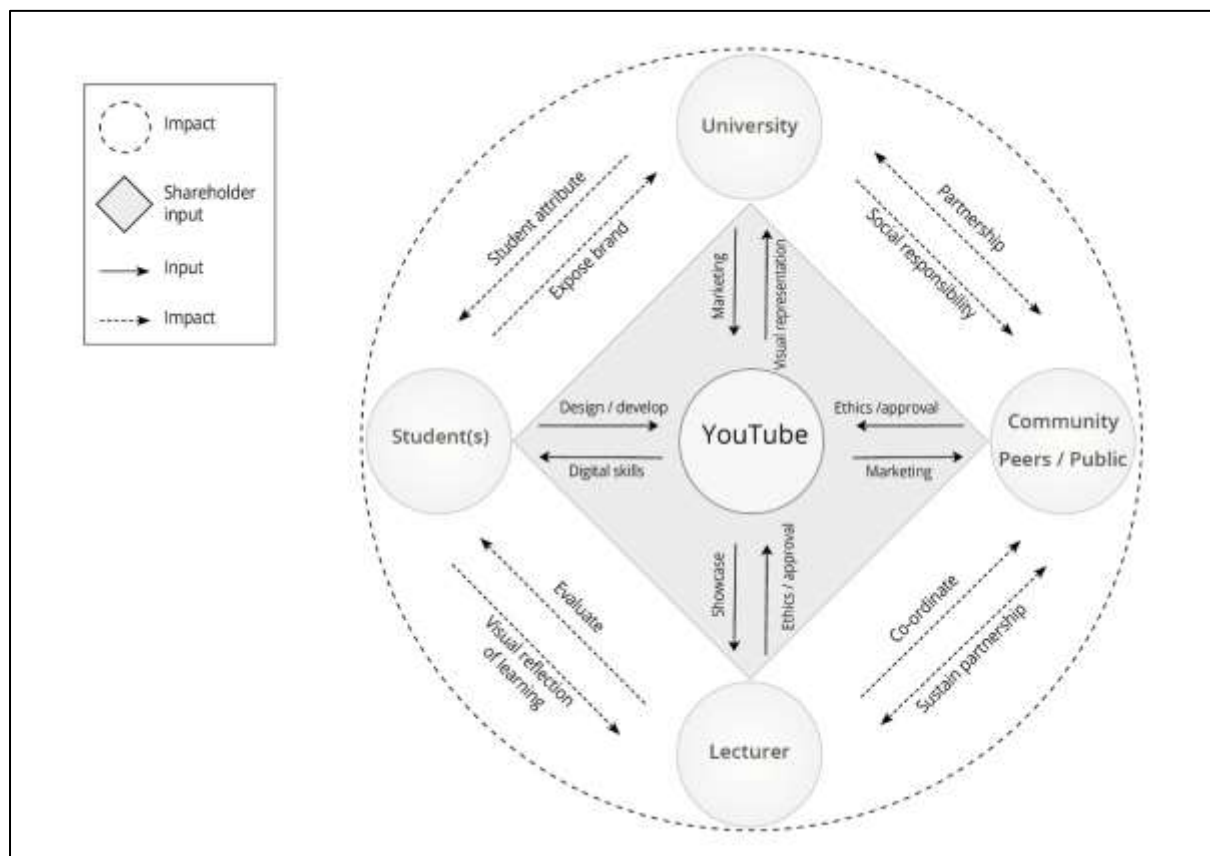


Figure 2. The conceptual framework: the impact of a YouTube video on stakeholders.

The YouTube videos showcase the expected graduate attributes. The University received student-generated marketing exposure for its brand and social responsibility to society. The students provide a visual representation of their involvement in supporting the University's mission to integrate engagement with society and communities into pursuing recognition and excellence in its core functions (University of Pretoria, 2017).

The students collaborate with the community in the development of the video and receive approval, including ethical approval from the community, for publication on YouTube. The lecturer coordinates the interaction between the students and the community and ensures that the video's quality will protect and promote the branding of the University and community. The lecturer also ensures that the video complies with ethical and privacy regulations to safeguard these brands.

Research topics and questions

This study will explore the potential of using YouTube as a reflection tool for a service-learning module in an engineering faculty context. A longitudinal study, through a survey administered in 2013, 2014 and 2015, provided data for this study. The aim of the research was to investigate students' perceptions of the level of difficulty involved in developing a YouTube video, as well as the impact of the video design and development on the effort and skills required from students, assessment preferences, possible financial implications, time impact, and assignment validity. The study also aimed to investigate YouTube's marketing value for the module, the University and community.

The following research questions determined the impact of the YouTube assignment: Do students have the necessary skills to develop a YouTube video as an assignment? Which skills did students acquire by developing the YouTube video? What is the impact of the YouTube videos of the curriculum, students and the branding of the University?

The first research question aimed to determine the technical difficulty and duration of YouTube video development. The second research question sought to understand the new skills acquired by the students and therefore the educational value of making a YouTube video. The final research question aimed to determine the branding value by identifying with whom students shared their YouTube videos. Establishing how YouTube views served as a proxy for measuring marketing value was a secondary aim of this final research question.

Methodology

This study focused students enrolled for the module between 2013 and 2015. The student who was responsible for the YouTube video was requested to complete a survey.

A small group of students completed the survey in 2012 to validate the questions. After that, ethical clearance was received from the University. The survey consisted of 19 questions and included four open-ended questions. It was designed to allow the branching of questions based on answers provided in previous questions.

The first question focused on the informed consent for the study. Questions 2 and 3 collected biographical data about the students. Questions 4 to 12 examined the students' confidence and necessary skills to make a YouTube video, Questions 13 to 17 related to the skills the students acquired through making a YouTube video. Question 18 to 19 focused on the added value of the video.

From the 482 YouTube videos made in 2013, 192 group respondents (39.83%) completed the survey. Of the 504 YouTube videos developed in 2014, 219 group respondents (43.45%) completed the survey. The 2015 students' response rate was the lowest. Only 98 respondents (20.20%) completed the survey out of the 485 groups.

Findings and discussion

Results from the study shed light on the research questions concerning the impact of the use of a YouTube video as a reflection tool for a service-learning module. The results will be discussed in relation to the research questions in the rest of this section. Most of the respondents were male (2013: 72.92%; 2014: 65.75%; 2015: 69.70%) and studied Engineering (2013: 60.42%; 2014: 63.93%; 2015: 66.67%).

Required skills to make a YouTube video as an assignment for the module

The aim was to analyse the students' perceptions towards the level of difficulty to make a YouTube video and the skills required. This was determined by the students' reflection on the difficulty of developing and uploading the video to YouTube, and the time it took for the students to design, develop and upload it. Previous experience in the development of YouTube videos provided a benchmark for interpreting students' feedback about the levels of difficulty.

Most of the students (2013: 81%; 2014: 68%; 2015: 61%) indicated that this was the first YouTube video they had created. Two trends were visible over the three years included in the study. There was a decline in the percentage of students who stated that they had not developed any YouTube video before, and there was an increase in the number of students who had developed at least two videos, and those who had developed five or more videos.

A cross-tabulation analysis of the results aimed to investigate the hypothesis that the students who had never developed a YouTube video struggled the most. More than 70% (2013: 72%; 2014: 71%; 2015: 75%) of the students who had never developed a YouTube video disagreed with the statement that it "was difficult to make a YouTube video". Less than 15% of the students agreed with this statement. Those students who indicated that it was difficult to develop a YouTube video stated the reasons in an open-ended question. Their answers were coded and categorised. Students indicated six categories of reasons. Table 1 presents a summary of the reasons and the percentages shown per reason.

Table 1. Reasons stated to support the level of difficulty in developing the YouTube video.

Number	Reason category	Percentage indicated
1	Video editing skills	42%
2	Software knowledge	19%
3	Time-consuming	16%
4	Strive towards high quality	9%
5	Find software and needed software skills	7%
6	Evaluation criteria	7%

Some 42% of students indicated the lack of required video editing skills as the main reason why they struggled to develop a YouTube video. The knowledge needed to use specific software (19%) to produce the video was the second reason. Only 16% of the students indicated that the development of the YouTube video was time-consuming.

The second criteria to determine the students' perceived level of difficulty focused on their experience in uploading the video to YouTube. The question aimed to understand if students also struggled with the process of uploading the YouTube video as it required, among other

things, access to the internet. Internet access implies a possible financial burden on the student, as the cost of internet access is relatively high in South Africa in comparison to other countries.

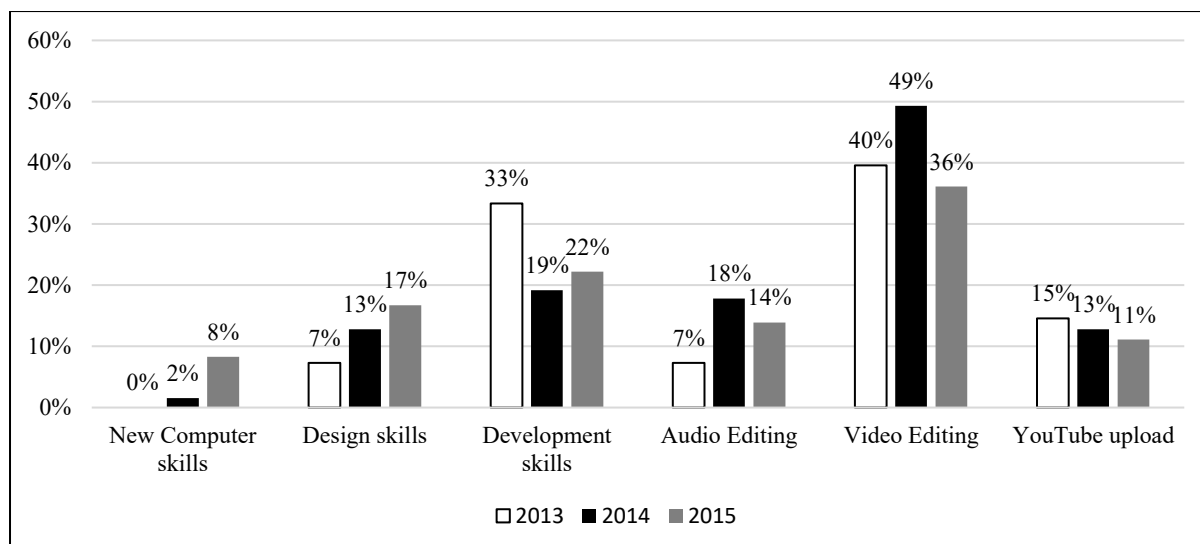
The majority of students indicated that they did not struggle to upload the video. Less than 10% of the students reported that they struggled to upload their video to YouTube. The highest percentage of students stated that they had not uploaded a YouTube video before and struggled with the process. Some students also indicated that the software they used was not compatible. These students reported that they had to find alternative ways to upload the video. A few students were not aware that YouTube filtered their video for copyright-protected content, such as music, and this affected their upload experience.

Two-thirds of the students indicated that they did not experience any difficulty in developing or uploading the YouTube video. The remaining third focused on the time it took them to design, develop and upload the video. This time frame was important to the study due to the possible impact of the video development on the JCP module's allocated notional hours. It was also important to critically evaluate the use of YouTube as a reflective assessment tool. The breakdown of the JCP module's notional hours includes the allocation of 10 to 15 hours to prepare the project presentation for assessment purposes. The preparation includes the design, development and uploading of the video.

The percentage of students who used 0 to 5 hours to design, develop and upload the video declined significantly in 2014 and 2015, while the percentage of students who took more than 15 hours increased in 2014 and 2015. The data validated the time allocated in the notional hours for the design, development and uploading of the video, as on average only 16% of the students indicated that it took them more than 15 hours to complete the YouTube assignment. The overall increase in students who used more than 5 to 10 hours can be linked to the additional motivation to improve the quality of the videos based on the quality benchmark set by the 2013 group of students. The quality of the 2014 and 2015 YouTube videos was much better as the students could use the 2013 and 2014 videos as examples. The rubric for assessment was also adapted to include a detailed explanation for every assessment criterion.

Skills acquired while developing the YouTube video

The value of the YouTube assignment lies in the skills that are developed to complete it successfully. In the open-ended question, the students were requested to indicate the skills they needed during the development of the YouTube video. The answers to the question were categorised and coded. Soft skills like time management, professionalism and group work were identified as acquired skills. The 2015 students' indication of time management as an acquired skill can be linked to the trend in the percentage of students who took more than 15 hours to complete the assignment. The majority of the "new skills" the students acquired focused on the different skills needed to design, develop, edit and upload the video. Graph 1 indicates these video-related skills.



Graph 1. Video-related skills acquired.

More than a third of the students indicated that designing, developing and editing the video and audio were the most valuable skills they acquired through this assignment.

Less than 20% of the students indicated that they did not learn any new skills. This can be linked to the percentage of students who reported that they had already developed at least one video before the assignment. Some students mentioned in their feedback that they had previous experience of creating videos. Students who completed the survey were enrolled in the School of Information Science, which includes degrees like BSc (Multimedia) and BSc (Computer Science).

Students were motivated to allocate the video development to a single group member, as it required planning from the beginning of the project. In investigating the development process, students were requested to indicate how they coordinated the task of video development and if they asked anyone who was not enrolled for the JCP-module to assist them. It was important to investigate the contribution of such a person, as it would indicate the validity of the assignment and video authenticity.

In more than 50% of the groups, the task to design and develop the video was allocated to one student. The guidelines of the module recommend assigning the responsibility for the design and development of the YouTube video to a single group member. Irrespective of this recommendation, the video development became a team effort as a few groups indicated that either a few members of the group or the whole group contributed to the development. The group effort might have had an influence on the quality of the YouTube videos in 2014 and 2015.

A small percentage of students requested another person who was not involved in the module to assist in making the YouTube video. Table 2 presents an overview of the five categories of reasons why the students asked for assistance and the percentage of all the students from 2013 to 2015 who indicated that they asked for assistance from another student or person who was not enrolled in the module.

Table 2. Reasons why students asked for assistance.

Number	Reason category	Percentage 2013-15
1	Video editing	40%
2	Need for assistance from an experienced person	19%
3	Quality improvement	17%
4	Small group	17%
5	Time constrains	4%

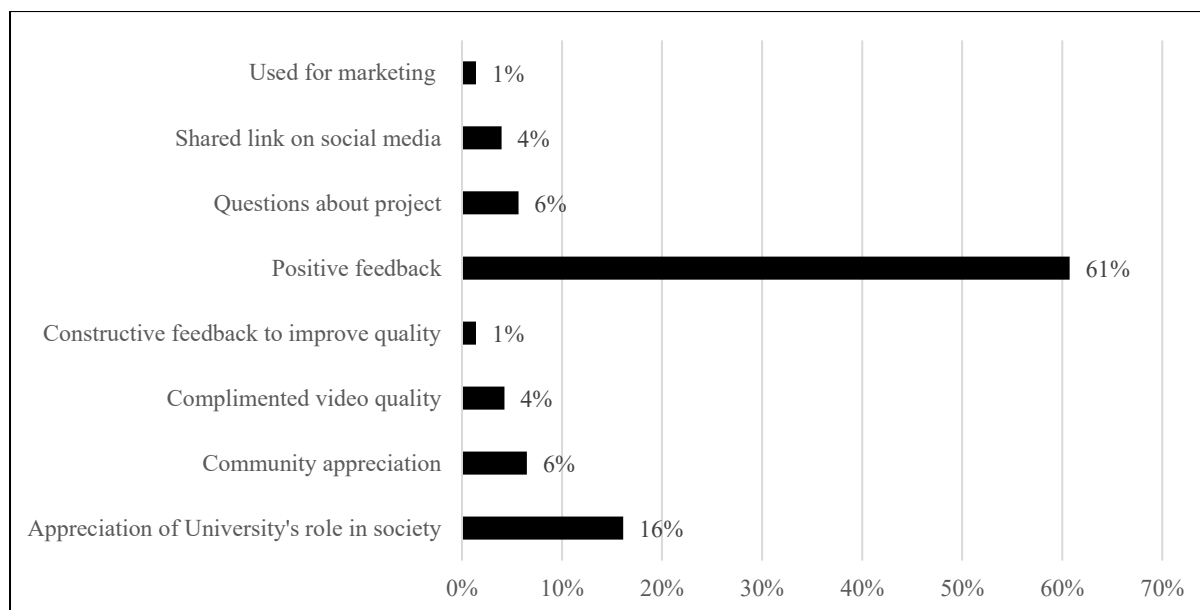
The biggest challenge the students experienced with video development was their lack of basic and advanced video editing skills. This was the key reason why the students indicated that they asked for assistance from another experienced person. Only a small group of students mentioned time constraints as the reason for asking for assistance.

Impact of the YouTube videos for the curriculum, students and branding of the University

It is important to investigate the impact of video design and development to critically reflect not only on the curriculum impact but also on the unforeseen financial implications for the students. Research on the branding and marketing impact will validate the indirect effects of the assignment. The students' preferences about the type of reflective assignment allow the lecturer to validate the impact of the assignment's format.

Students were asked to indicate the type of software they used. Two-thirds of the students preferred using open and free software for the creation of the videos, such as Windows Movie Maker or Microsoft PowerPoint. The remainder of the students used commercial software. The University provides free internet access on campus, and the students could use their campus access to upload the video. Students did not indicate financial constraints as a challenge to complete the assignment.

The possibility of sharing their video with their friends, relatives, community or the world provided external motivation for the students, not only to develop a high-quality video but also to showcase their community service project. Most of the students shared the YouTube video with their friends and relatives. In an open-ended question, the students were requested to provide feedback on the response they had received. The question was categorised and coded in the three surveys. The feedback provided valuable information about the value of the YouTube videos for the students, the university and the communities. Graph 2 gives an overview of the feedback from the open-ended question.



Graph 2. Students' comments on feedback received.

The majority (61%) of the students' feedback was general feedback. The word "positive" was often directly mentioned in these general statements. Students also specifically mentioned that they had received either a compliment about the professional quality (4%) of their video or questions (6%) about their project.

Only 1% of students indicated that the community used their video for marketing purposes. The authors used the video views on YouTube as a proxy, not only to establish the marketing value of the community project videos but also for the brand of the University. The students were requested to identify the videos on YouTube using a particular naming convention, which included the module code, their group number and the University's name. The results of a search for the University's name include the more than 1 200 videos developed by the students. The number of YouTube views per video was recorded in August 2016. The highest number of views for the YouTube videos was between 1 150 and 2 289 with 17 5432 views for all videos.

The marketing value of the YouTube videos for the module and the University was acknowledged when the module received a National Marketing Advancement and Communication in Education Excellence (MACE) Award in the category Integrated Campaigns/Projects and subcategory Social Responsibility Citizenship Development in 2014. One of the YouTube videos of 2014 was also a finalist in the American Society for Engineering Education Community Engagement Division Film Festival. The video received more than 7 000 views and 2 000 likes.

The students' preferences of the types of assignments measure the impact of the reflective YouTube assignment on their willingness to acquire new skills to complete the assignment and the recognition that the assignment may require more effort than the suggested alternative types of assessment. More than two-thirds of students preferred the design and development of YouTube videos for assessment purposes.

Future research

This research study was done within a service orientated context within the Faculty of Engineering, the Built Environment and Information Technology at the University of Pretoria. A similar study in other faculties results may be different. Administering the survey in the future within the same Faculty may validate the hypothesis that the level of digital skills may improve in new cohorts. There was an indication of an increased level of video development knowledge and skills in the 2015 cohort in comparison to the 2013 cohort.

Conclusion

Bringle and Hatcher (1999) indicated that the structure of a reflection assignment could influence the results of the service-learning experience. The reflection activity must allow students to realise the value of dialogue and make meaning of the service-learning experience. The research confirms the value of the development of a YouTube video as a reflective assessment.

The challenge of a YouTube reflection assignment lies in the fact that students must reflect on their experiences, but it should not indicate the negative aspects of the learning experience on the internet. This might have implications for the campus-community partnership, as well as possible future projects at that particular site. Additional reflection opportunities must be created for students where they have the chance to discuss all the aspects of the project. Students also complete other assignments on the university's Learning Management System, which includes a written report. They have to do a presentation with an in-depth discussion on the outcomes of the project with the lecturer.

The challenge remains to upload the YouTube videos on one account. It may remain a challenge as the University has to manage YouTube videos on campus due to bandwidth-constraints and management. Uploading the YouTube videos on the module's channel will provide analytical data of the module's YouTube videos.

The versatility of an online video, as well as its accessibility, breadth of content and up-to-date material, gives students the opportunity to reflect on a broader platform and share their experiences on this larger platform. A service-learning module provides a variety of photographic possibilities, and it is easy to collect enough visual content for a captivating YouTube video. The students preferred this type of reflection method and learnt various skills in the process. There is also the possibility of instant fame. The video is readily available to the broader community and provides a portal to showcase the involvement of the University and students in the community. The research validates the conceptual framework used to illustrate the impact of the development of YouTube videos within a community service module.

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A lot right, a lot wrong! An analysis of student responses to a design, build and assess project in a thermodynamics course

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This paper reports the findings of a reflective investigation into how students responded to a double course innovation in a third year thermodynamics course in chemical engineering in 2015. The first innovation involved a practical project in which students designed and built a working model of a Sterling engine. As expected from the literature, the students responded very positively to this. The second innovation was a reflective assignment which students reacted to very negatively, prompting the investigation reported in this paper. The investigation analysed the reports the students submitted and found two underlying problems: a mismatch between the students' and the teacher's expectations; and a misunderstanding on the part of the teacher about the nature of the demands the assessment placed on the students. Apart from the recommendations for future implementations of the project that emerged from the investigation, fresh ideas emerged about how the project assignment could be used as a means of assessing *for* learning as opposed to assessment *of* learning.

Introduction

In 2015, third-year students in a chemical engineering thermodynamics class were given a practical, design-and-build project in which they were required to construct a working model of a Stirling engine using commonly available and inexpensive materials and guided by design principles found on a web-site¹. (A Stirling engine is an external combustion engine that converts heat to work using air as the working fluid.) Students had freedom to work alone or in teams and were given eight weeks to build their models and write a report.

In the context of the course, the project was innovative in two respects: a practical, self-directed project was new to the course; and the assessment scheme was unfamiliar to the students in that it required a reflective report. The design-and-build aspect of the project was well received; students found it to be, in their words, "enlightening", "instructive" and "enjoyable". However, most of the reports submitted did not address what was asked for and were generally of low quality. Student reactions to the relatively poor marks they consequently received were vociferous and invariably negative. They complained that the assessment system had not been fair in that the marks awarded did not properly reward the effort put in. The stormy protest led the teacher, among other measures, to conduct, with a colleague, the reflective investigation reported in this paper. The objective of the investigation was to establish 'what had gone wrong' as well as 'what had gone right' so that future implementations of the project would avoid the 'pains' experienced and that the potential of the project to enrich student learning could be optimized.

The design, build and assess project

The motivation behind the project was to generate a learning experience for the students that would have multiple learning benefits including experience in practical design work and the

¹ <http://www.instructables.com/id/A-Stirling-Engine-Project/>

construction of a device, and in the practical kind of problem solving that is associated with trying to make the device work. It was intended that the project would facilitate deeper experiential insight into the relevance and application of thermodynamic principles in real world situations. Additional learning benefits that were anticipated included the development of practical and team work skills; and the sparking of greater interest and motivation in the subject.

A secondary motivation for the project had to do with satisfying ECSA exit-level outcomes. As part of its strategy for satisfying accreditation requirements, the school had assigned, as one of the intended outcomes of the course, the ECSA exit-level outcome for problem solving which, as stated in the assignment hand out, was ...

Demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively. (ECSA, 2004).

The teacher reasoned that the project could help to provide evidence that this ECSA outcome had been achieved through the project, in addition to providing the learning benefits just listed. Accordingly, he included as part of the project assessment a component that required the students to evaluate and reflect on how the project had satisfied required ECSA outcomes. The assessment scheme therefore had two components, one focused on the design-and-build exercise, and one on the reflective assignment.

With regard to the assessment related to the design-and-build exercise, it was anticipated that it would be unreasonable, given the limited time available and workload constraints, to require that the models built were fully functional. Accordingly, this was not made a requirement of the project. Students received a 100% mark for submitting a reasonable model and 0% if it was clear that insufficient effort had been expended in building it. Of the 30 models or so built, only three worked reasonably well. At the end of the project, students presented their models in class and external adjudicators judged which were the best three and graded the work. All students received 100%.

With regard to the reflective assignment, students were required to submit a one page individual report “indicating how the ECSA requirements have been addressed through the assignment”. What this required students to do was first to pick out the key aspects of the relevant ECSA outcome statement (identify, assess, formulate, solve convergent and divergent problems, creatively, innovatively); to explain what each aspect meant; and then to present examples from the project which demonstrated those aspects. The following somewhat abbreviated extract from one of the best reports illustrates what was expected.

How the assignment assisted me to “demonstrate competency to identify, assess, formulate, and solve convergent and divergent engineering problems creatively and innovatively”. Before the engine was designed, potential problems were **identified** and dealt with [...] for instance the decision [example given]. [...] The engine was designed and the new arising problems were **assessed** for instance [example given]. After [...] the engine was still not working new solutions and ideas were **formulated**, for instance we decided to try a different design, and this enhanced our out of the box thinking because we were thinking **divergently** and tried to **converge** all our ideas to build a working engine. We explored all sorts of different materials for the different components of the engine, for instance [example given]. (Quotes and text highlighting are as in the original report .)

Investigating the students' experience of and responses to the project

It was evident that there were a number of problems with the way the project as a whole had been set up and with how its requirements had been communicated to the students. The main problem, however, stemmed from the reflective assignment and seemed to be that the students had not properly grasped what was required. This created an assessment problem with affective consequences. The starting point for the investigation, therefore, was to focus on the students' experience and how they had conceived and responded to the reflective assignment. To do this, the students' reports were analysed. All 109 reports were re-read to gain a preliminary perspective on the students' experience and what they had done. Thereafter, the best five reports were analysed in more detail along with 53 other reports selected randomly, i.e. more than half the reports were analysed.

The analysis of the student reports was based on six questions formulated to study the problems with the assignment and how the students had responded to it. The first two questions focused on the students' experience of the design-and-build exercise. The intention here was to establish the context out of which the students had written their reflective reports. The third question addressed the issue of the extent to which ECSA outcomes had actually been achieved by the design and build project. The analysis then considered what the students had written. Here two questions were in focus: how the students had or had not addressed what had been asked for; and what kind of report they had written. Finally, the analysis searched the reports for any indications of reasons why students had deviated from what was expected. The findings from these analyses were then used, along with relevant literature and the coordinator's reflections, to address the broader questions – i.e. What went right? What went wrong? And what should be done in the future?

The presentation of the findings is framed around the questions that guided the analysis.

The design-and-build exercise

Question set 1: What were the intended learning outcomes of the project and of the assessment scheme? What did the coordinator expect the students to do and to learn?

These questions have already been addressed in the description of the design, build and assess project given earlier.

Question set 2: What were the students' experiences of the design-and-build aspect of the project? What was the value of this task for them?

All the indications are that the students' experience of the design-and-build exercise was very positive and that they found it to be a valuable and worthwhile learning experience. The tone of most reports was a happy one and at the end of the exercise the models were presented to the class with enthusiasm. Student reports indicated heavy engagement in the designing and building of the models and in trying to make them work properly. Many students built two or three models and virtually all went through several cycles of testing and modification of their models. Some reported learning to overcome difficulties in group dynamics; learning how to resource materials; learning useful construction skills; improving their mechanical aptitudes, and having a conceptual breakthrough with regard to how heat can be converted to work. Many students commented on how much they had learned from the exercise and several explicitly reported really enjoying it. These findings demonstrate the pedagogical efficacy and motivational benefits of hands-on engineering project work which is very much in line with the literature (see, for example, Bullen & Knight, 2006; Carleson & Sullivan, 1999; Knight et al., 2003; Newman & Amir, 2001; West et al., 1990).

Question 3: To what extent were the expected learning outcomes of the design-and-build aspect of the project achieved?

Apart from the production of physical models, the most obvious outcome of the project was extensive engagement in problem-solving. All the reports gave extensive details of specific problems that had arisen and how these had been partially or completely solved. Some of the reports distinguished between convergent and divergent problems that had arisen and gave pertinent examples. Some also distinguished between the different stages of problem solving as intimated in the ECSA outcome statement and illustrated these by reference to incidents in their projects. Even in those reports which did not explicitly make these distinctions and were essentially descriptive in nature, it was clear that all the learning outcomes stipulated in the ECSA outcome statement had been achieved to some degree.

The assessment aspect of the project

Here attention is given only to the reflective assignment, the assessment of the design-and-build exercise being unproblematic for students in that all received 100%.

Question 4: How did the students' responses to the reflective assessment task diverge from what was expected?

As found from Question 3, all students had what they needed to produce a report of the kind expected; they all had personal data readily available for making the kind of connections between the ECSA outcomes in question and what had transpired in their project. It is therefore somewhat incongruous that very few students made those connections or, more accurately, articulated doing so. Only in 29 reports, i.e. 50% of the reports analysed, was there any explicit attempt to make these connections. Worse, only with 13 (22% of them) were the attempts reasonable or better than reasonable; only 5 could be described as being good examples of what was expected.

These observations need to be mitigated by exploring whether any students had addressed the assessment requirements somewhat differently from what was expected but still in a way that was compatible with the intent behind what had been asked for. It was found that some students seemed to have been simply describing what they had done as a way of showing that the relevant skills had been exercised. The following abbreviated and annotated extract is a case in point.

- [1] We built a form of the Stirling engine called a displacer [...*followed by 4 long sentences describing the engine components, their function, and some technical observations.*]
[2] Initially when the engine wasn't working a troubleshooting process was conducted and it was realized that [...*followed by 2 long sentences explaining how the problem had been fixed.*]
[3] The efficiency for this engine was low because [... *followed by details derived from relevant theory.*] [4] At this point we realized that we required to modify our engine [... *followed by details of the adjustments made described in terms derived from their theoretical insight. End of the one page report.*]

What we see in this report extract is, firstly, that it makes no mention of ECSA at all. Secondly, it is descriptive in nature rather than being reflective or evaluative. Point [1], in particular, was simply a narrative of what they had done, along with some technical observations and a few reasons why certain decisions had been made. Point [2] described trouble shooting and the consequential problem-solving activities needed to progress. Point [3] described some theoretical observations that were made in order to further refine the model. Point [4] described some evaluation activity that led to more refinements.

Additionally, it is clear that the project had drawn the student into the exercise of many of the aspects of problem solving mentioned in the ECSA outcomes statement and that the student had indeed enriched his/her levels of competency in those aspects. As such, the project had been successful, for this student, in addressing the relevant ECSA requirements effectively. However, the student had not specifically articulated this.

Because the student had not explicitly done this, it is difficult to assess whether or not s/he was implicitly rather than explicitly addressing what the assignment asked for. In this regard, there were several possible readings of the students' intentions. The four most likely are described below with the first two not being too far off what the assignment asked for.

Possibility 1: The student has recognized that the crux of what was required was to focus on problem solving and to show that the project had facilitated the development of competency in this area. S/he had simply forgotten to mention ECSA and to make the connection to the relevant outcomes. In this case, all that was missing in the report was a sentence or two to the effect that in order to demonstrate achievement of the relevant ECSA outcomes it was necessary to show successful engagement with the various aspects of problem solving.

Possibility 2: This possibility is similar to the last except that the student has not thought through what was required to demonstrate achievement of the ECSA outcomes. S/he has implicitly assumed that the focus was problem solving and whether or not the project had developed competencies in that area.

Possibility 3: Here the student did not have in mind any notion of developing the kinds of arguments that Possibilities 1 and 2 develop. S/he just presented an unfocused and unstructured narrative of what had happened in a 'show and tell' manner, oblivious to what the assignment required.

Possibility 4: Here the student is guided by some form of 'standard format' for an engineering report such as 'introduction', 'experimental' (describe what you did), 'analysis' (explain significance and problems encountered), 'conclusion'.

Question 5: What kinds of report did the students write?

To address this question, a form of thematic analysis (Cohen, Manion, & Morrison, 2007) of the 58 reports was undertaken. The analysis proceeded by splitting the report being analysed into sections that had the same focus, and labelling each section according to that focus. The labelling was emergent in nature in that as common foci became apparent while reading through the reports they were given the same label. By then examining the set of labels that had emerged from the reports taken as a whole, it was possible to identify the common themes in terms of the most common labels.

Six themes were found. The first was 'addressed the ECSA outcomes' and involved evaluating whether or not the project had addressed ECSA outcomes in some way. As already mentioned, this was evident in only 29 of the reports analysed. The other five themes are listed below in a way that describes a kind of generic format of the reports taken as a whole; the reports were a mix of these themes and few included all of them.

- *Introduction* – usually quite short and often with irrelevancies.
- *About the Stirling engine* – statements that included attention to one or more of the following: how the Stirling engine worked; its advantages; its history; and its potential.
- *What we did* – a description of the various design and construction steps taken. In most cases, this section, along with the next, took up the majority of the report.

- *Problems encountered* – a description, with details, of the challenges, difficulties and problems that had arisen and how these had been addressed.
- *Personal reflection* – a descriptive reflection on one or more of the following: what they had learned; how they had experienced the project; personal growth in awareness and experience brought about by doing the project; and explicit statements of enjoyment and/or satisfaction with their efforts and what they had learned.

As is evident from this ‘generic format’, the tone of the reports was, with very few exceptions, essentially descriptive in nature rather than being reflective or evaluative. The dilemma facing the assessor of these reports is the same as that outlined under Question 4, i.e. to decide which of the four possibilities listed there applied to a particular report. In most cases, it was obvious that the ‘show and tell’ nature described under Possibility 3 applied and the student was marked down accordingly.

Other aspects of the reports

Question 6: What factors, if any, are evident in the reports that might indicate why students had diverged from what had been expected?

The final stage of the analysis was to search through the 58 reports looking for any mitigating factors or any indications of possible reasons why the students had diverged from what had been expected in the reports. The following points emerged.

- *The ECSA language.* In several reports it was clear that the student had not properly understood the meaning and thrust of the ECSA statements. In particular, many were uncertain about the distinction between convergent and divergent problems, and perhaps conceptually unfamiliar with or uncertain about the different stages of problem solving as articulated in the statement – i.e. identify, assess, and formulate.
- *Rushed report.* Some reports were clearly rushed.
- *Report quality.* The structure, coherence, argumentation and focus of many reports was poor suggesting either a rushed report, uncertainty about what was required, poor report preparation or poor communication skills.
- *Default to familiar patterns.* The structure of some reports suggested that some students had defaulted to familiar formatting patterns as was alluded to in Possibility 4 presented earlier.
- *Unfamiliarity with argumentation.* It was evident that many students lacked skill in structuring an argument or even of realizing an argument was required.

Discussion

The analyses just presented provide a variety of perspectives on how students experienced and reported on the project. To draw these towards useful conclusions, we now address the three broad questions proposed earlier – What went right? What went wrong? What should be done in future?

What went right?

From a pedagogical point of view, the design-and-build exercise was a great success. The learning benefits were numerous and addressed relevant ECSA exit-level outcomes. The way that building the Stirling engine enabled some students to have a conceptual breakthrough with regard to how heat can be transformation into work is particularly noteworthy. In addition, the students found the exercise to be valuable and worthwhile and described the experience using words such as “enlightening”, “instructive” and “enjoyable”.

What went wrong?

The most troubling aspects in this project stemmed from the reflective assignment. In this regard, the problem did not appear to derive from the kind of issues reported in the literature such as students having different views of reflection (Moon, 2004, p. 155), or that they generally find reflection difficult so that, without appropriate guidance, their reflective work is likely to be superficial (Gibbs, 1988, p. 51). Essentially, the underlying problem appeared to have been a mismatch of expectations about the nature of the task that was set. Most students perceived that what was needed was a report on the project; the teacher expected an argument to be developed. Most students perceived that marks would be given for effort; the teacher expected to give marks for appropriate responses to the task that was set. Most students thought the focus was on the model; the teacher's focus was on the reflective aspect of the project. Many students thought that a description of what happened was what was required; the teacher expected an evaluation and reflection that addressed a specific question and that the only descriptions of what happened that were appropriate were those that provided evidence for the argument.

These particular mismatches arose because students misunderstood the teacher's expectations. However, there were also mismatches that arose because the teacher misunderstood the nature of the demands that the task placed on the students and of what was required of them to meet those demands. For an academic, a task is defined essentially by a question that needs to be answered. With students, the context, and their experience of it, influence how the task is perceived to a greater extent than is the case with an academic. This is quite evident in the way the students responded to the reflective assignment. The teacher's understanding of what the task required was to develop an argument by (1) clarifying the question (Did the project meet ECSA outcomes?); (2) clarifying what the statement meant (the different aspects of problem solving, i.e. identify, assess etc., and what these mean); (3) searching through the experience of the project for instances relevant to the question; (4) weighing the evidence relevant to the question posed and discussing the findings. Most students have yet to develop robust competency in this kind of argumentation. Therefore, the task demanded of students that they make a number of mental adaptations in addition to the actual development of an argument. They had to rise above their perceptions of what was required, and orientate their minds and efforts to the stages of argumentation just described. It is clear from the project hand-out, that the teacher was not aware of these extra dimensions of what the students had to do; the hand-out provided no guidance in this regard. To be fair, the teacher did address some of these issues verbally in class in the form of reminders and responses to questions raised by the students about difficulties they were having. However, more focused and formal guidance was necessary.

The literature provides some insight into the problem here. Add-on projects, like the one in focus here, have the potential to lead to what some authors refer to as student inability to perform role adjustment in multiplex tasks. For example, Garrison et al. (2004), working in the context of on-line education, state that lecturers need to be aware that students should not be left to their own devices when presented with unfamiliar requirements and that they need to be guided to align themselves appropriately with what these entail.

What should be done in future?

Two levels of recommendations for future implementations of this project emerge from this study. The first is simply to suggest that what went right should be continued while what went wrong should be avoided or minimized. Here the primary focus is on the shortcomings of the previous implementation of the project – i.e. shortcomings in the assessment strategy, in the

structure of the project, and in its implementation. These should be appropriately addressed. For example, the assessment strategy should be re-evaluated with respect to appropriately rewarding marks for effort; the efficacy of limiting the report to one page; the communication of the assessment rubric used; and the weighting of the marks given for the model and for the reflective assignment. With respect to the project structure, more consideration should be given to establishing a sharper understanding of the mismatches in expectations that have been identified, so that appropriate guidance and mediation can be provided to the students. In addition, attention should be given to how the curriculum in earlier years prepares students for reflective and evaluative work. With respect to implementation, the instructions in the project hand-out could be less cryptic; better monitoring and control of group composition and dynamics could be exercised; and, most importantly, better and more appropriate communication with the students should be provided so that they receive the guidance they need to adapt and align themselves effectively to the requirements of the project.

The second level of recommendations that emerges from the study includes many but not all of the recommendations just made. However, it is more forward thinking in nature and focuses on what went right and how this might be enhanced before focusing on what went wrong.

In conversations with the teacher, it became evident that he was very much concerned about the students gaining a better appreciation about what engineering work in the real-world is like, and, in particular, that most of that work is about the ‘pains and gains’ of the struggle towards a successful end-product. It involves iterative cycles of designing and building prototypes that fail or are not adequate, identifying the inadequacies and the reasons for them, and then embarking on another round of designing and building to refine the prototype. Learning from failure, and the mistakes made, is as much a characteristic of engineering work as doing meticulous and accurate engineering calculations and applying theory correctly, if not more so. This was why the project’s rationale focused more on the reflective assignment than on a project report and why the production of a functioning model was far less of consequence than the ‘pains and gains’ of the design-and-build process.

Given this rationale, a reflective assignment was a very appropriate means of assessing what the students had learned, as was the strategy of de-emphasizing the importance of a fully functioning model, and of shifting the focus away from ‘marks-for-effort’. However, implementational shortcomings thwarted the teacher’s intentions, as has already been pointed out. The findings and observations that have emerged from this study suggest that modifications of the following kind be given attention in order to obtain more promising outcomes from future implementations of the project.

- *Communication*: The project hand-out and any verbal pitching of the project to students should communicate the project rationale and should highlight where and how it might differ from the students’ expectations and conceptions of engineering projects.
- *Project Specification*: The focus of the project specification should accurately reflect and align with the project rationale by emphasizing that the primary focus of the design-and-build exercise was the process of building the model (the ‘pains and gains’) and the primary focus of the reflective assignment was the nature of engineering work as illustrated by their experiences in the project.
- *Scaffolding*: Measures should be taken during the project to assist students to align appropriately their focus and perceptions of the task by, for example, a mid-project peer ‘dry-run’ of the reflective assignment followed by a discussion in class on what transpired.

Conclusion

The study presented in this paper was prompted by an intervention that seemed to have ‘gone wrong’ even though the teacher’s intuition and literature indicated it should have led to many learning benefits for the students. The fact that it was a double innovation, though not intended to be, complicated the understanding of what had transpired. What has emerged from this study is very interesting. In the first place, all the learning benefits anticipated from the design-and-build exercise, i.e. the first innovation, were forthcoming; in fact they exceeded expectations. So much so, that it can be concluded from the study findings that no assessment seems to be necessary beyond ensuring that the project work had been undertaken. It is not needed to prove or disprove that students has gained the learning benefits that accrue from this kind of hands-on exercise; they gained these whether or not the assessment indicated so. In addition, it would take a very detailed and time consuming assessment process to determine the extent of the learning and skill development that the doing of the design-build task had engendered.

This observation has the interesting corollary that, because an assessment is not needed to prove that the requisite learning has taken place, an assessment task can be added to the exercise to achieve additional learning benefits. This was not the explicit intention of the project assessment that was set, i.e. the second course innovation (the reflective assignment), but it could have been. What has emerged from the study is not just how and why that assessment ‘went wrong’ and what could be done to ‘fix’ it, but a deeper understanding for the teacher of how that assessment could be used for another purpose, notably, to develop reflective and argumentation skills.

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Insight Quotient (InQ): How to discover what it means to have learned something

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Abstract: In engineering education, students often pass exams without actually learning something. This is evidenced by the fact that when they come back the following semester most of them seem to have “forgotten” the work that was covered in the subjects that they had passed. Further, the examination process can allow students to pass on submissions that have no actual meaning for the students themselves. This two-way arrangement colludes in creating a culture of “passing” rather than learning in many higher education departments. At present we don’t have a way of knowing if each student’s knowledge is embedded in long-term memory and if this information is sufficiently cross linked in a student’s brain to give it significance. This results in students “passing” at lower levels only to find that they don’t have the underlying knowledge for the higher levels, instead of actually learning properly from the beginning. In order to get around this problematic state of affairs a new approach is put forward which is based on the findings of neuroscience. This new approach involves the development of the Insight Quotient (InQ) of students and lectures alike. The purpose of this approach is to bring to conscious awareness what learning actually consists of (as far as this is possible), by eliciting the *subconscious* underlying elements that make up the knowledge of things. In this way both students and lecturers can have a way of determining the presence or absence of learning. Most importantly, by having a means to scrutinise the structure and content of their learning, students can become responsible for the levels of learning they achieve.

Introduction

One of the key difficulties in education is to know whether the student has internalised the knowledge being assessed. Most often students engage in rote learning which just gets then to pass an exam and is of no further use. This type of apparent learning is mostly structured in short term memory, only “loosely” related to deeper brain structures if at all (Doidge 2007, Swaab 2014), and generally disappears after exams are written. In Engineering Education environments where knowledge is developed sequentially from the first year level to the levels above, the internalisation of preceding work is a must for the more advanced material to have a foundation. Given the common Oxford dictionary definition of learning below, we can observe that the words “acquisition of knowledge” is the key term used to define learning, followed by the means of acquisition.

Learning: The acquisition of knowledge or skills through study, experience, or being taught. (Oxford dictionary)

In this paper the term acquisition will be made explicit by reference to findings in neuroscience, in such a way that both the student and the lecturer can be consciously aware of the presence or absence of the long term memory subconscious associations which we refer to as “acquisition of knowledge”. Another factor that must be considered is the plethora of published material on human cognition. This development makes it very difficult to get past all the individual research findings to the point of being able to actually use them in engineering education. To overcome this problem the author has made use of experts, as listed in the references, who have provided overviews of the state of the art in human cognition studies. This gives us the opportunity to use their overview perspective to draw conclusions which find application in the material covered below, which we can use in the classroom.

The background to the Problem

The key term to be clarified is the term “acquisition”. How do we know that knowledge has been acquired? Normally we try to find out what students know by means of examinations, assignments, practical assessments in laboratories, etc. The problem with this approach is that by setting a single question in an exam, which is put to all the students, we have no way of knowing how the question is interpreted by each student’s brain (particularly with second language learners). More importantly we don’t know whether the response is simply short-term memory (rote) based or not (Swaab 2014). This is often the case with many students who may be able to repeat a definition or solve a calculation problem, but they are doing so without being able to explain the meaning of the words of the definition, or by simply memorising the sequence of steps for the problem calculations without actually understanding the significance of all the elements involved (Swaab 2014). One could argue, as most students do, that there is no time, given the density of most engineering curricula, available to understand everything that is covered, but that does not eliminate the problem above. In fact it makes it worse as what we get is the illusion of learning, supported by the illusion of assessment, when we accept rote answers and award “pass” marks for them, particularly for core concepts in the lower levels. It is not suggested that all learning and assessment processes are in vain, far from that. What this paper is saying is that we are not quite sure (in the context of Engineering Education, not science as a whole) how to actually find out if a student’s brain has been sufficiently altered in terms of new synaptic connections, for us to declare that they have in fact learned something (Swaab 2014). This is a very complex problem which has many facets such as psychological, socioeconomic, linguistic, etc., which will not be discussed here at all. However, at the level of brain function it may be a lot simpler to deal with, if only one could access that level.

Problem statement

Having acknowledged that this problem has many facets, here is what will be addressed in this paper: How does each student and the lecturer know if information (this term includes all the learning experiences presented to a student) is embedded in long term memory and is this information sufficiently cross linked in a student’s brain to give it significance (Pinker 1997, Swaab 2014) and depth (Chomsky 1965)?

In order to resolve this problem the difference between subconscious and unconscious

processing will be defined, and an introduction to the method used to access the subconscious representations of experience will be demonstrated in the following section.

Literature Review to establish the Proposed Solution

To address the problem above it is imperative that we clearly define what learning acquisition is, in order to be able to identify if it has happened or not. To come up with a workable definition, I propose we turn to neuroscience. In this context the computational model of the mind arising in a brain is a well-accepted model of how the mind arises and works (Pinker 1997, p. 21). In this model a brain is regarded as a set of operators interacting with a set of information components, Pinker calls them “demons” and “notices” on a board (1997, p. 69). As an example, let us consider how a written word is recognised and then given meaning. In this model, the meaning or significance of words (or any other learning experience) is developed in layers from unconscious processing, to qualia, to words, to sentences, to the experience (as a combination of all the sensory modalities) (Damasio 2010) of actually knowing something. These “notices”, the individual components listed above, are acted upon by various “demons” in order to arrive at some meaning or action, along the different layers of processing in a brain.

Quale ‘kweil’: noun, the internal and subjective component of sense perceptions, arising from stimulation of the senses by phenomena. Qualia: plural (Oxford dictionary)

Layers of processing are activated in a person’s brain when perception and learning take place. According to Pinker (1999, p. 87) in order to identify a word, the shape of the constituents of the letters of the word are recognized first, then the shape of the word itself, then the sound of it, and finally its ultimate meaning by means of very fast parallel cross-referencing in many parts of the brain at once. This type of activity cascades across brain regions through the limbic system and up to the neo cortex mostly unconsciously, then subconsciously, until conscious experience arises. Waves of brain activity access the whole brain as required in order to put together the different components of stored information (such as images, sounds, sensations, etc.), which make up all the associations with that word, within the background context in which it is placed (the sentence etc.) (Damasio 2010, Pinker 1997, Ramachandran & Hirstein 1997). All this is taking place in an individual brain, based on its previously acquired and stored (in long term memory) associations (Pinker 2017, Swaab 2014), along different hierarchies, and structures, which are activated unconsciously and subconsciously to finally create or arrive at the meaning of the particular word or concept. Other writers like Noam Chomsky (1965), a linguist, alluded to this when he distinguished between deep structures and surface structure in linguistic expression. The key difference between short term memory (rote learning) and long term memory (actual learning) as demonstrated by Nobel laureate Eric Kandel (Doidge 2007, p. 218) is this: When information is stored in short term memory neuron synapses in the brain are simply exited, whereas when actual learning or long term memory storage takes place new synapses are formed. The brain changes its structure when learning takes place.

Ramachandran and Hirstein (1997) state that the absence of qualia-rich structures is what they regard as the distinguishing criterion between words repeated without deep meaning (in rote

fashion), and actual knowledge. Words repeated in such a (rote) fashion are by definition **not** associated with deep structure components and therefore are qualia-poor. Learning, which we refer to by the term “acquisition of knowledge”, is associated with qualia-rich, spontaneously arising, cross-linked subconscious experiences, which give meaning to words, associated to long term memory structures (Damasio 2010, Doidge 2007, Pinker 1997, Swaab 2014). Short-term memory, as mentioned above, simply excites the amplitude of synaptic potentials so that when the excitation is lost so is the information, whereas long-term memory involves new synaptic connections so that information is retained and can be reported on. Thus the arising of the experience of qualia as a function of new synaptic connections is another very significant distinguishing factor between proper learning and rote learning.

This then is our criterion of knowledge acquisition: Knowledge acquisition is said to be in place when the structure and content of long-term memory embedded, spontaneously arising qualia-rich representations (in all five modalities such as hearing, seeing, feeling, etc.) (Damasio 2010, Doidge 2007), arising in the minds of students, are compared with the representations in the assessor’s mind (who is the expert in a particular field by virtue of him/her having a rich subconscious store of such representations) and are found to be in accord with another.

In this way (by direct comparison) we can establish whether the students have mentally embedded the new knowledge in long-term memory, at the subconscious level, in such a way as they can use it to make meaningful decisions (Damasio 2010). This approach is quite different from the current method of written exams, where one question is given to all students, and no feedback on the individual interpretation or the presence or absence of complex equivalences is explored for each student, and it is easiest implemented for projects. This does not mean we do away with exams, what this paper proposes is that we should supplement what we already do with this new approach in preparation for exams. Having established a significant difference between knowledge acquisition (as defined above) and rote learning, at the brain level, we will now see how we can identify this sort of difference in an individual student’s mind.

The method(s) used to elicit the presence of the existence of such spontaneously arising, qualia-rich, subconscious structures, is based on techniques from Neuro-Linguistic Programming (NLP) (Bandler 1989), which when applied correctly by a trained lecturer can help a student reveal what he *actually* knows, by means of revealing to the assessor the presence of complex associations (in the form of qualia representations in the five modalities, visual being the most significant), and other long-term memory subconsciously embedded (Bandler 1989; Damasio 2010) references. These NLP questioning techniques make possible the elicitation of the qualia-rich structure and the content (Bandler 1989) of students’ subconscious references of learning, which we established (above) to be the criterion of learning acquisition. A student’s ability to report on their subconscious experience is then defined as their Insight Quotient (InQ).

The Method Used

At this stage we need to establish the meaning of terms like unconscious, subconscious and

conscious experience as used in this paper.

The term “Unconscious” in the context of this paper refers to events of which we have no conscious access to. For instance the neural processing of information between our brain regions right now is and will remain outside our awareness (Damasio 2010, Swaab 2014). Such processing is the foundation on which our conscious experience and ideas are based. This is like saying that an image appearing on a computer screen will never become aware of the individual transistors firing in the central processor which make its very existence possible. This definition is different from the Freudian unconscious.

The term “Subconscious” refers to aspects of mental experience, which can be brought to conscious awareness but are not initially conscious (Swaab 2014). For instance your memories are subconscious until you actually bring them to awareness.

The term “Conscious” refers to the content of one’s awareness at this moment (Damasio 2010). It consists of sensations, thoughts, and feelings which one is fully aware of in what we call this moment. It is the awareness of all conscious experiences, as the brain generates them, while they are processed up through the layers of processing to conscious awareness (Doidge 2007).

Unconscious processes are outside the realm of conscious access (Damasio 2010, p. 151; Swaab 2014, p. 329), so they will be excluded in this discussion. The process of bringing the subconscious representations existing in the brain of a person to conscious awareness will be discussed next. This will be done by illustrating how one can ask questions in such a way as to elicit the structure and the content of the internal subconscious images in a student’s brain. This is achieved by assisting the student to divert their focus from the normal conscious level to the subconscious domain by turning their attention to it. These subconscious images arise in response to properly chosen questions, which direct a student’s attention to subconscious phenomena. In other words, as shown by Bandler (1989) and Lazanas (2012), it is possible to report (provided that the skill of observation and the necessary vocabulary are present) on the subconscious qualia-rich images that give meaning to our experiences and which constitute evidence of learning in the context of this discussion. As the type of questions used are simple, of the kind that require descriptive answers about viewed (or other modality) experiences, students with English as a second language do very well in answering them.

To demonstrate this method, let us consider the following example of a student describing the layout of a Western Cape distribution network that he works with on a daily basis. This is something that he is very well acquainted with, for which he has qualia-rich references as evident in the description below.

Student talking: ...so the bus bars I will be looking at are at Bluedown and at Khayelitsha ... is 132, ... then at Spine, ... so that the 66kv substations around N2, ...

As the student is saying these words the following can be observed:

His gaze is turned out into the distance as if he is looking at a mental picture, and with his right

hand he is making gestures pointing to an imaginary landscape from left to right. His hand pauses to indicate each substation as he mentions the substation names, Bluedown (to his left,) – Khayelitsha (almost in front of him at about chest height) – Spine (to his right and up higher than the other two, presumably because Spine is at a different voltage level).

Please note that the thoughts in terms of words and other experiences, which this student is using in his description, are limited conscious aspects of the much richer subconscious associations to which these words relate. The student at this stage is not consciously aware of the subconscious representations behind his narration. As we observe the student's face, one can actually notice that the student's gaze is diverted. He is not looking at the persons he is talking to but out into the distance as if he is in another, mental, world. This diversion of his gaze takes place in order for him to mentally reference the arising of all the imagery etc. that their brain is accessing with respect to the words he is using (the substations at different voltage levels etc.). All this is taking place without him being aware of this initially as indicated by Bandler (1989), and Damasio (2010). The image of the network has spontaneously appeared in his mental landscape, just outside conscious awareness, and his narration is all about his view of it from the perspective he occupies, but can be brought to consciousness if required (Lazanas 2012). **The first step** of this elicitation process therefore, is to notice when the student starts to access the internal meaning-giving processes as they arise by observing the student's eye movements and other clues (in this case hand movements and eye accessing), in their physiology. Then, instead of allowing him to continue talking, his attention is now guided to report on the mental representations he is seeing.

When questioned about what he is looking at when his gaze is diverted, he replied as follows.

I see Khayelitsha in the middle ... with two transformers ... there is a line coming down from Bluedown .. Bluedown in a bit fuzzy I don't see it so clearly. I don't work with it very often.

Then there is a line to Mpilo ...

Q. Where is Mpilo?

A. Lower down from Khayelitsha ...

Q. Then what?

A. Then there is Spine

Q. Where is that?

A. To the right. Khayelitsha is connected to Spine via Mpilo. Mpilo is down from Khayelitsha and Spine to the left of Mpilo.

Q. What kind of image is it? Is it photos of places, or lines you are seeing?

A. It's a schematic drawing

Q. Is it in colour or black and white?

A. Black and white.

The second step then is for the student to be made aware of, and then find the words to describe the content and structure of the mental processes that have arisen from somewhere in their brain. This level of description may take some time, but it can be as detailed as you wish it to be, as long as the words being explored (in this case his network) have meaning for him, and

the person asking the questions is suitably trained. The student's ability to provide accurate, detailed, qualia-rich feedback on these mental images (sounds, tastes, smells, and other sensations could also be included), constitutes **the last step**. These three steps can be used to elicit the subconscious structure and content of what in this case is the description of a distribution network.

This form of NLP elicitation reveals information, which is consistent with Ramachandran and Hirstein's (1997) qualia criterion and Kandel's criterion of synaptic connectivity (as the two go together) (Damasio 2010, Doidge 2007, Pinker 1997, Swaab 2014), of long term memory embedded information. The presence of long term memory representations in a student's mind can be revealed in this way, and this is the evidence of what was defined above as actual learning. This is because if the arising of internal images etc. does not take place, in response to words used, there is no evidence of such words having been embedded in the long-term memory of the person using them. This means that actual learning has not taken place yet. A typical example of the absence of learning is when you ask a student to explain or describe the meaning of a word like "voltage", and they say "potential difference". But when you ask them to describe what potential difference is, they say voltage, looking at the lecturer to validate their reply as either right or wrong, instead of referencing internal representations of their own. This shows that the words used have not been associated with experiences in long-term memory and are just "floating" sounds in the student's mind. It also shows how terrible a habit they have acquired, which is to look for external validation in order to "pass". On the other hand if you asked them to describe in detail how they got to class they would not hesitate at all, nor look for validation. They would answer with confidence while reviewing the video of their actions as it plays out spontaneously on their mental screen.

The turning point in the whole process is the point when the student recognises the difference between rote and actual learning. In this respect the process of acquiring knowledge is made clear. Then the *context* in which it is to be placed and other uses of the knowledge are introduced in lab sessions etc. The best part of it is that the images, sounds, etc., arise spontaneously when everything is working at it should. The experience of this process is a tremendous boost for the student's self-confidence as they realize, for the first time perhaps, that they can gain control of the learning process. This has been the case with hundreds of students over the past twelve or more years at UJ and CPUT, both for theoretical and project based subjects. The students' ability to consciously recognize and report on subconscious phenomena will be discussed in the next section as the Insight Quotient (InQ).

Insight Quotient (In Q)

A lecturer's efforts, therefore, should be directed at creating elaborate, interconnected, networks of imagery (including the other modalities as well) of the concepts being taught. This responsibility is to be shared by the students who in the process of continuously monitoring the presence or absence of subconscious representations with respect to the topic covered (Damasio 2010; Doidge 2007; Ramachandran & Hirstein 1997) must make sure that they are "learning".

It is this ability of a student, or anyone else for that matter, to consciously access and provide detailed feedback on these mental processes as they arise, just on the edge of conscious awareness, that is now defined as “In-sight Quotient” (InQ). The higher a person’s InQ, the better the person can interact with and report on the content and structure of the representations arising in their brain with respect to learning. As students realize that their subconscious domain can become available for observation, they can become responsible for the quality of their own learning. It is now their task to ask appropriate questions of the lecturer in order to make sure that their inner representations are complex and their learning both deeper and more satisfying (this has been indicated by students in lecturer review forms at UJ and CPUT).

This method of encouraging InQ in students has been applied with the author’s students, and has enabled him to achieve pass rates of over 98 % in second, third, and fourth year electrical engineering projects and theory classes over the last twelve years. This is not to say that this is the only factor contributing to the high throughput rate. However since each student is interviewed individually (for project subjects) and the method of checking for qualia-rich learning evidence is the main method of assessment used (together with written reports), we can infer that the method is reliable and effective. Keeping in mind that if qualia-rich learning evidence is not found to be present a student will not be promoted. Therefore the results of using this approach are very positive since all the students were evaluated this way. The students are afforded numerous assessment opportunities *until* they satisfy this criterion, and they get interviewed over and over until they do. The student feedback has been excellent because they are in control of the assessment process, which depends on satisfying the criterion when they are ready rather than sitting for a fixed duration exam. For these efforts the author has been awarded teaching excellence awards at UJ (2013) and CPUT (2015). Similarly, with research conducted at the Eskom National Control Centre, this approach has revealed significant findings (Lazanas 2012) with Eskom staff that have developed very sophisticated mental structures (revealed by this method) in order to perfect fast, what others call intuitive, decisions. This approach has therefore been validated both in the classroom as well as in industry.

Based on all the above, teaching can be redefined as a process of modifying neurology (i.e. creating long term memory synaptic connections evidenced by qualia-rich descriptions). Lecturers are therefore, according to this definition, neuro-programmers, or as Doidge (2007, p 188) puts it “Neuroplastic surgeons”, not orators who deliver random monologues. They should be seen as responsible for the “code” they instil in their students’ brains using closed-loop feedback by means of a well-developed InQ. On the other hand, together with the lecturer’s efforts, the students’ ability to look “within” and report on the arising of the content and structure of their mental associations, with respect to the topic presented, closes the loop of the learning process. This then is to be verified at the final assessment stage in an appropriate way, perhaps different to the way it’s done at present with written exams, so as to avoid the use of short term memory which is to everyone’s detriment.

The promotion and development of InQ in students and lecturers provides a more substantial solution to the problem of human communication in general as meaning, in terms of its

subconscious references, “resonates” between two individuals. As individuals share the actual underlying components of the words they use (so that eventually both parties see the same images), a better appreciation of the other’s person’s inner world arises as mirror neuron structures are activated (Damasio 2010, Swaab 2014). This in turn contributes to making all parties feel understood and appreciated, which can be a most satisfying experience.

Conclusion

It is the position of this paper, that when the presence of qualia-rich subconscious associations in long term memory is verified, in response to a question, and only then, that we can say that a student has actually learned something. That is because it is the presence of complex subconscious associations, which arise spontaneously in the minds of learners, and are revealed by carefully structured questions that constitute the evidence of actual deep structure learning. This is the type of learning, the evidence of which is made clear to both the student and the lecturer, which can serve as the foundation for further learning development. This is a new approach of establishing the existence of and verifying the “acquisition of knowledge” or learning, in the field of engineering education.

Finally it must be made clear, as was said in the beginning, that this is a very complex problem with many facets, therefore it is not the intention of the author to make light of a difficult problem. The intention is to find a way to approach this problem that subsumes a lot of the complexity. That level is the level of information processing in a student’s brain. Fortunately that dimension has been rendered accessible by the findings of neuroscience. The techniques of elicitation briefly mentioned above require considerable training and practice if they are to be mastered. This is because the required form of questioning is not something that most are familiar with, and it is imperative that the person doing the elicitation has first-hand experience with their own brain before they attempt to work with others.

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Feedback from first-year industrial engineering students: Influences on student retention

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Abstract: Engineering educators are facing increasing challenges relating to a lack of resources whilst under pressure to increase student numbers, and develop and retain students. Internationally and locally, a number of interventions have been suggested to assist students beyond the academic classroom to complete their degrees successfully. Research has indicated that it is important to elicit information from students themselves regarding their perceptions of their needs and progress and that a strategic and integrated approach is followed to develop practices to support students and improve their retention rate. Accordingly, the aim of this research was to determine the aspirations, obstacles, preferred study programme, percentage of first-generation students and the parental employment background of first-year industrial engineering students at a South African university. This research reports on selected results from questionnaires completed by first-year industrial engineering students at a South African university over a period of five years to develop the most appropriate interventions to support the students. It is proposed that this research could be specifically applicable to engineering faculties in South Africa who are concerned with the effective utilisation of scarce resources, increasing student numbers, design of co-curricular interventions as well as the personal and academic growth, development and retention of students.

Key words: *First-year engineering students, retention, development, co-curricular interventions*

Introduction

Student retention and study completion continues to be problematic in higher education systems worldwide (Pocock, 2012). Apart from the loss of income and prospects for individual students and the economic growth of the country, the financial implications for universities are substantial in terms of subsidies and fees (Pocock, 2012). The Engineering Council of South Africa (ECSA) (2011:30) stated that, although it varies across universities, and between engineering departments, the overall throughput and graduation rates in engineering, needed to improve if graduation growth targets were to be met. Moodley and Singh (2015) identify that the ever-increasing number of students who do not complete their university qualifications remains an area of concern for Higher Education Institutions (HEIs), and that many student retention strategies have been developed in response to this situation. Monama (2013) and Smith (2013) found that only five percent of black and coloured students graduated from university, which supports the need for more proactive, strategic, and innovative approaches to address the problem of student retention, especially amongst previously disadvantaged groups.

Du Toit and Roodt (2008) listed several factors that contribute to students completing their engineering studies successfully. These factors include English for Specific or Academic Purposes (ESP and EAP) courses to improve language proficiency, more bursaries being made available for black students, appointment of specialised personnel including psychologists, student supporting and monitoring services, extended curriculum students, inclusion of cultural diversity dynamics in the curriculum and soft skills training such as communication, ethics, presentation and management skills. When resources are not made available to assist students,

it can be disastrous for student retention and satisfaction. Along with providing the necessary financial and physical resources, interventions to retain and facilitate student success must constantly be re-evaluated, designed, and re-designed and research needs to be conducted to establish the impact of interventions as well as student assistance and support systems.

It has also been proposed that a strategic deployment of resources into people, processes and learning spaces are needed to engage with students so that their aspirations, uncertainties, lack of engineering career knowledge and insecurities are recognised and addressed as these factors often contribute to student success and retention (Crosthwaite & Kavanagh, 2012). In addition, it is important to recognise and consider student voices in matters that directly influence their academic success and failure. This need is supported by Killen (1994) who found that the factors perceived to influence academic success and failure were consistently rated differently by academics and students.

The aim of this research was to gain a better understanding of first-year industrial engineering (IE) students, and to develop strategies to improve student development and retention. Even if attrition and success of industrial engineering students are satisfactory, the Department subscribes to a continuous improvement philosophy and therefore endeavours to be cognisant of student issues and to develop interventions and activities to support students. Accordingly, this research reports on selected results, namely, the aspirations, obstacles, preferred study programme, first-generation students (FGS) and familial involvement in the manufacturing or operations industry. Data for this research has been collected over a five-year period, from questionnaires completed by first-year IE students at a South African university.

Influences on retention

Du Toit and Roodt (2008) found that, in general, engineering throughput rates are poor in South African universities. They proposed that possible contributing factors to poor throughput rates could include HEIs not applying entry requirements, learners with poor mathematics and physical science grounding, low language proficiency, insufficient bridging or foundation programmes, large class sizes, staff with inadequate qualifications as well as financial constraints and pressures. Additionally, many psychological factors can predict academic success (Hsieh, Sullivan, Sass & Guerra, 2012) including coping strategies, self-efficacy, personal control, action and achievement. Students enrolled in engineering fields are particularly vulnerable to programme non-completion and could require a high degree of initiation and orientation, persistence and self-monitoring to cope with higher education challenges (Suresh, 2007). Pillay and Ngcobo (2010) found that students experienced several stress factors that influenced retention, including accommodation and financial issues, academic demands and incorrect study choice as information available was often limited when making career choices.

Swail (1995) developed a retention framework based on an extensive review of literature. The retention framework was designed around five components that were further broken down into categories based on specialisation areas and specific objectives. The five framework categories were financial aid, recruitment and admission, academic and student service as well as curriculum and instruction.

Swail's Theory on Retention

Swail (1995) identified financial concerns for students from low-income backgrounds as a make-or-break factor in successfully completing their studies. Further to that, a lack of information for parents and students regarding funding options and mechanisms was another

barrier to student retention. Although some university admission departments incorporate some level of student assessment to verify programme fit, the process could be improved. Swail (1995) proposed that universities should use a number of assessment and evaluation practices to ensure student-institution and student-programme congruence.

Swail (1995) also suggested that orientation was an important part of social and academic student integration on campus. Furthermore, the orientation process should also offer opportunities to families, guardians, and partners, as the university experience is usually an experience for the entire family and not just the university student. According to Swail (1995:26), “the academic services component is the most diversified and expansive component in the framework”. The focus of the academic services component is to provide supplementary support and instruction to students and is divided into six categories, namely, academic advising, supplementary instruction, tutoring and mentoring, research opportunities, precollege programming and bridging programmes.

Swail (1995) also proposed that continued curriculum review, revision, development, and innovative as well as improved pedagogical practice were the most important aspects that universities should address in terms of student retention. In addition, assessment practices needed to be reviewed and this is especially relevant in the South African context as students call for decolonisation of the curriculum and a more humanised pedagogy. As the fifth component or mechanism, Swail (1995) recommended that universities pay special attention to the university environment. This would include campus climate, transport to campus, campus housing, as well as career and personal counselling as these factors could also influence student retention. Finally, Swail (1995) suggested that administrative and academic departments must work together in a campus-wide effort of support to develop and retain students.

As a result, it becomes evident that student retention is a university-wide effort encompassing academic support services, administration, and faculty. In addition, consideration must be given to Killen’s (1994) findings that identified the factors perceived to influence academic success as these were consistently rated differently by academics and students. Therefore, to plan and execute support mechanisms, it would be important to hear and understand student voices and perceptions of factors that affect their retention and academic success. This will require engaging with students and therefore, effort must be made to engage with students to obtain the relevant information and understanding. To this end, IE students have been completing a First-Year Questionnaire (FYQ) at the beginning of the academic year since 2008.

Relevance of first-year student feedback

Yorke and Longden (2004) found that the most common problems faced by most first-year students included flawed decision-making about programme selection, student experiences of the programme and university, failure to cope with the demands of their study programme and events external to the university that impacted on student lives. Tinto (1987) suggested that the first two years of university are crucial to student success and retention, and McInnis (2001) found that the first-year experience is significant in terms of predicting a student’s ongoing success. In addition, the first two years of study are the time when students are most vulnerable in terms of academic failure and the most likely to experience challenges relating to social, emotional and financial issues.

Moodley and Singh (2015) suggested a systemic approach to first-year experience and student success. Such an approach would require an integrated effort of support and engagement of the university, its support, and academic departments, students, high schools and external experts to improve the undergraduate experience.

The aim of the FYQ has always been to gain a greater understanding of the IE students in terms of their background, aspirations, challenges and interests. This paper reports on selected questions and data obtained from the responses to these questions. The questions that are reported on in this paper were selected as they possibly influenced student retention.

Methodology

The FYQ is issued to all first year IE students to complete within the first few weeks of the academic year and was developed to gain a greater understanding of IE students and what can be done on a departmental level to assist students to successfully complete their studies.

Therefore, the aim of this research was to identify possible influences on student retention and, accordingly, this research reports on selected findings and presents data from 2012 to 2016 in response to selected questions (see Table 1).

Table 1. Selected questions and years

Question	Years
What was your first choice of study?	2012-2016
Where do you see yourself in the future?	2012- 2016
What do you see as challenges in being an engineering student?	2015-2016
Has your mother studied for a diploma or degree?	2014-2016
Has your father studied for a diploma or degree?	2014-2016
Does any of your family work in the manufacturing/production environment?	2012-2016

Table 2 illustrates the number of students who completed surveys from 2012 to 2016.

Table 2. Number of respondents per year

Year	Number of 1 st year students	Number of respondents	%
2012	45	45	100
2013	45	39	87
2014	50	44	88
2015	36	25	69
2016	61	52	85
total	237	205	86.5%

It becomes evident from Table 2 that two hundred and five students completed the FYQ over a five-year period. This represents 87% of first year IE students. For this research, the results of the past five years were averaged and is presented in the section below.

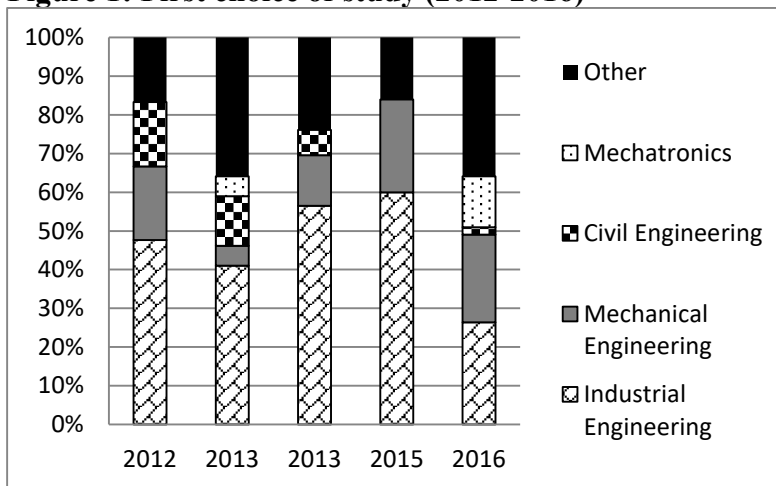
Results

The results of the FYQ is discussed and illustrated below.

Choice of study programme

The average results (2012-2016) showed that forty-six percent of respondents indicated that IE was their first choice of study, while seventeen percent indicated their first choice of study was mechanical engineering and seven percent indicated civil engineering and four percent, mechatronics. Twenty-five percent of the respondents indicated their first choice of study was a completely unrelated degree, for example, pharmacy, and quantity surveying. As a result, it becomes apparent that over a five year period, less than half of the respondents indicated IE as their first choice of study. A graphical representation of the results (2012-2016) is shown below in Figure 1.

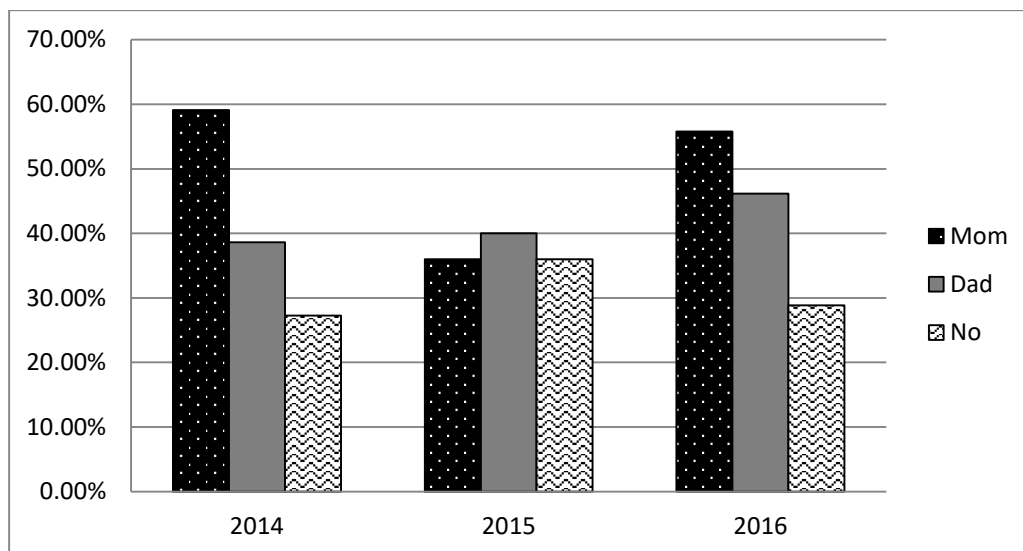
Figure 1: First choice of study (2012-2016)



FGS

The results (average 2014-2016) of this study indicated that fifty percent of the mothers and forty-six percent of the fathers of respondents held university or technikon qualifications and thirty percent of respondents had parents who did not hold any higher education qualifications. Therefore, thirty percent of the students could be regarded as FGS. The results over a three-year period is illustrated below in Figure 2.

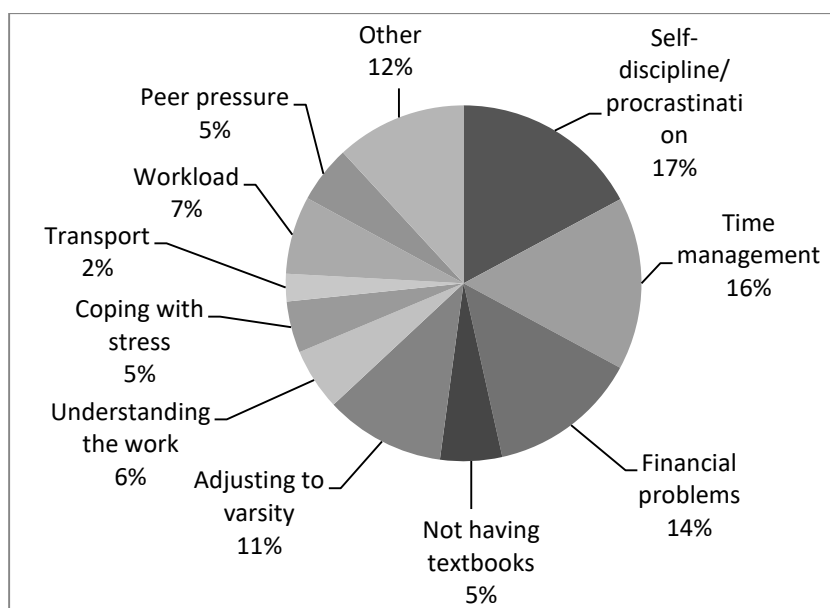
Figure 2: First generation students (2014- 2016)



Perceived challenges

When students were asked what they saw as obstacles or challenges to completing their qualifications successfully, a majority of 54% (average over two years) indicated challenges relating to life skills. For instance, seventeen percent listed self-discipline or procrastination, time management (16%), adjusting to university life (11%), peer pressure and stress (10%) as challenges. Twenty-two percent of respondents listed potential financial issues as challenges; this included a lack of textbooks, transportation costs, and financial problems. Thirteen percent of the respondents listed engineering programme-related concerns or obstacles that could prevent them from completing the industrial engineering programme, such as not coping with the workload. The average results over a two-year period is illustrated below in Figure 3.

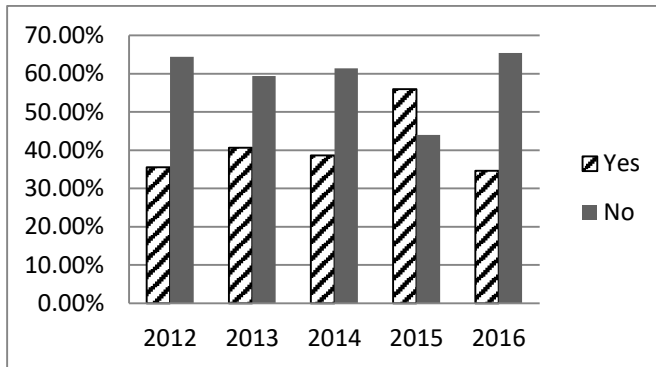
Figure 3: Perceived challenges (2015 -2016)



Family ties

The average results from the FYQ (2012-2016) indicated that thirty-four percent of respondents had family members employed in manufacturing and operations management industries whereas sixty-five percent did not. The results over a five-year period is illustrated below in Figure 4.

Figure 4: Family employment (2012-2016)



Findings and Recommendations

Selected questions from the FYQ focusing on student aspirations, obstacles, course selection, and family background are discussed as this study's findings.

Aspirations and Preferred study programme

Baillie and Fitzgerald (2000) proposed that when graduates move into other fields, some of them might have had the intention of doing so early on in their degrees, thus increasing their demotivation, creating a situation whereby they will do the minimum just to pass and obtain a degree. When asked where they saw themselves in the future, forty-one percent of respondents of this study indicated they would be Industrial Engineers, however, twenty-one percent wanted to be self-employed. The aspiration of being self-employed could possibly present a threat to the IE industry as it could negatively influence the retention of practising engineers, it does however indicate positive entrepreneurship ambitions.

Interest, along with cultural factors can also play a role in selecting engineering as a career choice (Carrico, Paretti & Boynton, 2014). Therefore, it is very important for potential students to learn about engineering from an early age, not only to evoke an interest, but also to equip them to make informed career choices. Swail's (1995) suggestion of providing a number of assessments and evaluation practises could be applied to ensure students select the course of study that is right for them.

Du Toit and Roodt (2008) found that engineering is often a study field influenced by family as opposed to an exclusive individual choice. Alpay, Ahearn, Graham and Bull (2008) found that the majority of students who took part in their study cited their parents as the most consistent influence on their decision to study engineering. Schools or a teacher was identified as the second most common reason for studying engineering. In addition, more than fifty percent of students had a parent with an engineering, science or mathematics background.

Less than half of the respondents taking part in this study indicated IE as their first choice of study. Such a situation could lead to demotivated and negative students resulting in a low retention of students, thus making the case for better marketing and promotion of industrial

engineering as a field of study and career choice. In addition, Swail's (1995) proposal of more effective academic services to include academic advising, pre-university programming and bridging courses should be considered. Furthermore, application assessments and evaluation should be included to ensure the correct individual study choice. It would also be very important to market and explain engineering career choices to not only high school, but also primary school learners to ensure an understanding of career field from an early age on. Currently, one of the initiatives being developed at the University is an on-line tool (Drive to Success) in the form of a game that would indicate a potential students' most preferred field of engineering study. The game will also include video clips showing the different engineering stream and in addition to details on the various engineering jobs.

Obstacles

Educational persistence is a complex mix of interactions among personal, institutional, and external factors and the match between the student and the university is particularly important (Rintala, Andersson & Kairamo, 2011). Baillie and Fitzgerald (2000) found that students often feel isolated when they have trouble in adapting from a small friendly school to the larger more impersonal university environment. In addition, they can feel out of their depth and experience feelings of failure, as they might not be top of the university class. These factors can lead to low motivation and often result in students dropping out. In their study, Baillie and Fitzgerald (2000) found that students expected their engineering courses to be more practical and less theoretical, with a workload higher than expected in addition to a higher level of maths and more pressure than expected. It would, therefore be important to manage student expectations and ensure the correct information is conveyed during marketing campaigns and orientation.

Rintala, *et al.* (2011) suggested that institutions need to take proactive steps to build student relations, ensuring an effective system of identifying at-risk students. The Department of Industrial Engineering has over time developed an "early identification system" that indicates to students if they are at risk. In addition, all first years students attend a compulsory mentorship programme during the first year of study. The mentorship programme focuses on developmental and academic issues. Academic staff in department are encouraged to become involved in the mentorship programme and work closely with university professional support services. A recommendation for the IE Department is from Baillie and Fitzgerald, (2000:152) who suggested training courses for staff to help them identify signs that students are experiencing problems as students need more support from tutors and academics, there is also a need "to simply talk more to students" about their academic experiences.

The financing of university costs is arguably one of the most important and costly endeavours a family may take, and financial aid staff must be cognizant of the burden these decisions place on families and provide support for them during the decision-making process. Additionally, families need information early so that they can be informed to plan and budget for university expenses. Information sharing could also be achieved if universities work with school systems to develop financial aid information sessions (Swail, 1995).

First Generation Students (FGS)

Universities, with their unique language, customs, rules, and history can be difficult for FGS and their parents to understand and therefore they often lack resources when compared to non-FGS, often experiencing difficulty regarding professional, financial, psychological and academics issues (Banks-Santilly, 2015). Furthermore, FGS will often apply to the nearest and most conveniently located university, and are often unsure how to determine a good fit, be that for the university or the course selection. Banks-Santilly (2015) also found that FGS are often

reluctant to seek assistance as there is a stigma attached to being a FGS. As a result, they often prefer to remain invisible, as they fear being underestimated and judged by others. Low-income FGS may arrive at university with fewer resources and more academic needs, which could make them targets for discrimination. There are, however, also FGS that view their status as a strength and motivator to complete their studies successfully (Banks-Santilly, 2015).

FGS face many unique challenges that can include a lack of knowledge of expectations, behaviour, and jargon associated with higher education (Parks, n.d.). For instance, non-FGS can ask their parents to assist them with writing a paper or an essay, advice about a citation method or explain certain university-related terminology and customs. It thus becomes evident that FGS need special attention and support to make them feel part of the university, as they need to feel they belong and deserve to be there. Often they also require professional mentoring especially since their parents often lack professional networks. Other suggestions to facilitate the climatisation of FGS can be to use First Generation faculty members as advisors and mentors and to create a dedicated web page for FGS and their families to share information and success stories (Banks-Santilly, 2015). Banks-Santilly (2015) summarises this by stating, “with the right support from institution of higher education, first generation students can earn a degree, reinvent themselves and reposition their families in positive ways for generations to come”. Furthermore, Swail (1995) recommends comprehensive academic services and orientation programmes for students and their families to integrate them more successfully into university life as this can contribute to student retention. At the university where this study is based, all students are invited to attend a first year orientation programme and as previously mentioned, the engineering school also offers a compulsory first year mentorship programme. The School of engineering also offers support for female engineering students by inviting participation in the Women in Engineering Leadership Association (WELA). Towards the end of the second academic year, a Workplace Orientation Workshop is offered to prepare students for entering the workplace in their experiential training year. It is however recommended that more attention is paid to the challenges that FGS students experience.

Familial involvement in the manufacturing or operations industry

If parents had no knowledge of the manufacturing industry, it could disadvantage students. However, the potential also exists for recruiting students who do not come from an engineering household and thus both parents and potential students need to be educated on the nature of engineering and the future prospects of students studying engineering (Alpay *et al.*, 2008). The department of industrial engineering is currently experimenting with social media marketing in an effort to reach and educate a wider and more diverse market about the industrial engineering department and the services and programmes offered. The FYQ has also been helpful in indicating feeder schools, which has led to increased marketing efforts to those schools. Engineering departments could also consider Swail’s (1995) recommendation to review the curriculum continually and to assist those unfamiliar with the manufacturing and engineering industry by creating more practical, hands-on engineering experiences. To familiarise students with the manufacturing industry, the department endeavours to organise factory visits for students in addition to issuing practical industrial engineering related projects that must be completed in industry. Furthermore, the department of industrial engineering boasts a simulated working environment that allows for simulated industrial engineering tasks and experiences.

Below is a summary of the six potential challenges identified and the possible solutions

Factors	Possible solutions
Engineering study choice and career knowledge	Drive to Success, closer relationships with primary and high school teachers, more information sessions and open days, social media marketing, entry assessments
Life Skills	Mentorship and life skills developmental workshops, orientation programme, early identification programmes, talk to students, financial education and budgeting for parents and guardians, WELA
Familial influence	Educate parents, guardian and potential students: social media marketing, open days, school visits
Student and university match	Careful university and study programme selection (provide education), WELA, social media marketing
FGS	Use staff as mentors who were also FGS, mentorship and orientation, also for parents and guardians, WELA
Knowledge of Industry	Factory visits, experiential projects, social media marketing, SWEAT lab, renewal of curriculum

Conclusion and recommendations

In an effort to develop and retain industrial engineering students, an orientation programme is offered to all first year engineering students in addition to a compulsory first year mentorship programme and female engineering students are encouraged to join WELA. Industrial Engineering students are warned when they are at risk and students are take part in factory visits and are required to execute some of their projects practically in industry. All industrial engineering students are regularly exposed to a simulated working environment and it is anticipated that the Drive to Success on line interactive game will be launched later in 2017. It has not been proved statistically that these interventions and activities have improved development and retention as many and varied factors can influence student success and retention. However, research indicates that interventions and activities such as those mentioned should have a positive effect on students and the department will endeavour to continuously develop new and improve on current endeavours. The department will pay special attention to FGS and make effort to “simply talk more” to students.

When considering these findings, it becomes evident that it is critical for faculties to know and understand their students as this knowledge can contribute to students’ university experience, success, personal development and the retention of engineering students. It is thus recommended that staff and students engage so that faculty can be aware of student experiences to respond to them effectively. It is recommended that resources are deployed strategically to assist students by means of workshops and co-curricular interventions to create spaces for learning and development. Parents and guardians should be involved, along with students to undergo orientation and information sharing to integrate them into university life successfully. Faculties also need to pay special attention to FGS and develop integration strategies to assist them. Furthermore, staff need to be trained and made aware of the problems and obstacles that students, in particular, FGS face so that they can be advised on how to understand and support

students. Additional aspects that need to be addressed are student aspirations, engineering career knowledge, life skills, self-efficacy, and mentorship.

Future research will include in-depth interviews and questions specially relating to retention issues. In addition, students who have left the university without completing their studies would need to be interviewed to establish the reasons therefore and possible solutions.

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Lesson learned from exposing computer systems engineering students to entrepreneurship and innovation activities

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This paper reports on lessons learned (from 2013 to 2016) on implementing entrepreneurial and innovation activities. Using action research and lesson learned techniques, Bachelor of Technology: Computer Systems Engineering students, were tasked to group themselves and use their knowledge to explore ideas and suggest solutions that could address societal challenges. Their ideas were assessed through interactions with the lecturer. It is this paper's recommendation that concepts of entrepreneurship and innovation should be embedded to existing curriculum as part of students training especially on project or assignment tasks. The results of this paper contributes to the ongoing discussion of bridging the entrepreneurial and innovation chasm (using the existing engineering curriculum).

Introduction

To deliver a 21st century curriculum in an engineering class, academics need to be innovative and have intentions of improving students' lives beyond the classroom. For example, they should prepare the students to be aware of any entrepreneurial and innovative ideas that they could exploit into new ventures.

Rabbitt and Hughes (2013) advise that the 21st century engineering curriculum should focus on communication, creativity, problem-solving, teamwork, and technology. However, entrepreneurship and innovation should not be disjoint from the 21st century engineering curriculum because it is an out-of-the-box strategy that could make students relevant and ready as agents-of-change.

Academics and students should realise that every lecture scenario is different and unique in its own right, allowing academics to be intentional on the type of graduates they intend to produce, preparing them for being agents of change that will address potential challenges, now and in the near-future.

Against this background, this paper uses action research and lesson learned from the curriculum offerings of the Bachelor of Technology (BTech): Computer System Engineering (CSE) at Tshwane University of Technology (TUT). It contributes to the ongoing discussion of bridging the entrepreneurial and innovation chasm by viewing students as entrepreneurship and innovation actors. It reports on lessons learned (from 2013 to 2016) from modifying CSE curriculum to include entrepreneurship and innovation activities as part of student training.

The rest of this paper, briefly states the study's aim and research question; briefly discusses the concepts of action research and lesson learned; discusses how the research was conducted and data collected using principles of action research and lesson learned methods; discusses the introduction of Ideation model and University-Sponsored Student Business Venture (USSBV) process model to students. It concludes by providing recommendations and future studies.

Study Aim and Research Question

Moore (1991; 1999) defined the concept of innovation chasm as the inability of academic outputs to reach the market as products and/or services. Bridging the innovation chasm requires different solutions, one of which is to view and train students as entrepreneurial and innovation actors capable of contributing outputs with a probability of minimising the chasm.

To achieve the latter, this paper attempted to answer the following research question: *“how can entrepreneurship and innovation concepts be taught to CSE students without affecting their current curriculum but aimed at improving their educational, social and economic outcomes”*? To answer this question, this paper reports on the study aimed at implementing a teaching and learning strategy that expose students to the concepts of entrepreneurship and innovation.

Action Research

Action research helps academics and students to be more effective in creating new options or approaches to old and new problems (Coats, 2005). The primary reason for implementing action research is to assist the academics to improve and/or refine the actions of teaching and learning (Sagor, 2000).

In this paper, three definitions made sense, Action research is a (i) disciplined process of inquiry conducted by and for those taking the action (Sagor, 2000); (ii) method of finding out what works best in the classroom by implementing strategies that improve teaching and learning (Mettetal, 2012); and (iii) reflective process of progressive problem solving that integrates research, action, and analysis (O'Byrne, 2016).

Action research is a natural process that comes in many forms and has been developed for different applications (Tripp, 2005). Literature identify various action research processes with mutual elements comprising of at least four to seven different steps aimed at improving or bringing a change into an identified focus area or practise (Whitehead, 1999; Sagor, 2000; Mettetal, 2012; Tripp, 2005; O'Byrne, 2016). In the positivist approach to research, action research is seen as being unscientific leading to some questions being asked about the relevance of its findings beyond the immediate research setting (Rose, Spinks, & Canhoto, 2015).

Lesson Learned

There exist several definitions of lessons learned (Milton, 2010; Kitimbo, 2015). In this study, two definitions made sense, Lesson learned is: (i) the learning gained from the process of performing the project (Project Management Institute, 2013); and (ii) knowledge or understanding gained by experience (Milton, 2010).

Literature identify various lesson learned processes with mutual elements, comprising of at least four to five different steps used to collect and observe lesson learned (Weber, Aha & Becerra-Fernandez, 2000; Milton, 2010; Kovach, Cudney & Elrod, 2011; White & Cohan, 2016).

There exists a mutual relationship between action research and lesson learned, and both are implemented through processes. Action research is conducted with an aim of improving practice, this generates lesson/s and new knowledge from which one could learn and disseminate.

Methodology

How was the study conducted?

The following steps, summarised as an iterative and cyclic framework - Observe/Plan, Design, Act and Share (OPDAS) (see Figure 1), were used to guide this paper throughout the years (2013 to 2016): (i) identification of a focus area or problem statement; (ii) conduct some form of data/information/knowledge collection and review; (iii) take an action of analysis/implementation/evaluation; (iv) reflect on findings, then communicate the findings with the action research participants and other stakeholders; and (v) repeat step (i) to (iv) until satisfaction. The latter steps, resulted from a combination and analysis of both the steps of action research and lesson learned.

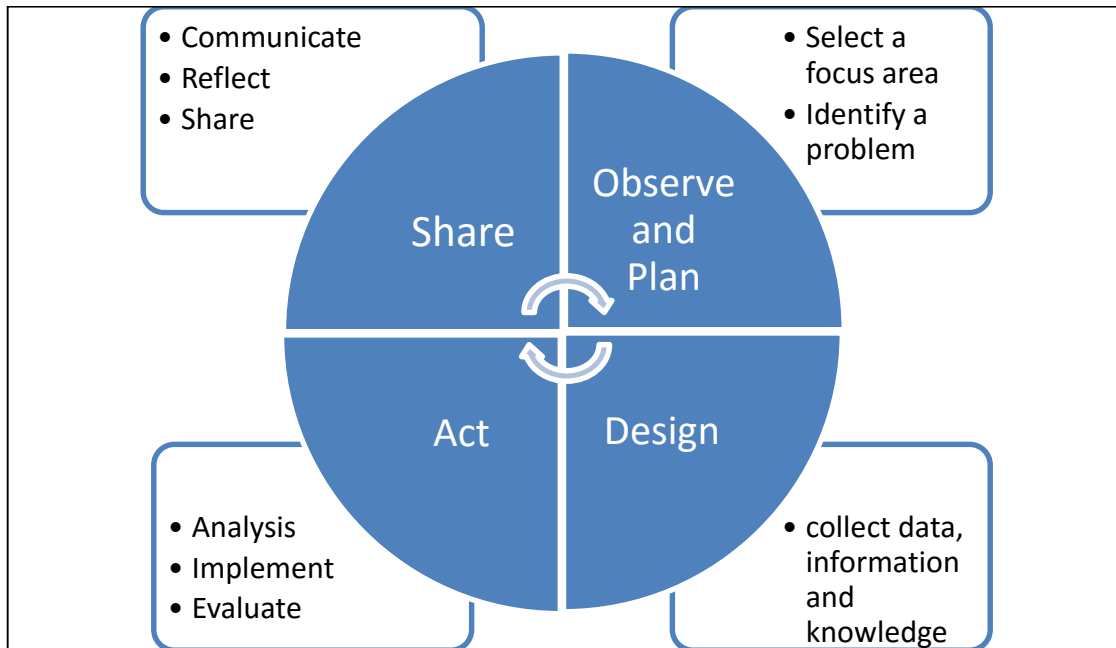


Figure 1. The iterative and cyclic OPDAS steps for conducting action research and lesson learned (Source: Authors adaptation).

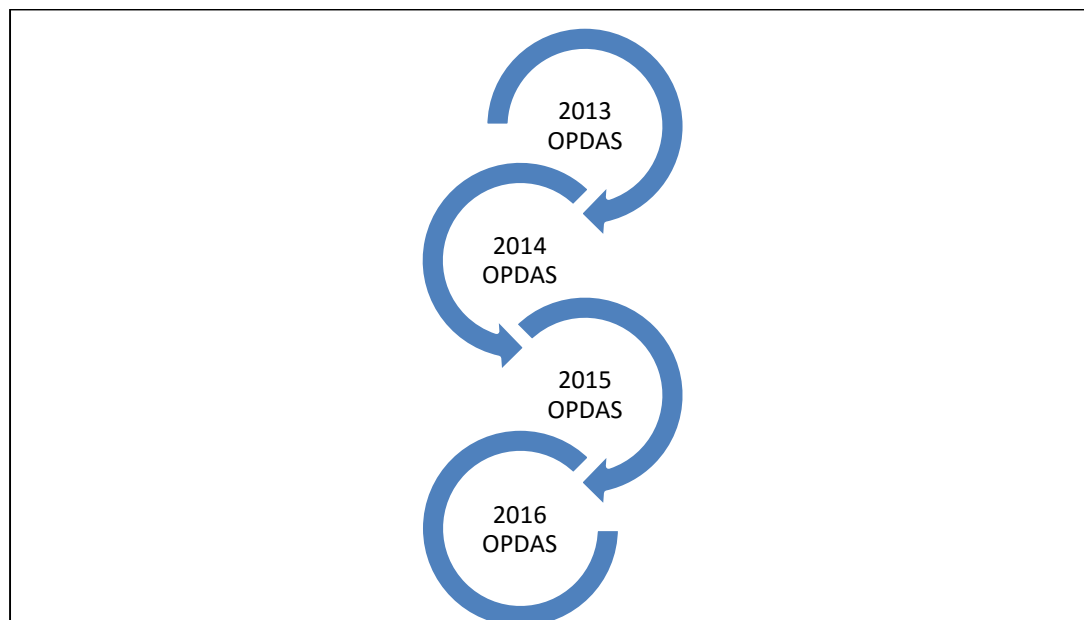


Figure 2. The OPDAS circle (Source: Authors adaptation).

Who were the study participants?

This paper is an extract of the doctoral study which obtained ethical clearance from the TUT ethical research committee. From 2013 to 2016, a total of 159 students registered for a second semester module, Network Systems IV (NSY401T), offered to the BTech: CSE degree students at TUT were sampled. The NSY401T module trained students on wireless and mobile communication theories, principles and techniques; and it was assessed through tests, oral/written assignments and a written examination.

As summarised in Table 1, of the 159 participants 100 were from the 20 to 25-year age group, and 59 were from the 26 years and above age group. Majority of participants 88 (55%) were male and 71 (45%) were female students.

Table 1. The age and gender distribution of respondents.

Age	Gender	No. of Years			
		2013	2014	2015	2016
20 to 25	Male	15	12	11	15
	Female	13	11	8	15
26 and above	Male	9	10	6	10
	Female	8	6	5	5

How was the data collected?

Mix-method (qualitative and quantitative) were used to collect data, see Figure 3.

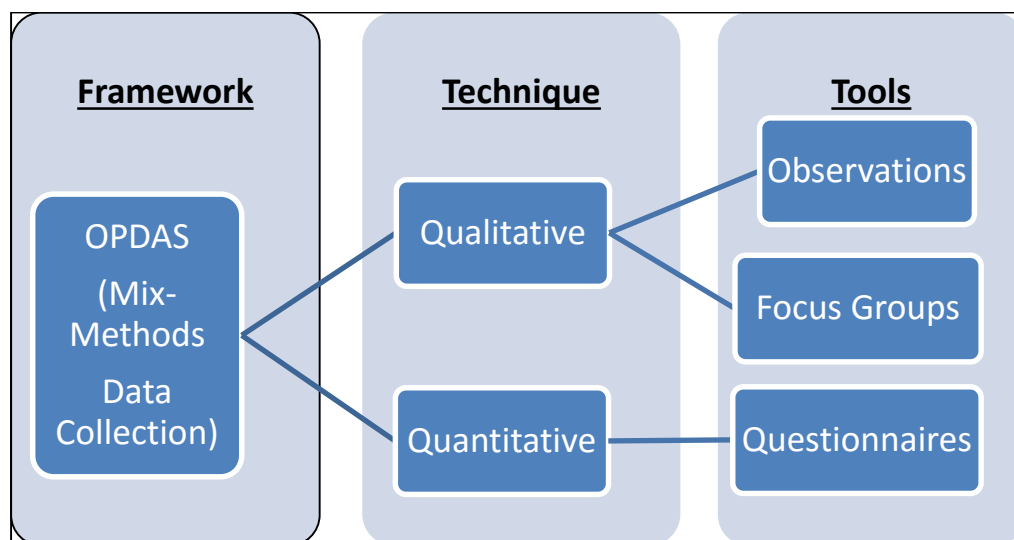


Figure 3. The OPDAS mix-method data collection techniques (Source: Authors' adaptation).

Qualitative data collection

Observations:

Observation is described by Merriam-Webster dictionary as the action or process of closely watching something or someone. As a research procedure for producing evidence, observation study uses field notes to record the behaviors, activities, events, and other features (Schwandt, 2015). In this paper, observations (some which were recorded using field notes) were used to observe students conducting an entrepreneurship and innovation activity.

Focus Group:

A random selection was used to divide students. Students were provided with a choice of a number from 1 to 5, and all those who selected a number 1 were grouped together and depending on the number of registered students, between four-to-five groups comprising of at least five members per group per year were formed.

Quantitative data collection

Questionnaires:

Throughout the years (2013 to 2016), the dichotomous type of questions that ask for a Yes/No or Agree/Disagree were used to measure different aspects of the paper.

Results

The OPDAS processes (see Figure 1 and 2) were used to formulate an answer to the following research question: *“how can entrepreneurship and innovation concepts be taught to CSE students without affecting their current curriculum”?*

The 2013 OPDAS process

Step 1: Identification of a focus area or problem statement

The worldwide financial crisis had worsened the levels of unemployment. In 2012 and 2013, different reports about the level of unemployment faced by the South African youth were communicated. For example, Statistics South Africa reported that the youth (15 to 24 years) unemployment rate increased from 32.7% to 35.8% in 2008 and 2012, respectively.

Lesson Learned:

Observing and analysing the reports showed that youth unemployment is also an international challenge which would need to be addressed using different models or solutions. One such solution would be to focus on developing new student business ventures aimed at addressing academia, government, society and industry challenges needed to be considered.

This led to the following research question: *“how can entrepreneurship and innovation concepts (aimed at improving students educational, social and economic outcomes) be taught to CSE student”?* The purpose was to foster a culture and possibilities of self-employment among students that could be achieved through the implementation of new evidence based models and strategies.

Step 2: Conduct some form of data/information/knowledge collection and review

To answer the research question in step 1, literature review (*on engineering teaching practice and curriculum vice-versa skills need for addressing the 21st century challenges*) and class group discussions (*with 45 NSY401T students, who were requested to form five groups*) were conducted. The discussions were driven by the following five questions: (i) what were the challenges of the 21st century? (ii) what did students think the career in engineering involves? (iii) what were their attitudes and interest towards engineering entrepreneurship and innovation? (iv) what was their motivation as they engage in their entrepreneurship and innovation assignment activity? and (v) thereafter, will they be keen to become entrepreneur/innovation actors.

Lesson Learned:

On engineering teaching practice and curriculum vice-versa skills need for addressing the 21st century challenges, literature revealed that beyond the technical skills, managerial skills, people skills, communication skills, decision making skills, team skills and project management skills, future engineers would need entrepreneurship and the innovation skills (Apelian, 2007; Tayal, 2013; Mohd-Yusof, Helmi, Phang, and Mohammad, 2015).

The entrepreneurship and innovation was identified as the central theme of the 21st century engineering curriculum as it would foster imagination and creativity. It was recognised as the key driver of economic growth, success and survival (Millic, 2013; Kritikos, 2014). Universities were advised to involve entrepreneurship and innovation in their curriculum with an aim of exploiting new or existing knowledge and ideas to achieve an establishment of new ventures (Etzkowitz, 2002; Rasmussen and Sørheim, 2006; Elpida, Galanakis, Bakouros and Platias, 2010; Hoskisson, Covin, Volberda and Johnson, 2011; Bailetti, 2011; Åstebro, Bazzazian and Braguinsky, 2011; Nakkazi, 2012; Amit and Zolt, 2012).

The general observations captured in the field notes (Annexure 1) showed that students had misconceptions about what a career in engineering would actually involve. They linked it to salary and status benefits. They appreciated the technical skills that it develops, but often underestimated the amount of other skills needed to execute its tasks. and negotiation skills. They also appreciated the fact that it allows them to be imaginative and innovative.

Step 3: Take an action of analysis/implementation/evaluation

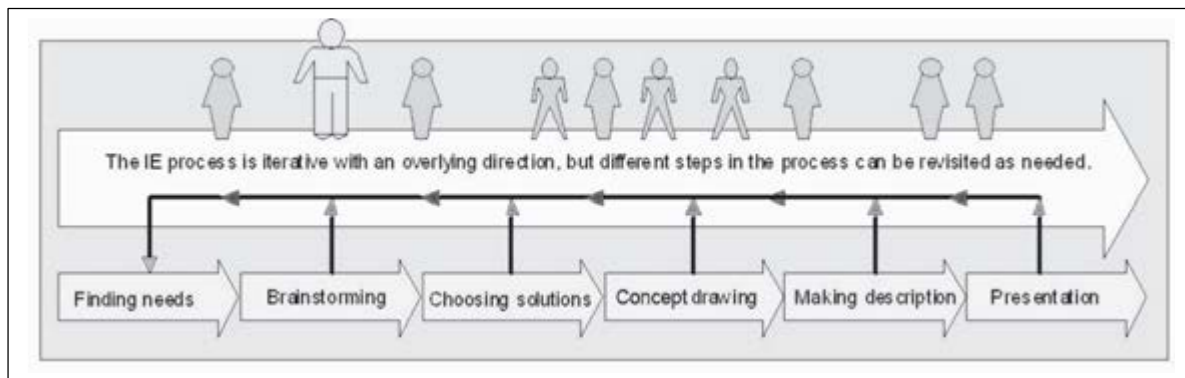


Figure 4. The Ideation within the IE process (Source: Thorsteinsson and Page, 2008).

To take an action on the findings suggested by step 2 and there advise of re-examining how students are taught the fundamentals of engineering science for being relevant in the 21st century (Apelian, 2007); a compulsory assignment section of the existing NSY401T curriculum was modified to include the entrepreneurship and innovation activity.

Students were introduced to the concepts of Innovation Education (IE) known as Ideation (see Figure 4) which involves searching for needs and problems in the student's environment and finding appropriate solutions or applying and developing known solutions. Ideation is an interactive process seeking to determine feasible ideas that could be exploited for establishing business enterprises.

Students were requested to conduct four tasks of the Ideation process as their entrepreneurship and innovation activity: (i) finding the needs, (ii) brainstorming, (iii) finding the initial concept, and (iv) make a presentation. Towards the end-of-the semester

students made oral presentations of their ideas. To protect students' intellectual property (IP), students presented their ideas at the lecturer's office. Five points were used to assess students: (A). Problem Identification (PI); (B). Information/Knowledge on PI; (C). At least five proposed ideas on solving the PI and choice of one feasible with a motivation; (D). Creativity and Innovativeness of possible ideas; and (E). Argument on presenting the assignment.

Lesson Learned:

The groups scored 55% on average for PI, 59% for information/knowledge, 60% for ideas and motivation of their ideas, 70% creativity and innovativeness of possible ideas, and 60% for their argument on presenting the assignment.

Although students' participation on this entrepreneurial and innovation activity was impressive, some students were only motivated to tackle their different tasks because of the need to pass their assignment not because they would like to be entrepreneur/innovation actors. Some ideas were observed to be direct representation of students' theoretical content of NSY401T. Therefore, there was a need for motivating students to think beyond the course content but to use it as a platform for creativity.

Step 4: Reflect on findings, then communicate the findings

In general, wireless and mobile networking ideas that could solve societal challenges were brought forward and reported by five different groups. Some students felt that they needed more time to execute their assignment. Most students did not have thoughts of exploiting their ideas into prototypes/products/services.

A general assessment and the above mentioned reflections were communicated with the students and also taking into consideration the lesson learned, plans for improving the assignment task were put into place. This provided a direction for the next OPDAS process which took place in the second semester of 2014 with a group of new students.

The 2014 OPDAS process

Step 1: Identification of a focus area or problem statement

The focus area was identified in 2013 and was introduced to 39 new NSY401T students in 2014. The students were requested to form five groups. An explanation of the assignment's expectation was provided to students with an introduction of a different slant.

In 2014, students were encouraged to identify, select ideas and an entrepreneurship and innovation solution that could be used to address challenges in three boundary areas: energy, agriculture and manufacturing.

Lesson Learned:

Kamel and James (2011) through a bibliometric analysis study identified 12 areas in which South Africa had strength as compared to other developing countries. Therefore, the boundary areas were selected from such a list since those areas had direct effect on students' socio-economic status.

Step 2: Conduct some form of data/information/knowledge collection and review

As a way of grounding the three boundary areas, dichotomous questions were used to facilitated a discussion on their appropriateness and response recorded in Table 2.

Table 2. Responses of the effectiveness on boundary areas.

Questions	Yes	No
Were the boundary areas adequate	62%	38%
Could wireless and mobile technology be applied in those areas	95%	5%

Lesson Learned:

During the discussion on the appropriateness of the boundary areas, the following was observed:

Boundaries and lack of exposure in the selected areas would limit students' innovativeness and flow of ideas.

Those respondents who disagreed, argued that their exposure in the boundary areas is limited. However, other students provided them with different examples (like purchasing an electricity using a mobile phones) which help them with awareness.

Step 3: Take an action of analysis/implementation/evaluation

In 2014, students conducted the same Ideation tasks as in 2013, except that all six tasks were executed (see Figure 4). The same five points as in 2013 were used to assess students: (A). Problem Identification (PI); (B). Information/Knowledge on PI; (C). At least five proposed ideas on solving the PI and choice of one feasible with a motivation; (D). Creativity and Innovativeness of possible ideas; and (E). Argument on presenting the assignment.

Lesson Learned:

The groups scored 62% on average for PI, 67% for information/knowledge, 70% for ideas and motivation of their ideas, 78% creativity and innovativeness of possible ideas, and 69% for their argument on presenting the assignment. Almost the same reasons as in 2013 were highlighted.

Step 4: Reflect on findings, then communicate the findings

In 2014, one group of students reported that they inquired from nannies on what challenges they face when taking care of the babies. A lot of challenges were raised; however, the group selected a challenge in which they planned to use Wireless Sensor and Bluetooth technology to measure the level of wetness on babies' bum. These students were assisted in developing technical drawings and were advised to consult the TUT's Research and Innovation (R&I) unit for further development. However, the students failed to consult the R&I unit and scattered after completing their module.

It was observed that students might have used the 2013 assessment yardstick to evaluate their assignments, while a different slant was introduced to them. They were supposed to expect new assessment method.

Very few students had put an emphasis on developing clear technical drawings or modelling of their ideas and those did were advised interact with TUT R&I unit. However, the failed to consult with the R&I unit. This created a need to improve interaction between students and the R&I unit.

The 2015 OPDAS process

Step 1: Identification of a focus area or problem statement

The focus area was identified in 2013 and was introduced to 30 new NSY401T students in 2015. The students were requested to form five groups.

In 2015, a new model, University Sponsored Students Business Venture (USSBV) was introduced to the students and they were encouraged to use it to identify societal/economic challenges, propose possible entrepreneurship and innovation ideas as solutions, select their best feasible solutions, present it, and do more business document and market research (in consultation with the intended target market).

The USSBV process model (sequential view in Figure 5) is generally a hybrid and agile new venture creation model which comprise of four stages: (i) idea generation, (ii) agreement, (iii) business research and development, and (iv) venture creation.

The first stage of the USSBV process model is known as *Ideation Stage* similar to that identified in Figure 4, the USSBV's ideation stage allows students to source ideas from their intuitiveness projects, IP search, brainstorming or competitions, students' environment and knowledge holders such as community or knowledge holders. It allows students to sift the ideas and determine the feasible one that would address the highlighted challenge.

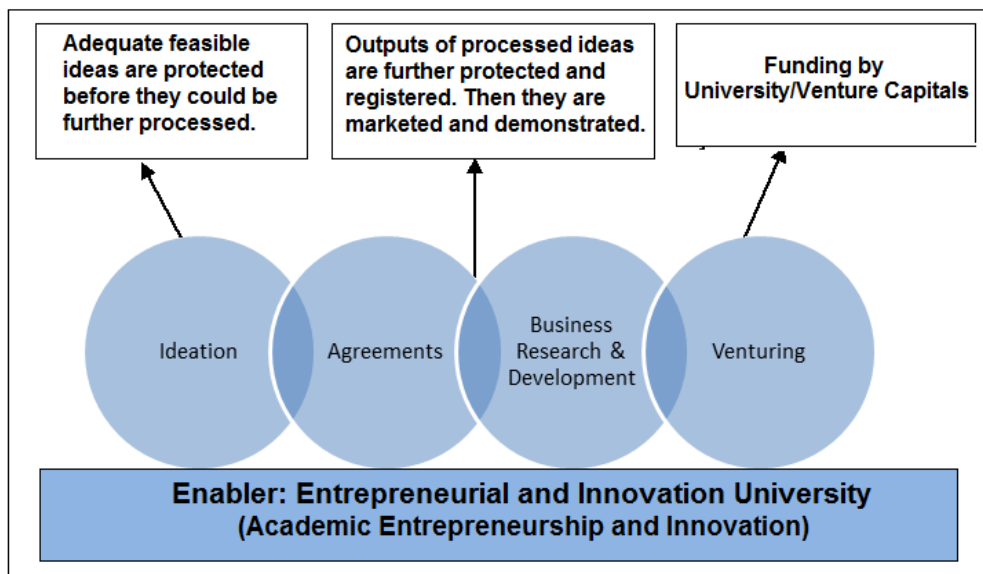


Figure 5. The sequential view of the USSBV process model (Source: Authors' Adaptation).

The Ideation stage is followed by an *Agreements or Intellectual Property Rights (IPR) Stage* which involves patent registration, the signing of agreements of understanding and agreements of exploiting the ideas. In this context, it included simulating agreements that students would sign with individuals from whom they source their ideas.

Depending on the purpose of an idea and the agreements that were signed, in the *Business Research and Development Stage*, an idea is either developed as a prototype or product or service; then under the auspices of the university preliminary marketed/demonstrated to the target market.

The business research and development stage is followed by the *Venturing Stage* in which the university, venture capital, and community help the students to strategically form and register an organisation that will be used to commercialise the prototype/product/service. In a training context this task could be simulated.

Lesson Learned:

After introducing students to the USSBV process model and briefing them on the expected outputs of the assignments, on their own students saw it fit to simulate their groups as dummy companies and appointed group leaders as managing directors (MDs). In this regard, over and above oral presentations students requested to submit their reports using a business plan format to show how they could develop their ideas into business.

Step 2: Conduct some form of data/information/knowledge collection and review

Students were requested to submit projected project plans and questions that they would use to source challenges and ideas from community members to accumulate grades for the ideation stage. The plans and questions were assessed for workability, reliability and ethical issues.

Lesson Learned:

A dichotomous question (Table 3) that ask for a Yes/No was used to gauge students basic understanding of project management concepts. The results showed that about 67% of students understood project management concepts. In this regard, Portny (2014) was used to train and bring students understand at the same level. Thereafter, the students revised the plans and the level of their workability, reliability and ethics improved.

Table 3. Responses on the understanding of project management.

PM understanding	YES	NO
Project scheduling	7	4
Milestones	3	5
Critical path methods	5	1
Project evaluation and review technique (PERT)	5	0
	67%	33%

To address the 2013 and 2014 issues regarding time for executing their assignment, students' frequent discussions and assessment of students' ideas took place, with one major assessment (reflection the USSBV stages) made on monthly basis to assess the major outputs.

Step 3: Take an action of analysis/implementation/evaluation

In 2015, students conducted an entrepreneurial and innovation activity using the USSBV. The same five points used in the past years were used to assess their work: (A). Problem Identification (PI); (B). Information/Knowledge on PI; (C). At least five proposed ideas on solving the PI and choice of one feasible with a motivation; (D). Creativity and Innovativeness of possible ideas; and (E). Argument on presenting the assignment.

Lesson Learned:

The groups scored 65% on average for PI, 68% for information/knowledge, 75% for ideas and motivation of their ideas, 83% creativity and innovativeness of possible ideas, and 70% for their argument on presenting the assignment.

Step 4: Reflect on findings, then communicate the findings

Unlike other years (2013 and 2014) where the assignment was discussed after few classes were conducted for grounding students in wireless and mobile networking concepts, in 2015 the discussion with students was conducted during the first class at the beginning of the year.

Notable challenges were that students looked at the problem areas that were beyond the course scope. These were solved by frequent interaction with the students.

The 2016 OPDAS process

Step 1: Identification of a focus area or problem statement

In 2016, the USSBV model was introduced to 45 new NSY401T students with boundary areas to sources of ideas being their knowledge holders such indigenous knowledge business.

Lesson Learned:

Learning from the 2015 lessons that of students not consulting the TUT R&I unit, in 2016 students were introduced to the work of the South African Technology Innovation Agency (TIA) (www.tia.org.za/funding), agency of the Department of Science and Technology and to the GAP ICT competition hosted by The Innovation Hub Management Company (TIHMC) (test.theinnovationhub.com/gap/ict/).

Students also identified the TUT's Innovation Competition as the vehicle for submitting their proposed entrepreneurial and innovation ideas with an aim of winning prizes.

Step 2: Conduct some form of data/information/knowledge collection and review

A dichotomous questionnaire asking if students agree or disagree with the inclusion of the entrepreneurship and innovation activity as part of their studies was disseminated and results are in Table 4, represents the results of the questionnaire.

Table 4. Responses on the inclusion of entrepreneurship and innovation to the module.

Inclusion of E&I could...	Agree	Disagree
develop an entrepreneurship interest in me.	14	1
introduce me to the foundations of business theory	13	2
help me to explore the development of business ideas.	15	0
	93%	7%

Lesson Learned:

A total of 93% students showed that they were very keen for the inclusion of an entrepreneurship and innovation concepts in their curriculum.

Step 3: Take an action of analysis/implementation/evaluation

Students were requested to propose entrepreneurship and innovation ideas by using a USSBV process model. The same five points as in previous years were used: (A). Problem Identification (PI); (B). Information/Knowledge on PI; (C). At least five proposed ideas on solving the PI and choice of one feasible with a motivation; (D). Creativity and Innovativeness of possible ideas; and (E). Argument on presenting the assignment.

Lesson Learned:

The groups scored 68% on average for PI, 70% for information/knowledge, 74% for ideas and motivation of their ideas, 85% creativity and innovativeness of possible ideas, and 72% for their argument on presenting the assignment.

Step 4: Reflect on findings, then communicate the findings

Of particular importance was a group of five students (comprising of two members employed as teachers, one as a technician and two unemployed) who used Design Thinking for Educators toolkits (www.ideo.com) to develop a web-based physical science simulation software for the classroom.

The simulation accessed through smart mobile phones had an online communication module imitated the ShareIt app algorithm to foster learners' collaboration. The students were assisted in developing technical drawings which illustrated the simulation different modules and the overall flow chart of how the simulation would work. The simulation was packaged as a proprietary software (i.e. license fee needed for usage) and the main target market was the South African Department of Basic Education (DBE) which could deploy it in all schools. The students could then earn by maintaining the system.

The group of students consulted TIA and TIHMC for funding; and were presented with an opportunity to join an TIHMC's Maxum Business Incubator to further pursue their idea as work product. The three employed students promised to contribute some stipend for the other two unemployed students to finalise their simulation development.

Lesson Learned:

If students could be trained using the USSBV chances are they would manage to value, the process of proposing and exploiting the entrepreneurship and innovation products/services; and eventually, they will establish their own organisations.

Funding seems to be a challenge for the exploitation of students' entrepreneurship and innovation products/services.

Discussion

In general, NSY401T students were found to be interested in entrepreneurship and innovation activity as throughout the years they proposed wireless and mobile networking different ideas/solutions to resolve identified societal and economic challenges.

The 2013 and 2014 students complained about time for the assignment meaning that a semester was not enough. However, the 2015 to 2016 group felt that a semester was good enough for proposing ideas. The latter could have been driven by the fact that USSBV (a more in-depth, purposeful and intentional driven model) than just Ideation was used. The evidence to that fact was the group of students who developed a physical science simulation software.

As illustrated by Figure 4, the average score on students' argument or reasoning during the presentation of their assignments was good compared to their problem identification task. But the score was significantly high on creativity and innovativeness because students tend to own

the process as it allowed them to think out of the box. Furthermore, students did not perform badly score in a task of identifying problems because they generally proposed and motivated workable ideas aimed at solving the identified problem. They also manage to motivate their choice of best ideas.

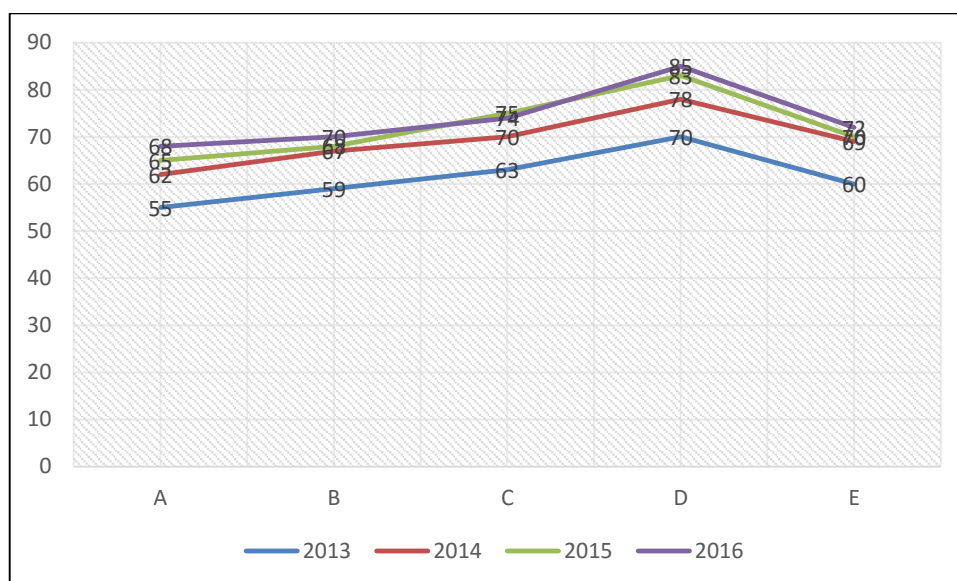


Figure 4. The average performance of the groups (Source: Authors' adaptation).

Given all of the above, it is without a doubt that students were motivated, interested and had positive attitude towards the inclusion of the concepts or activity of entrepreneurship and innovation in their NSY401T curriculum.

Conclusion

In this paper an answer to the research question: "How can entrepreneurship and innovation concepts be taught to CSE students without disturbing their existing curriculum?" was provided through the use of Ideation process and the USSBV process model. In general, the concepts of entrepreneurship and innovation could be embedded in the existing curriculum through different methods.

Academics are encouraged to use USSBV to blend concepts of entrepreneurship and innovation to their students' training especially on project or assignment tasks.

Future studies could investigate other models that could be used to blend concepts of entrepreneurship and innovation to students' curriculum and learning without making student to enrol for an entrepreneurship and innovation course.

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ANNEXURE 1

13/04/2013 NSY401T
Discussion with students
on 21st Challenges and
knowing all this challenges
why they choose engineer-
ing related module
Challenges
1) Unemployment 2) Poverty
3) Economic decline
4) Vulture
Challenges

13/07/2013
14/07/2013

1) Mismatch between
Curriculum and indus-
try needs and societal
needs.

2) Engineers need extra
skills beyond technical ones
3) Engineers might need
to learn cooking start restaurant
business.

Choose of Engineering

- 1) Engineering pays a better salary
- 2) Provides skills that could be utilised beyond the individuals work area.
- 3) A person becomes more analytical in solving daily projects

What was their motivation?

- Solving existing problem
- Safe solutions.
- Become rich.

Choose of Engineering

- 4) A person becomes a problem solver
- 5) A person becomes creative and innovative
- 6) It allows one to think beyond the class boundaries
- 7) Networking it requires one to be social.

The interest created an opportunity for others to pursue entrepreneurship and innovation as a career choices.

05/10/2013

Those who had ideas that were good enough were keen to expand their ideas and try to market or sale them.
The interest of solving the ideas as solutions to identify problems was positive.

05 Oct 2013 NSY401T

This day the lecture observed the students behaviour interest in motivation.
About half of the class were complaining about not get good projects to present as the assignment solution.

Lecturer perceptions about integrating HIV and AIDS education into the electrical engineering curriculum of an African University of Technology

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Statistics show that South Africa has the largest number of people living with HIV and AIDS in the world. There is now a movement to introduce more HIV and AIDS education into all South African tertiary curricula. The purpose of this paper is to present lecturers' perceptions about integrating HIV and AIDS education into the curriculum of the department of electrical, electronic and computer engineering of an African University of Technology. The study was done using a mixed methods approach and its paradigmatic position was interpretive. All lecturers in the department were purposively selected to complete open and closed questionnaires. It was found that a combination of failure to understand what integration entails and a lack of interest made lecturers dislike incorporating HIV and AIDS education in their engineering curricula. It was concluded that a culture that is prevalent among engineering lecturers that HIV and AIDS education should be addressed elsewhere is tantamount to claiming that teaching about the epidemic is irrelevant.

Introduction and Background

HIV and AIDS has become a global disease, spreading rapidly since the first cases were identified in the 1970s. The epidemic is currently one of the main causes of death in various countries of the world. Sub-Saharan is the worst affected region (Goldberg and Short, 2016); it accounted for 74% of people dying from AIDS-related causes in 2013 (UNAIDS, 2014: 9). South Africa has the largest number of people living with the disease in the world. The country is estimated to have approximately 5,51 million people living with HIV and AIDS (Statistics South Africa 2014, p. 2). In this 2016, South Africa remains the country with largest numbers of infected people in the world (Fourie and Meyer, 2016).

Within the context of widespread HIV and AIDS, universities have a critical role to play. Youde (2016) states that at the centre of much of the work in combating HIV and AIDS must surely be the recognition that universities have a key role to play. Integrating HIV and AIDS education into the university curriculum has great potential of raising students' levels of understanding the scourge and reduce risky behaviours (Fourie and Meyer, 2016).

In South Africa, the adolescent group comprises the largest number of people living with HIV and AIDS. HEAIDS (2007, p. 1) estimates that, "in South Africa, almost 1 in 6 university students could be HIV positive". It is against this backdrop and the realisation that the majority of university students fall in the 'at-risk group' of adolescents that Higher Education South Africa (HESA) mandates universities to integrate HIV and AIDS education into the curriculum (HEAIDS, 2010a). All universities in South Africa have been challenged to play a leading role in the nation's battle to alleviate HIV and AIDS in the society (HEAIDS, 2010a). There is a pressing need to integrate HIV and AIDS education into the university curriculum in order to prepare students to live and work in a context where millions of people are infected with the virus (Wood, 2014; UNAIDS, 2014).

Generally, lecturers agree that it is essential to integrate HIV and AIDS education into a university curriculum. However, they differ on where it should be integrated into the university curriculum. Some categorically maintain that HIV and AIDS education should be taught exclusively in generic social science modules. Others maintain that a discipline specific approach to teaching HIV and AIDS education is more effective because it ensures that students graduate with necessary competencies to deal with the epidemic in their respective professional areas (Wood, 2014; Van Laren, 2012). A discipline specific approach to integrating HIV and AIDS education into the curriculum contributes to public good because of its potential of educating students to be competent about how to deal with the epidemic in their respective professions (De Lange, 2014).

Tanga, De Lange and Van Laren (2014) argued that integrating HIV and AIDS education into the academic curriculum is not engaged with vigorously enough in South African higher education institutions. Lecturers have mixed feelings about integrating HIV and AIDS education in disciplines like Engineering, Information Technology and Business Management. Reasons for this include lecturers' claims that they lack time and space in the curriculum (Wood, 2011). The curriculum is said to be overloaded, hence, no space to integrate HIV and AIDS education.

Some lecturers are not integrating HIV and AIDS education into the curriculum because they do not understand what integration entails. Wood (2011) postulates that some lecturers think that integrating HIV and AIDS education entails making significant changes into the curriculum which require a university council to approve. The ending result is that lecturers do not want to integrate HIV and AIDS education into their teaching. Some lecturers do not want to integrate HIV and AIDS education into their curricula because it is irrelevant to their subjects.

HEAIDS (2010a) concluded that representatives of some faculties (like engineering) in South African universities did not see it reasonable to integrate HIV and AIDS education into the curriculum. Similarly, one accounting lecturer who was convinced that HIV and AIDS education should be taught exclusively in medical and psychology programmes said, 'HIV and AIDS does not belong in an accounting curriculum' (HEAIDS, 2010b, p. 48). The subject (HIV and AIDS) is conceptualised as a social issue which must be taught solely in social and medical science modules.

Integration of HIV and AIDS education across different disciplines requires lecturers to have a positive attitude (Van Laren, 2012). Van Laren (2014) used metaphors for integrating HIV and AIDS education in mathematics curriculum - something that may be deemed impossible by a person with negative attitude. De Lange, Van Laren and Tanga (2014) maintained that as long as a lecturer has positive attitude, there will be a way of integrating HIV and AIDS education into the university curriculum.

Lecturers are sceptical about integrating HIV and AIDS education in their disciplines because they claim that the subject (HIV and AIDS) has been over emphasised. Students in South Africa learn about HIV and AIDS in primary, secondary and tertiary education. Hence, a perception that there is no need of teaching students about HIV and AIDS education because they have been taught what they needed to know about the scourge (Wood, 2011). Such an opinion corresponds with another view from lecturers who claim that integrating HIV and AIDS education into their disciplines is 'a waste of time' because students learnt about the epidemic in school and in some generic modules at university (Wilmot and Wood, 2012). The underlying assumption behind this perception is university students already know everything there is to know about the scourge (Tanga et al., 2014). This is quite contrary to literature which states

that university students lack comprehensive understanding of HIV and AIDS (Meda, 2013; HEAIDS, 2010a).

Some lecturers distance themselves when it comes to integrating HIV and AIDS into their curriculum. They speak to an individualistic and limiting approach, of only working within the parameters of a particular discipline and claim that they are not supposed to be doing it (Van Laren, De Lange and Tanga, 2013). The argument behind is, HIV and AIDS is a sensitive topic which needs to be approached with care. The task has to be done by a trained person who is aware of developments in that field (Van Laren, 2007). The current state of the epidemic in the South African context needs collective efforts in order to minimise the rampant effects of HIV and AIDS (Van Laren et al., 2013). Addressing the epidemic is just too big an issue to be taken up by only a few (Van Laren et al., 2013). There is a need for lecturers and every person in the country to join hands and commit themselves to alleviating the spread of HIV and AIDS. This resonates with a view of Kelly (2001) that combating HIV and AIDS requires more commitment and togetherness than fighting a war of independence.

The purpose of this paper is to present lecturers' perceptions about integrating HIV and AIDS education into the curriculum of the department of electrical, electronic and computer engineering of an African University of Technology. A study related to this focused on introducing HIV and AIDS education into the electrical engineering curriculum (Craig, Xia and Venter, 2004). None of the studies, to the knowledge of researchers explored lecturers' (in electrical engineering) perceptions about integrating HIV and AIDS education into their modules. A lack of knowledge in this area is what this study seeks to address.

Theoretical Framework

This study was underpinned by two theoretical frameworks. The first was Kosslyn and Rosenberg's (2001) notion of perception which they viewed like attitude which can be positive or negative. Whether perception is positive or negative, it influences behaviour which in turn affects beliefs (Kosslyn and Rosenberg, 2001). Lecturers' perception of integrating HIV and AIDS education into the engineering curriculum can either be positive or negative. When a lecturer has a positive perception of integration, he/she will be having a desire to make a difference in the age of HIV and AIDS. In contrast, lecturers with negative perception have various excuses about integrating HIV and AIDS education in their teaching.

The second theoretical framework is Golding's (2009) theory of interdisciplinary. According to Golding (2009), there are various ways of integrating a subject to a particular discipline. However, it is essential for one to clearly identify a specific way of integrating which is relevant to what needs to be achieved. In this study, the outcome is to investigate lecturers' perceptions about integrating HIV and AIDS education into their engineering curriculum. Lecturers are expected to integrate HIV and AIDS education into their engineering curriculum without necessarily going deeper into HIV and AIDS content material. One does not have to be an expert in interdisciplinary subject in order to teach disciplinary content (Golding, 2014).

Similarly, by employing the interdisciplinary approach to integrating HIV and AIDS education, lecturers do not have to be experts in the medical field in order to be able to teach it in their respective engineering modules. This is because much interdisciplinary work does not require disciplinary depth (Golding, 2009). Similarly, engineering lecturers do not have to go in depth when teaching about HIV and AIDS education to students. This approach of interdisciplinary is ideal to use in electrical engineering since all students and lecturers are from one discipline. Teaching an interdisciplinary subject, especially to a cohort of students from different

disciplines, is more difficult than teaching one discipline (Golding, 2009). This is because interdisciplinary approach is complex and it needs to be explained to both students and lecturers within a particular cohort in order to be able to implement it effectively (Golding, 2014).

Research Methodology

The study was done using a mixed methods approach. It was mainly qualitative approach which informed the study while quantitative was complementing. Fraenkel and Wallen (2007) argue that both qualitative and quantitative approaches can complement each other in a single study. A qualitative approach within an interpretive paradigm was preferred to enable lecturers to express their perceptions about integrating HIV and AIDS into the curriculum. Creswell (2012) states that a qualitative approach enables participants to express their perceptions and provide rich textual data about a particular phenomenon. Interpretive position was preferred because of its compatibility with a qualitative approach. Lapan, Quartaroli and Riemer (2012) argue that all qualitative research has an interpretive perspective which focuses on uncovering participants' perceptions. A quantitative approach was used in this study during data collection and analysis phases.

The study was done as a case study of the department of electrical, electronic and computer engineering at a university of technology in South Africa. A case study was ideal to use in this study because it seeks to understand people's perceptions in a defined setting (Rule and John 2011). A case study was useful for an in-depth study of lecturers in their natural setting in order to understand their perceptions about integrating HIV and AIDS in electrical engineering. According to Punch (2009, p. 119) "The case study aims to understand the case in depth, and in its natural setting, recognising its complexity and its context."

Twenty-five lecturers in the department of electrical, electronic and computer engineering were purposively selected to complete open and closed questionnaires over a period of a month. The number (25 lecturers) was preferred because it represented all lecturers in the department. Purposive sampling was used because researchers wanted the participation of all lecturers exclusively from the department of electrical, electronic and computer engineering where HIV and AIDS education was going to be integrated.

Qualitative data was analysed using content analysis whilst analysis of variables was used to analyse quantitative data. Respondents were requested to participate in the study voluntarily and were also informed about the purpose of the study. Confidentiality and anonymity were guaranteed to all participants. They were told that they were free to withdraw from the study at any point. Researchers avoided deception of any kind to respondents, but instead, guaranteed them maximum confidentiality, anonymity, non-identifiability and non-traceability. Pseudonyms were used to further enhance privacy and anonymity.

Results

Findings of this study are presented by showing quantitative data first and qualitative data second. Lecturers in an African University of Technology, in the department of electrical, electronic and computer engineering generally demonstrated a negative attitude towards integration of HIV and AIDS education into their curriculum.

There was a lack of interest and motivation in completing the questionnaire. The few that did answer the questionnaire started off as follow:

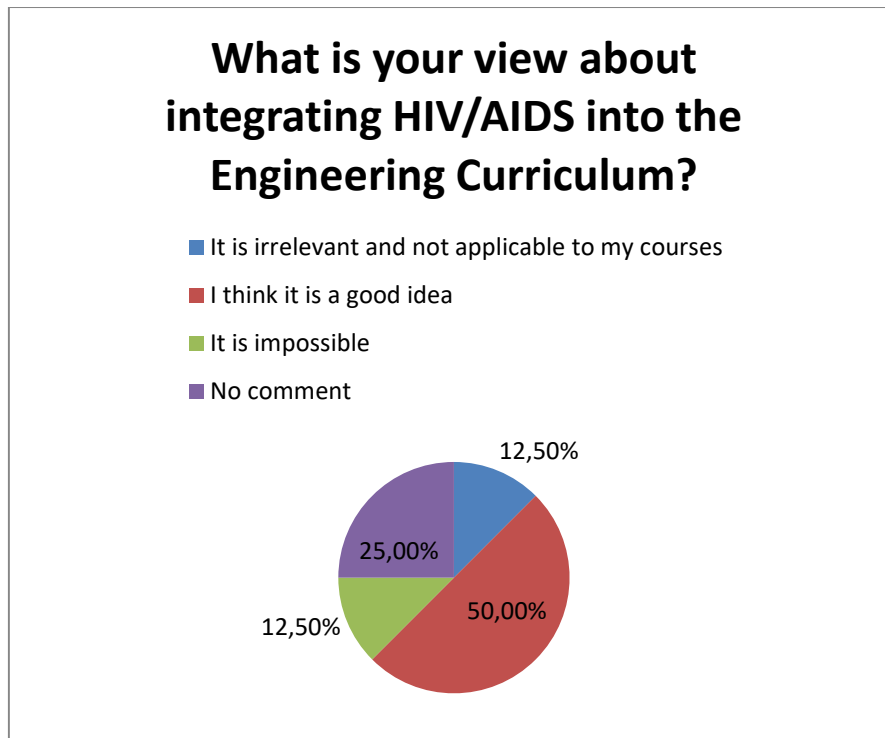


Figure 1. Views about integrating HIV and AIDS into the Engineering Curriculum

Although 50% felt it is a good idea to integrate HIV and AIDS education into the engineering curriculum, a total of 25% saw it as irrelevant (12,5%) or impossible (12,5%), but 12,5% would mean that's only 1 lecture. The other "no comment" 25% can be seen as a negative and thus there is divided feelings on integration. Compounding this to the low number of staff that answered the questionnaire (only 32%) demonstrates the overall negative attitude towards integration of HIV and AIDS education into the engineering curriculum.

Next was to get the perceptions of staff that might explain their perceptions:

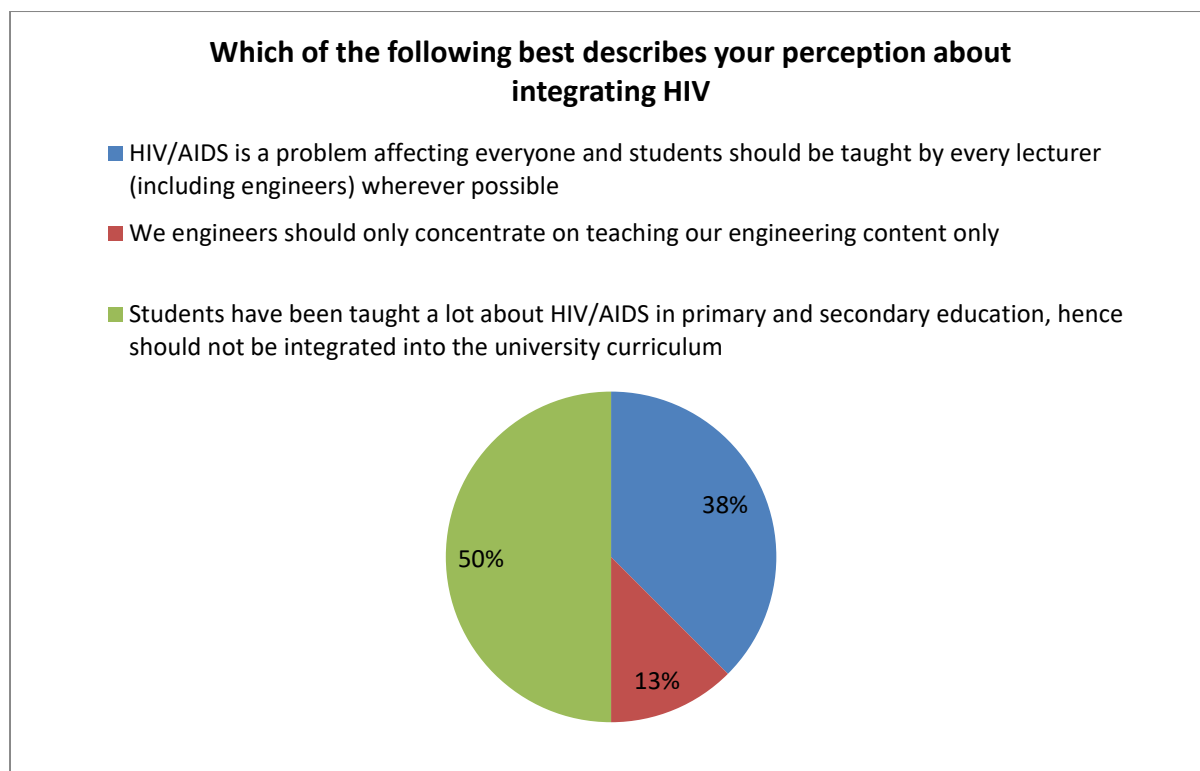


Figure 2. Perceptions about integrating HIV and AIDS education

38% percent of participants perceived HIV and AIDS as a problem affecting everyone and should be taught by every lecturer including engineers. This contrasted with 50% of lecturers who indicated that students have been taught about HIV and AIDS in primary and secondary education, hence, no need to integrate the subject into the engineering curriculum. Similarly, 13% of lecturers indicated that they prefer concentrating on teaching exclusively engineering content knowledge. This gives a total of 63% of participants who negatively perceived integration of HIV and AIDS education.

Reasons for the resistance against integration might be that lecturers do not see a link between HIV and AIDS education and the engineering curriculum or that they lack skills on delivery and or content. When lecturers were asked whether they can link HIV and AIDS education to their teaching, they indicated as shown in figure 3.

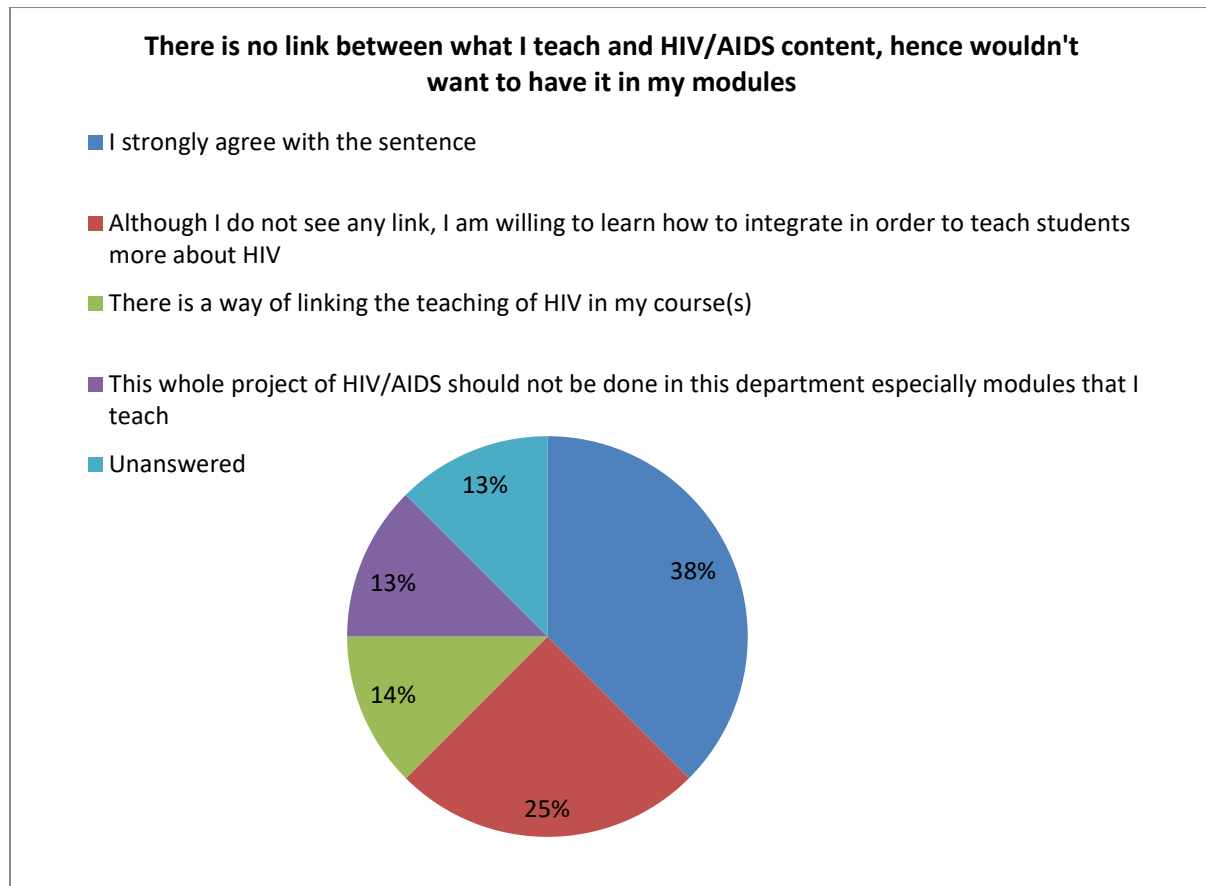


Figure 3. Perception on the link between engineering curriculum and HIV and AIDS content

As shown (on figure 3.) 37% see no link between what they teach and HIV and AIDS education. They do not want HIV and AIDS education to be integrated into their curricula. Added with 13% of participants who did not comment, the results point 50% of lecturers who do not see a link and not eager to learn. This contrasts with 12% of lecturers who felt that there is a way of linking HIV and AIDS education to their modules. 25% of participants indicated that although they do not see a link between what they teach and HIV and AIDS education, they are willing to learn how to integrate it in order to teach students more about the epidemic.

Generally, lecturers did not see a link and they were reluctant to learn about integrating HIV and AIDS education. They felt that HIV and AIDS education should be taught by a different department, not in engineering. This corresponds with 75% of lecturers who agreed that HIV and AIDS education should be taught in generic modules such as Life Skills, not in engineering modules. This point and others are detailed in qualitative data which follows.

When lecturers were asked what year they would prefer students learn about HIV and AIDS, majority indicated first year – a period when Life Skills module is taught at the university. Thus, lecturers support the idea of integrating HIV and AIDS education into the university curriculum, but, they do not want it in engineering as was echoed by one participant: “People know about HIV and AIDS, but, life styles expose them to risk. A Life Skills module should address the broader ‘life skills’, delivered by a specialist in the field”. Another respondent said, “I do not have a problem with integrating HIV and AIDS education, but, it makes me wonder where it will be done and if all students would be interested.” Lecturers want HIV and AIDS education to be introduced in a Life Skills module and be taught by trained personnel. Pushing

the teaching of HIV and AIDS to other departments is an indication of insecurity on skills on delivery and content.

Some lecturers were adamant against integrating HIV and AIDS into the engineering curriculum. One participant said, “this whole concept (of integrating HIV and AIDS in engineering) is preposterous, leave it.” Similarly, another lecturer said “integrating HIV and AIDS into the engineering curriculum might cause some students to lose focus.” The argument is, if HIV and AIDS education is integrated into the engineering curriculum, students will not concentrate on content knowledge, but, psychosocial effects of the epidemic.

The issue of time and difficultness of engineering modules was cited by some lecturers as a reason they do not want HIV and AIDS education to be integrated into their curriculum. A lecturer said “our students barely have time (to learn about HIV and AIDS). They struggle with our engineering modules in such a short period of time.” It is believed that students struggle to learn difficult content of electrical engineering, hence, no need of further compounding the modules with HIV and AIDS education which is also challenging. Another lecturer said “the syllabus is already full and time is limited, so at this stage, there is no way I can bring this into my syllabus.”

In spite of the fact that majority of lecturers disliked the idea of integrating HIV and AIDS education into the engineering curriculum, few saw the idea as noble. A respondent said “students might learn a lot about the epidemic, take it more seriously and start exercising more caution.” Lecturers who felt that integration has to be done in engineering were mindful of the fact that HIV and AIDS is a disease that affects every human regardless of his/her profession. As a result, it is sensible to educate students about the epidemic so that they learn how to handle the reality of HIV and AIDS cases which are prevalent in workplaces. A lecturer said “HIV and AIDS need to be addressed in all modules and should be relevant to all subject areas”. Another lecturer said, “it will help the student when they go into industry as they would know how to behave, act and react to situation that involves HIV and AIDS.” One lecturer linked brain functioning to a good health: “since the brain functions better with sound health, it is essential to integrate HIV and AIDS education in engineering in order to create awareness in our students”. If a student is troubled with HIV and AIDS, he/she may not academically perform to the maximum.

Discussion

Data on lecturers’ perceptions indicate that there are three main themes: first is that students already did HIV and AIDS education in primary and secondary levels; second is that HIV and AIDS education should be done by a professional in a Life Skills module in first year level, and thirdly, it seems like a time management issue. These three themes indicate lecturers’ negative perceptions about integrating HIV and AIDS education into the electrical engineering curriculum.

Kosslyn and Rosenberg (2001) state that negative perception just like negative attitude influence people to have disbelief about something. Lecturers’ perceptions about integrating HIV and AIDS education in the engineering curriculum manifested mainly as negative which in turn influenced them to believe that the epidemic cannot be addressed in their disciplines. This confirms a view of Tanga et al. (2014) that integrating HIV and AIDS education in South African universities is not being done vigorously. The way HIV and AIDS is negatively affecting education in South Africa requires lecturers in all disciplines to rethink how they can make a difference in this era.

This calls upon every lecturer to find a way of addressing HIV and AIDS education in their respective disciplines in order to prepare students to be able to deal with the epidemic in work places (Youde, 2016; De Lange 2014). There is no way HIV and AIDS education cannot be spoken about in a particular discipline because the epidemic affects people in all professions. Van Laren (2014) and HEAIDS (2010a) integrated HIV and AIDS education in mathematics and agriculture curricula respectively. Such initiatives are testimonies which show that there is a way of integrating the epidemic in any field. The only thing that is needed for one to successfully integrate HIV and AIDS education in their discipline is a positive mind (Van Laren, 2012). A positive mind influences one to have a belief that if he/she tries something, it will work out even if people with negative perceptions claim it to be impossible (Kosslyn and Rosenberg, 2001).

The epidemic is too big and ubiquitous to be addressed by specialists only or for some lecturers to distance themselves and claim that they are not supposed to be teaching it (Van Laren et al., 2013). If the culture of claiming that HIV and AIDS should be addressed elsewhere prevails, it would be hard to attain Education for All (EFA) goals and the Millennium Development Goal (MDG) for education “cannot be achieved without urgent attention to HIV/AIDS” (UNAIDS 2002, p. 8).

A claim made by some lecturers that integrating HIV and AIDS education into the engineering curriculum consumes time and result in diluting discipline content knowledge reveals a misunderstanding of what integration entails. Wood (2011) postulates that lecturers misunderstand what it means to integrate HIV and AIDS education into their curriculum. They think significant changes have to be made which results in a shift of discipline focus. This is contrary to Golding’s (2009) theory of interdisciplinary approach which maintains that interdisciplinary content should not dominate discipline content. Lecturers do not have to teach in-depth knowledge about HIV and AIDS because focus is on engineering content. The little information about HIV and AIDS taught to students in a discipline might seem like a drop in an ocean, but, it makes a difference in the age of prevalent HIV and AIDS. Golding’s (2009) interdisciplinary approach to integration where lecturers do not have to go in-depth with integrated subject is very applicable to integrating HIV and AIDS education in the engineering curriculum.

Conclusion

The purpose of this paper was to present lecturers’ perceptions about integrating HIV and AIDS education into the curriculum of the department of electrical, electronic and computer engineering of an African University of Technology. Based on findings and a discussion made, this paper concludes that lecturers’ perceptions about integrating HIV and AIDS education into the engineering curriculum gives rise to a culture that is consequential. A culture that arises among engineering lecturers is that HIV and AIDS education should be addressed elsewhere. This culture is tantamount to claiming that teaching about the epidemic is irrelevant in some disciplines. Such a view does not help alleviate the rampant spread of HIV and AIDS in South Africa and beyond. There is always a way of integrating HIV and AIDS education into the curriculum (Van Laren, 2012). What one needs to do is to rethink how to do it, and believe that integrating HIV and AIDS education into any discipline is not time wasted, but, time invested into the future of graduates.

If one is committed and passionate about integrating HIV and AIDS education into the curriculum, there is always a way of successfully doing it. This is regardless of the nature of module. Initiatives made by some academics of integrating HIV and AIDS education in mathematics (Van Laren, 2014), engineering (Craig, Xia and Venter, 2004), agriculture

(HEAIDS, 2010a) and Information Technology (HEAIDS, 2007) curricula are testimonies of practicality in any discipline.

Recommendations

Lecturers' negative perceptions about integrating HIV and AIDS education into the engineering curriculum are a result of a misunderstanding of what integration entails and a feeling of not being able to teach the subject. In that context, it is recommended that universities need to regulate staff academic development workshops with a twofold purpose: i) educate lecturers what integration entails. Majority of lecturers who demonstrated negative perceptions about integrating HIV and AIDS education into the engineering curriculum thought integration requires them to revise their current curriculum and add significant amount of information about HIV and AIDS. The Golding's (2009) conceptualisation of interdisciplinary approach can be helpful in this regard.

ii) Provide comprehensive information to lecturers about HIV and AIDS. Teaching HIV and AIDS to university students requires one to have a good knowledge and up-to-date information about the epidemic. This calls for staff capacity development workshops to be conducted by people with expertise in the field. That helps obliterate lecturers' fears of not being able to deliver HIV and AIDS content and subsequently minimise a claim that a specialist has to teach students.

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Diversity and first-year student integration in an engineering faculty

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Abstract

Within the backdrop of widening access to higher education in South Africa, shortage of skilled engineers, and a lack of ethnic representation in engineering professions, South Africa's universities are increasingly having a more diverse student profiles. However, government funded subsidies directed at reducing student attrition and poor throughput rates do not often yield the desired results. Most of the students who struggle to cope with first-year university studies come from a poor background with inadequate schooling and poor preparation for tertiary studies. These students are often perceived in the same frame as their counterparts who come from more resourced backgrounds.

This paper employs Bourdieu's concepts of habitus and capital in order to explore the influence of socio-economic factors in the retention of first-year university students in an engineering discipline. Using a case study approach whereby data was collected through surveys and focus group discussions, rich data from first-year engineering students at a university of technology in South Africa was extracted. The findings highlight some of the often ignored factors that account for poor retention and throughputs in engineering education within the context of unequal access to resources. The paper argues that these universities need to shift their gaze to the structural conditions such as poverty, poor schooling, first generation students, and lack of world view dispositions, as factors that constrain the integration and persistence of diverse students into the engineering profession.

Introduction

South Africa is a country known for its rich natural, ethnic, religious, and cultural diversity (Seekings, 2008). It is also a country with a turbulent historical past that has contributed enormously to current economic and social inequalities that the country faces (Badat, 2010). Such inequalities ultimately affect access and success of schooling at different levels (Donohue & Bornman, 2014). Many South African students enter the university from positions of extreme disparity, most noticeably is schooling, but also in terms of financial and social resources (Scott, Yeld & Hendry, 2007). Furthermore, there is huge under-representation and poor graduate numbers for students from previously disadvantaged backgrounds especially in disciplines like engineering, mathematics, and sciences (Akoojee & Nkomo, 2007). This is an indication that students entering university have diverse learning support needs which are related to their social, cultural and schooling transitions (Dumais & Ward, 2010). Consequently, universities in South Africa are expected to transform their curriculum and pedagogic practices to reflect the diverse nature of the country and to meet the economic and

social aspirations of the country (Banks, 2015). This paper explores how first-year students' socio-economic conditions affect retention and throughputs in an engineering faculty. Using Bourdieu's framework of habitus and capital, the paper argues that in a context of massive inequalities and difference, a university's disregard of first-year students' historical, social and economic backgrounds result in inefficient utilization of learning support being provided on campus. We suggest the use of theory to frame a more nuanced understanding of first-year learning in engineering.

Capital and habitus: Bourdieu's perspective of learning and society

Pierre Bourdieu is a French sociologist, anthropologist, and philosopher who spent some time as a French military conscript and also as a lecturer in Algeria. His research is dominated by issues of power and how it is perceived in the society (2002). Using innovative investigative frameworks, Bourdieu introduced influential concepts in sociology such as cultural, social and symbolic forms of capital, cultural reproduction, habitus, field and location (Fowler, 1997).

Habitus, for Bourdieu, is a system of dispositions (Grenfell, 2012). It expresses the clash between objectivism and subjectivism (Navarro, 2006). Through habitus, Bourdieu articulates how agents' dispositions is an inculcation of objective social structures into subjective mental experiences (Shusterman, 1999). This is a key outcome of Bourdieu's field theory, and its unique contribution is his extrapolation of habitus and doxa. An agent (any individual) has deeply ingrained beliefs and values seating in the unconscious which they take as self-evident universals (dispositions) and which influences the agents' actions and thoughts within a particular field (Grenfell, 2012). He states that we experience doxa when we become blind to the limits that propel inequality in the society; 'an adherence to relations of order which, because they structure inseparably both the real world and the thought world, are accepted as self-evident' (Bourdieu, 1984, p. 471). For Bourdieu therefore, habitus is crucial towards social reproduction because it enables the generation and reproduction of practices that constitute social life (Bourdieu, 1990). This conceptualization of habitus and field offers methodological and theoretical tools to understand the objective-subjective antinomy in the social sciences (Jenkins, 2002). Any given community has rules (structure/social laws) which are explicitly and tacitly demonstrated by how the people (agents) in that community think, perceive, and do things (agency). This relationship between structure and agency can be significant in how we understand first-year students' challenges in an engineering faculty within the backdrop of inequality and difference. In this regard, Bourdieu offers the term 'reflective sociology' (Navarro, 2006) to enable us to identify our own biases, beliefs, and assumptions as we attempt to rationalize the dismal first-year engineering students' retention statistics.

Capital and symbolic violence

The conventional Economics definition of capital, as the use of sums of money or assets to produce new wealth, is extended in Bourdieu's theory (Grenfell, 2012). Bourdieu suggests that there are several forms of capital, such as economic, symbolic, cultural and social (Shusterman, 1999). Cultural capital refers to qualities and competencies, qualifications that are seen as cultural assets in a society. Linked to cultural capital is economic capital, which is the ability to purchase a good or service (Fowler, 1997). Economic capital looks at the opportunity cost of purchasing a good or service (De Graaf, De Graaf & Kraaykamp, 2000). When social networks are created, and trust, reciprocity, transactions, and cooperation are established based on such networks, Bourdieu sees social capital (Bourdieu, 1986). Symbolic capital refers to the ability to garner prestige, honor, and attention as a source of power (Grenfell, 2012). These forms of capital give the holders authority over those that do not have them. When symbolic

capital is used against members of a society who lack such capital, it is referred to as symbolic violence (Jenkins, 2002). The concept of symbolic violence is crucial in challenging the practice (of universities in South Africa) of negating the historical, social, economic, political and cultural attributes that constrain first-year students' access to the engineering discipline in a context of inequality.

Context

This paper is set within the backdrop of the recently introduced First-Year Experience project in some universities across South Africa. The authors of this paper are academics involved at different levels in the conceptualization, planning, and delivering of the First-Year Experience program in one of such university in the Western Cape Province. As a consequence of post-apartheid liberalization of South Africa's higher education landscape, the majority of our students are profiled as coming from previously disadvantaged backgrounds and most of them are not sufficiently prepared to study the disciplines for which they enroll in. Such profiling often fails to appreciate the kinds of capital that these students tap into in order to make it to the university. Therefore, we as practitioners of academic development programs that seeks to improve student learning in challenging disciplines such as engineering are interested in theories and frameworks that enhance our understanding of the role of power dynamics and uneven access to economic resources as constraining first-year student learning. All the students reported in this paper were enrolled in the Faculty of Engineering at a university in the Western Cape in the 2016 academic year.

Methodology

This paper employs a case study approach in order to understand a phenomenon within clearly define conditions and in a real-life context (Yin, 2003). The methodology used in this study is a concurrent mixed data collection, relying largely on a quantitative questionnaire that probed students' perceptions of their readiness to engage in engineering studies at a university. The data reported in this paper is part of an institution-wide study that seeks to explore first-year learning at a university of technology in South Africa. The questions in the questionnaire were framed to extract information that responds to themes such as family background, economic and social conditions of students, and perceptions of readiness to study. This was necessary to enable a theory-based analysis of the findings. The survey was administered prior to the commencement of lectures for first-year students in 2016. Students from all the departments in the faculty participated in the surveys and discussions.

The data from the questionnaire was supported by concurrent focus group interviews with students, as well as informal discussions to further understand the responses that the students provided in the questionnaire. The focus group interviews and informal discussions provided subtle details that we could not have easily found if we had used only surveys. The focus group interviews and informal discussions also provided qualitative data that complemented the quantitative statistics obtained from the surveys (Denzin, 2012). While the quantitative data was captured in appropriate graphs and tables, we employed the thematic approach (Braune & Clarke, 2006) to classify and code the qualitative data. This helped us in finding correlations and specific details for analysis.

742 students out of an estimated 1800 first-year students from 6 departments (out of 8 departments that make up the faculty) participated in the surveys. This was a controlled sample of students based on the planning of the subject-specific lecturers. Because lecturers from the departments were involved as co-facilitators of the first-year experience program, they were able to make referrals of students who participated in the focus group discussions. Such

workshops and discussions happened as per department schedule, with an average of 18 students per department attending. In order not to put extra strain on the students, the subject-specific lecturers ensured that focus group discussions were planned and time allocated in the timetable. The students were not compelled to participate in the surveys, and they all signed consent forms that were read to them. Ethics Clearance for this project was obtained from the institutional ethics office.

Findings and discussions

This paper argues that first-year students' socio-economic backgrounds are not adequately foregrounded by university authorities when planning first-year student support. We use Bourdieu's concepts of habitus and capital to argue that a history of discrimination, repression, uneven access to economic resources, and unequal provision of pre-university schooling are significant attributes that constrain most first-year students who enroll for engineering qualifications in our context. We demonstrate this by presenting statistics extracted from 742 students in 6 departments in the Faculty of Engineering at a university in South Africa (see Table 1).

Table 1. Extract from Student Survey.

	Dept 1		Dept 2		Dept 3		Dept 4		Dept 5		Dept 6		Faculty	
Question/Statement	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Qualification was first choice	72	28	53	47	75	24	78	22	25	75	80	19	73	26
Qualification is aligned to career path	91	7	86	14	93	7	96	3	83	13	95	5	93	6
I knew about qualification before admission	86	14	65	33	80	19	91	9	58	42	86	13	83	16
School prepared me for CPUT demands	84	16	89	10	77	22	85	15	88	13	88	11	85	14
I have confidence in my capabilities to succeed	99	1	96	4	91	9	96	4	92	8	97	3	96	4
I have specific goals to motivate me	95	5	93	7	94	6	97	3	96	4	96	4	95	4
I know how to study	88	12	82	18	87	13	78	22	75	25	88	11	84	16
I know how to prepare for tests	84	16	75	25	80	19	75	25	63	38	82	16	79	21
I know how to do assignments	72	28	57	43	71	28	61	38	46	54	62	38	63	36
I manage time well	77	23	76	24	65	33	82	18	67	33	88	12	80	20
I feel stressed and cannot focus	17	83	26	74	32	68	20	81	46	54	18	81	22	77
I have self-discipline to pull me through my studies	94	6	92	8	89	11	94	6	83	17	93	5	93	7
I can control anxiety and stress before and after tests	80	20	71	29	77	20	74	26	63	38	81	18	77	23
I tend to give in to negative pressure	14	86	4	96	7	90	7	94	4	96	8	91	8	92
I experience relationship problems	8	92	22	76	23	77	21	80	29	71	17	82	19	81
I have sufficient funds to complete my studies	51	49	36	64	49	50	58	42	17	83	40	59	47	53
Poverty will affect my ability to study	19	80	39	61	24	74	21	78	58	42	36	63	29	70
I have conducive living conditions that support my studies	87	13	67	33	67	32	74	26	50	46	70	29	72	28
Transport is a challenge that can affect my studies	37	63	57	43	41	57	42	58	46	50	53	47	46	53
My parents support with my studies	85	15	79	21	68	30	78	22	58	33	74	26	75	24
I exercise regularly	55	44	28	72	39	60	53	47	38	58	47	52	46	53
I am aware of campus resources that support my studies	70	30	82	18	75	23	95	5	92	4	79	20	83	17

Socio-economic capital: financial readiness for higher education

A major indicator of a student's readiness to embark on higher education in South Africa is the student's (or parents') ability to fund the study. Owing to the debilitating economic conditions of many South African families, most of the learners who qualify for tertiary education cannot afford to pay for such studies. In Chart 1 below we find that 52.8% of first-year engineering students do not have sufficient funds for their studies. Furthermore, 23.9% of the students in the faculty also indicate that their parents cannot support them. Surprisingly, only 16.6% of these students indicate that they are aware of resources on campus to support them.

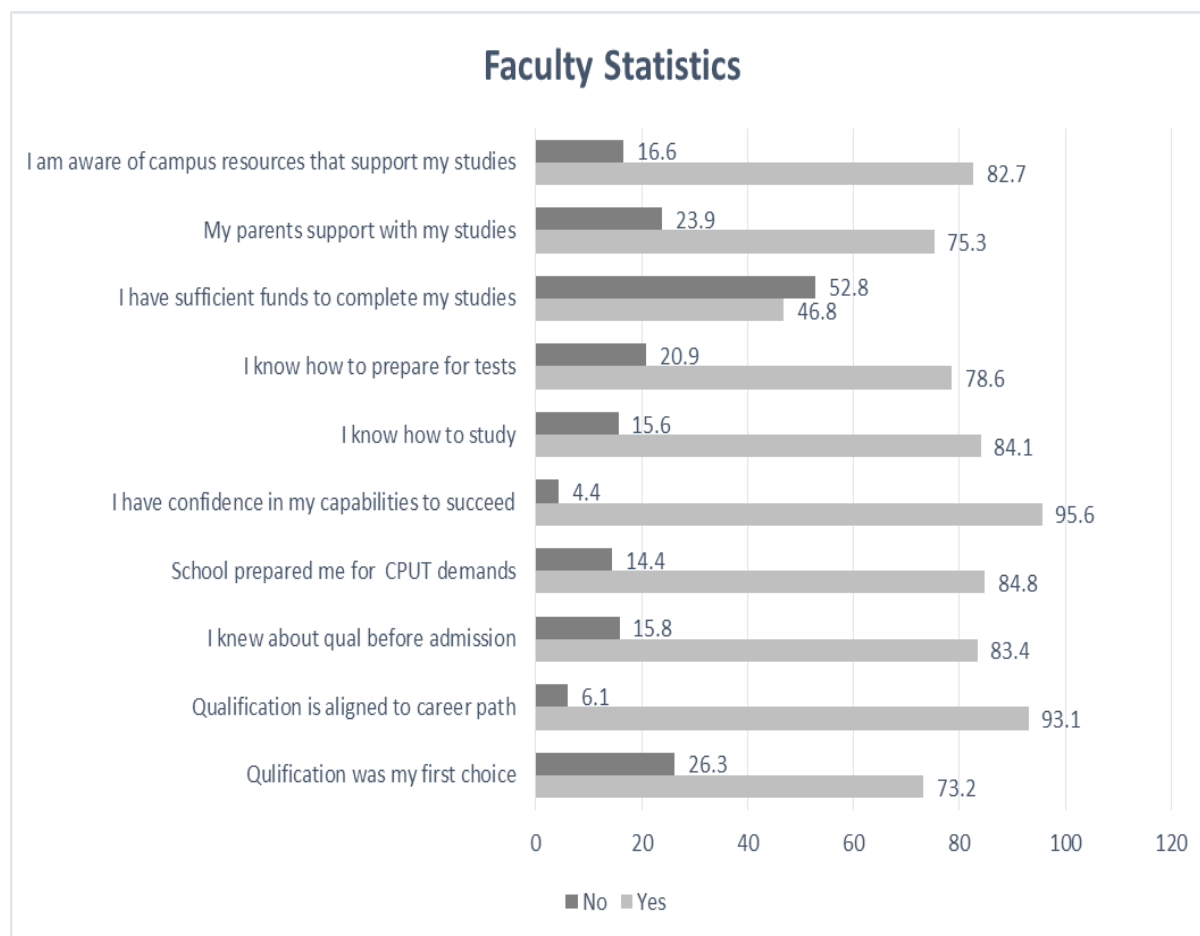


Chart 1. Faculty Statistics.

It is possible to consider that these first-year students in the engineering faculty consider the lack of resources as normal. In one of the focus group interviews, Tombela explained as follows:

Because my matric grades were ok, I got my NSFAS (National Student Financial Aid Scheme). So I think I am sorted. But now, you ask whether we have laptops and stuff. The NSFAS is not enough, so maybe next year, I will buy it. I didn't budget for it in the NSFAS and I don't think it is right to go back to them now and ask. For now, I will just manage and use my classmates' laptop whenever I can [Tombela¹, 19yrs old, Civil Engineering student].

¹ All names of participants used have been changed for purposes of confidentiality

Tombela's account above supports the statistics provided in Chart 1 above. From focus group discussion, some students confirm that while they are under-resourced at home, there seems to be clear inertia in making use of support that is available to the University. This is not just a case of ignorance of such support. It is more related to a predisposition to not enquire; to not be assertive enough to request for such support from staff in the university. De Graaf et al. (2000, p. 93) explain that 'cultural resources include familiarity with conceptual codes that underlie a specific culture with major artistic and normative manifestations. These can include high-status cultural signals such as behaviors, tastes, and attitudes (Lareau & Horvat, 1999; Farkas, 1996). Therefore, a student coming from a poor and impoverished background, who cannot articulate their needs clearly will not be able to get the help that is available within the university. This can be considered as an example of symbolic violence. It suggests that beyond a mastery of mathematics and physical sciences, a typical previously disadvantaged student from an impoverished background lacks the dispositions to engage with campus life proactively. This is captured vividly when Tombela says '... I don't think it is right to go back to them now and ask'.

Cultural capital: prior schooling and world view

In his book *Distinction: A social critique of judgment and taste*, Bourdieu (1984) asserts that judgments of taste are related to social position, or more precisely, are themselves acts of social positioning. The relationship between market forces and university education is what currently defines contemporary higher education systems globally (Coward, 2013). Thus, disciplines like engineering and medicine to name a few are now seen as high-status vocations whose training is more expensive compared to other disciplines such as Chemistry or History. De Graaf et al (2000, p. 94) explain that 'cultural capital theory usually refers to the importance of socialization into highbrow activities, like interest in art and classical music, theater, and museum attendance'. This view purports that learners who do not participate in such activities would find it difficult to 'fit in' the schooling environment. While this is a debatable view, our experience in supporting first-year students with academic writing activities indicate that students who master particular study skills such as the SQ3R method of reading (for example) cope with university reading tasks better than those who do not. These are skills that these students are expected to bring their pre-university education experience.

From Chart 1 above, we find that 26.3% of the students did not select as 'First choice' the discipline that they are currently studying for. Also, 15.8% of the students did not know anything about the qualifications before they enrolled. While only 4.4% of the students do not have confidence in their own capabilities, it is worrying that a further 15.6% of the students confessed that they do not know how to study; and 20.9% of them do not know how to prepare for exams. This is clear indication that almost 25% of the students do not have life skills that can enable them to negotiate University with a degree of independence. Vuyo puts this vividly when he says

I was just very happy that I finally got here. I think all my friends here will tell you the same thing. Once we passed matric, we just wanted to come to the university. Me and Nic and Temba applied to the other universities but were not taken. Then we came here and we were accepted; even though it was not in our first choice. I wanted to do Mechanical Engineering, but they put me in Clothing and Textile Technology. But it's cool [Vuyo, 20yrs old, Clothing and Textile Technology student].

From Vuyo's narration above, it is evident that his decision to study at a university was not well planned. Once confronted with the fact that he has passed the Senior Certificate examinations, he then realized that the next logical step is to embark on university studies. Without proper planning and career guidance, he is gambling with the choice of discipline to

study and the choice of institution to study at. This is a common trait in first generation students as explained by another student below:

Sir, I am the first to come to the university in our house. I asked my friend who had a sister in the university, then she said Civil Engineering is ok and that you can get good jobs when you graduate. So I applied to study Civil, but now I am worried. I want to study by Chemistry because it is my best subject and I understand it better. So maybe next year I will apply to switch to Chemical Engineering [Nelly, 21yrs old, Civil Engineering student]

DiMaggio (1982) in a pioneer research on the influence of cultural capital on educational attainment announced that cultural resources enable educational outcomes (school grades) even when factors such as parental influence are considered. This, therefore, means that poverty alone is not enough to account for Nelly's and Vuyo's predicaments in the university. Their situation is also influenced by the fact that they live in environments where people just do not talk about children's career trajectories.

Symbolic violence: habitus and (lack of) skills and abilities

As previously intimated in this paper, Bourdieu strongly affirms that symbolic violence is a key concept that enables us to deconstruct the reproduction of inequalities in societies (Bourdieu & Passeron, 1977; Bourdieu, 1990). Symbolic violence exposes the way people contribute towards 'reproducing their own subordination' through the cumulative and 'gradual internalization and acceptance of those ideas and structures that tend to subordinate them (Connolly & Healy, 2004). The skill sets that first-year students possess to determine how they perform. When looking at the basic skill sets that students should have at the university, such as academic literacy, there is a concern that shows a great need for support. To illustrate this, the graph below shows the percentage of students who feel they know how to study independently, gradually increasing for students who do not know how to prepare for tests and for students who do not know how to do assignments.

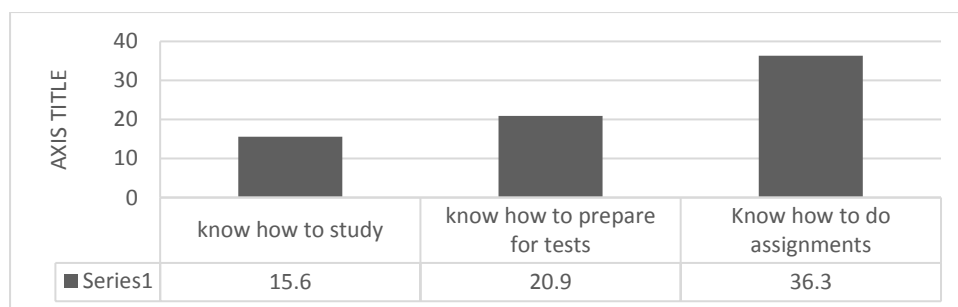


Chart 2: Academic readiness.

When studying the above graph alone, the average weighting of assignments marks at the faculty of engineering is on average around 20% and tests being around 60% (including final summative assessment). It means that about 20% of the marks is reserved for practical assessments. From the focus group discussions, we see more clearly elements of symbolic violence at play here:

You know, in high school you just relax and do your thing. When exams are approaching, then you start studying and revising hard so that you can remember the stuff on exam day. So, if exams are not around the corner, I don't study after school. Now I am struggling to adapt here in the university because there are just too many assignments and group projects. It is difficult to find time to chill [Nic, 20yrs old, Mechanical Engineering student]

Student: I am behind schedule with 2 of my individual assignments and 1 group project. I am worried that I might lose marks as a penalty for late submission.

Interviewer: What is the cause of you being so late with your assignments?

Student: Sir, the assignments were too many and the time was too short. Just the other day we were planning to do it with my mates before you know it, the due date is here.

Interview: How did you plan? Did you write down your plan somewhere like in a diary or personal planner?

Student: No Sir. We just discussed it and agreed that we will find time on the weekend and discuss the assignments and projects. We missed the weekend meeting and ... [dialogue between Dora, 21yrs old Chemical engineering student and First Year Experience workshop facilitator]

What stands out in the two extracts above is that there is some evidence that some first-year engineering students are reproducing their high school ways of learning and knowing in the university. Even though these students have been provided with tools such as time management and goal setting, they seem to struggle to use these tools to achieve their goals. The poor utilization of institutional resources such as the Writing Centre and First Year Experience Unit is an example of symbolic violence. This ends up creating frustration for both the students and their lecturers, especially when the students fail in their assessments. One of the participating lecturer captures such a frustration vividly below:

What our students, or at least my students to be specific, are suffering from is a strong sense of inertia or misdirection. I know that many of these students come from very difficult backgrounds; but surely if you have the drive to succeed and graduate on time, then you must be actively looking for all the help you can get in order to achieve your goals. Many of these students are not doing that; they are nothing asking for help, they are not using the learning support services, they are not engaging in positive extramural activities such as sports and competitions. Go to our gyms and sporting fields, you don't find them there. Those things are there to keep the students mentally alert. Instead, they just wait until they fail, then they panic. Is that not inertia? To be an engineer is beyond just taking up a profession; it is a way of life. We need to find ways to get these students to see this [Dr. Robertson, lecturer, Civil Engineering]

Dr. Robertson's narration above can be better understood by reading symbolic violence carefully. He identifies the lack of use of student learning support structures such as Writing Centre as symbolic of student's passive attitude towards their studies. He further explains this by adding that the students are not using social support services such as gyms and sports centers. Bourdieu argues that symbolic violence:

presupposes on the part of those who are subjected to it a form of complicity which is neither a passive submission to an external constraint nor a free adherence to values ... The specificity of symbolic violence resides precisely in the fact that it requires of the person who undergoes it an attitude which defies the ordinary alternative between freedom and constraint (Bourdieu & Wacquant, 1992, p. 168)

In essence, the concept of symbolic violence helps us to see why some students are not utilizing learning and social support structures in the university. It provides a more nuanced interpretation of the social conditions (habitus) and experiences of the social world ('institutions and structures') that cumulatively accounts for 'taken for granted ways of thinking and behaving' (Connolly & Healy, 2004, p. 16). There is a correlation between physical exercise/activity and academic performance (Khan, Jamil, Khan & Kareem, 2012). 53% of the students indicated that they do not engage in any sporting activities, despite many of them acknowledging that participation in sports improves student's grades, academic

achievement, raises their educational aspirations and keeps them in schools and colleges (Khan et al., 2012). Reading such trends using the lens of Bourdieu's concepts of capital and habitus, we can be able to challenge the hegemonic narrative of first-year student support especially in disciplines such as engineering; and to suggest that academic development practitioners need to go beyond such convenient student support models in order to adequately support students from difficult backgrounds (Tierney, 1999).

Conclusion

A university qualification means different things to different people. As indicated already, South Africa is a country recovering from the effects of a history of discrimination and inequalities. This means that while the widening of access to higher education is seen as a welcome panacea to the thousands of previously disadvantaged students, it is also important to begin the difficult conversation of questioning the quality of teaching and learning that these students will confront. Considering that the government, through the Department of Higher Education and Training, is disbursing huge sums of monies to subsidize undergraduate student learning support initiatives, it is paradoxical that retention and throughput rates continue to decrease.

In this paper, we borrow from Bourdieu's concepts of habitus and capital in order to explore the influence of socio-economic factors on first-year engineering students' retention. By doing so, we problematize the attitudes of universities to ignore students' habitus and capital in their planning. We propose that in the context of strong economic, social, political, and historical inequalities, universities in South Africa should not see first-year students as a homogenous entity. In a discipline such as engineering, many of the students who come from previously disadvantaged homes see the Engineering qualification as the only route out of poverty. The opportunity cost of studying for such student is so high that it will be very unfair to not acknowledge these students 'out-of-school' conditions when designing their learning support.

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In/between science and art: Posthumanist ruminations on Geomatics education

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Abstract

This paper reports on a pedagogical intervention in an engineering curriculum at a South African university of technology. A storytelling intervention was introduced into an undergraduate geomatics diploma programme, and was theorised using critical posthumanism. The storytelling intervention was introduced in the curriculum to investigate how points of compatibility between the ‘hard’ and ‘soft’ sciences can be identified and demonstrated, as called for by numerous theorists. It was also used as a means to develop students’ social, environmental and ethical awareness, as well as to foreground student subjugated knowledge through the lens of geomatics. The basic tenets of posthumanism are explicated and the philosophy is used as both a navigational and analytical tool. A cartographic, diffractive methodology was developed (mainly from the work of Rosi Braidotti and Karen Barad) and employed for analysis. The analysis shows that geomatics education in South Africa is intensely humanist and anthropocentric, even though there have been attempts to reform the curriculum. It makes the case for fostering novel relations across disciplinary boundaries, and contributes to the development of transformative pedagogical techniques that are aimed at decolonisation and social justice.

Introduction – Geomatics Education in South Africa

Geomatics includes the tools and techniques used in the disciplines of land surveying, photogrammetry, remote sensing, geographic information systems (GIS), geodesy, and cartography. The inclusion of these scientific disciplines under the umbrella of geomatics followed the increasing interdisciplinarity of their applications and theory. The spatial science community has been progressive in embracing changes in technology and practice, fuelled by a growing market. This is uncommon, however, and interconnections between the discursive communities of the ‘hard’ and ‘soft’ sciences are few.

In South Africa, geomatics qualifications at universities, like other engineering qualifications, are focused on maintaining minimum standards and covering specific technical knowledge areas (Winberg, 2008). In addition to this, current geomatics education in South Africa is an extension of the old surveying education which was developed during the apartheid era (and in turn was influenced by colonial education). Much of the professional surveying curriculum has been developed around cadastral surveying, which is the surveying and demarcation of land for the purposes of land ownership. During this development, power relations around the ownership of land were implicit. This paper reports on a digital storytelling intervention that was introduced into an undergraduate geomatics diploma programme at the Cape Peninsula University of Technology, and was theorised and navigated using critical posthumanism. Philosophically, posthumanism is an ambitious, holistic philosophy and this paper is intended to be introductory. A diffractive, cartographic

methodology is proposed and put to work in discussing the art/science divide in geomatics. Thereafter, the digital storytelling intervention is briefly discussed. This research forms part of a larger study on the use of posthumanism in higher education, and further explication and theorisation will be published elsewhere.

Posthumanism

Posthumanism is the historical moment that sees a convergence between anti-humanist philosophies on the one hand, and anti-anthropocentrism on the other. The basic characteristics of posthumanism are: overcoming humanism and humanist anthropocentrism, taking into account the nonhuman (i.e. animal, environmental and technological) others, and the affirmation of difference (Radomska, 2010). It is relatively new and has had important contributions from philosophers and theorists situated across a wide spectrum of thought. Posthumanism builds on the epistemological and ontological foundations of postcolonialism, anti-racism and material feminisms. Material feminism is closely linked to what has become known as new materialism, and prominent philosophers in the field of new materialism (such as Rosi Braidotti, Manuel DeLanda and Karen Barad) have contributed much to the development of posthumanist theory through their sociomaterial insights (Barad, 2003; Braidotti, 2013b; Delanda, 2006).

A problem with humanism is that it has developed into a European hegemonic civilizational model, and is typified by Leonardo Da Vinci's Vitruvian man. It is the ideal of human perfection – white, able-bodied, handsome, male, and youthful – and anything that is dissimilar is othered. It sets the standard for individuals and cultures, and its Eurocentric binary logic neatly places subjects into 'us' and 'them' boxes. Difference or otherness is equated to inferiority, and those branded as others are more often than not "the sexualized, racialized, and naturalized other, who are reduced to the less than human status of disposable bodies" (Braidotti, 2013b, p. 15). The western notion of human/nature (and other relationships of oppression) is strongly dualist and relies on a relation of domination/subordination (Plumwood, 1993). The racialized other is also extended to include non-Western and non-Christian others (Braidotti, 2009).

Critical posthumanism is a type of posthumanism that combines critical thinking with creativity. It aims to move beyond analytical posthumanism (which focuses on the science and technology aspects of posthumanism) and unlock the productive potential of posthumanism. According to Braidotti, the task of a critical theorist is to firstly account for the present. Once this is achieved, the critique can then be transformed into affirmative creation. Accounting for the present is a cartographic move.

Posthumanism attempts to traverse dualisms by developing a new understanding of difference (Van der Tuin & Dolphijn, 2012). Difference is seen as positive, and not in terms of a lack. Difference can be seen as a Deleuzian response to Western metaphysics' idea of difference, and in the classroom, students are encouraged to connect across difference.

Posthumanism represents a paradigm shift in the way we conceive of ourselves, our place in the world, and our subjectivity. Methodologically, it requires an analysis of *assemblages* and relations, as opposed to discrete people or things. Assemblages are products of specific historical processes, and analysis of assemblages can show that they are complex and in some cases, internally contradictory. This is especially relevant in the diverse South African university, which contains a multiplicity of influences, imperatives, socio-political realities, material conditions and relations. Posthumanism can be utilised as "both a genealogical and

navigational tool” (Braidotti, 2013b, p. 5). This allows for not just a ‘zig-zagging’ between theory and practice (Jackson & Mazzei, 2012; Lather, 2014), but also between critique and affirmation. In this regard, storytelling allows for complexity – stories can distil otherwise complicated ideas into tangible, understandable products, without necessarily losing important details. Donna Haraway, another influential feminist philosopher, is a strong advocate for situated storytelling as a means of knowledge creation. Stories can help to fulfil the posthumanist possibility of being both navigational and analytical – Haraway points out that “we need stories (and theories) that are just big enough to gather up the complexities and keep the edges open and greedy for surprising new and old connections” (2016, p. 101).

Hard and soft – why bridge the gap?

The interplay of science and art is encouraged to find points of compatibility between the humanities and the sciences. Braidotti points out that posthumanism can help to redefine the relationship between the ‘subtle’ and ‘hard’ sciences, and finds some interesting examples of studies that cut across both branches of knowledge (Braidotti, 2013a). Transversal connections across difference can be usefully harnessed, and this research is an example of such cross-pollination, approached from the direction of the geographical and technological sciences.

The division of labour has helped humankind to progress, by improving the overall efficiency of work processes. This is made possible by specialisation, where individual workers can focus on specific tasks within the overall process of production. The geomatics qualification, being a career-oriented, specialised qualification, produces surveyors, cartographers or GIS practitioners. Whilst I recognise this very important advantage, I am also critical of specialisation. As an employee, a specialist worker can lose overall sight of the aims of the company, and a specialist researcher risks seeing the world exclusively through her theoretical or methodological lens. Within the ‘family of professions’ too, specialisation results in once-close practitioners (such as surveyors, town planners and architects) seldom communicating or influencing each other’s work.

As a response to specialisation of geomatics-related professions, there have been calls for an increasingly multidisciplinary educational approach. This was to mitigate the effects of the increasingly isolated position that surveyors found themselves in, as well as an acknowledgement that relationships with other professions is important for success (Eekhout, 1989). While Eekhout focuses on collaboration with other related disciplines, I would go a step further and suggest that real value can also be found in traversing apparent boundaries between geomatics and other, seemingly unrelated areas. Haraway’s strategy of making ‘oddkin’ is important: “we require each other in unexpected collaborations and combinations We become-with each other or not at all” (Haraway, 2016, p. 4). It is in this spirit that I introduced a seemingly dissonant task into the GIS curriculum – one that involved students thinking about a social issue, and then performing an artistic exercise that would combine their spatial analytical and cartographic skills with digital storytelling.

A genealogical, diffractive analysis

The work of numerous philosophers and theorists (especially Braidotti and Barad) has been drawn on to develop an analytical and navigational framework which is appropriate to analyse and interpret the data that has been collected. The analytical tool of diffraction

(proposed by Barad) has been sharpened by empirical application (Barad, 2014; Hoel & Van Der Tuin, 2013; Sehgal, 2014; van der Tuin, 2014) and its ethics have been conceptualised and clarified (Thiele, 2014). A diffractive methodology seeks out the in-between spaces and does not subscribe to the masculine comparative methodology of pitting one theory against another. Insights are read through each other, sometimes enhancing each other's intensities, sometimes decreasing them, like diffraction patterns. Arising out of feminist theories, the methodology is concerned with subjectivity, relationality, positionality and trans-disciplinarity. Bridging the divide between art and science is important. Situated within geomatics higher education, I have drawn on geomatics theory, teaching and learning theory, non-representational theory, post-colonial theory, feminist theory, storytelling and new materialism. The intervention is one that is guided by a commitment to socially just pedagogy. Traditional power relations between lecturer and student have been problematised and students are given the opportunity to produce valuable teaching material themselves.

Diffraction changes the traditional way we think about ethics and ontology – Theile shows how these two concepts relate to each other more intimately, drawing on inspiration from Deleuze, who in turn was inspired by Spinoza (Thiele, 2014). Ethical thought is central to a diffractive interrogation of the world (Barad, 2007; Braidotti, 2006; Thiele, 2014) – it conveys a sense of being-in-the-world during practice as well as analysis. Barad(2007, p. 25) outlines the significance of careful, disciplinary observation in her methodology:

My aim in developing such a diffractive methodology ... is to provide a transdisciplinary approach that remains rigorously attentive to important details of specialized arguments within a given field, in an effort to foster constructive engagements across (and a reworking of) disciplinary boundaries

Foucault's work is influential in Braidotti's nomadic theorisation, and his genealogical method is incorporated into the analysis to make visible the link between knowledge and power. This is especially pertinent in surveying education, where its effects are manifested in power exerted over the land. Foucault (1980, pp. 50–51) alludes to the importance of the material in an effective analysis:

to make visible the unseen can also mean a change of level, addressing oneself to a layer of material which had hitherto had no pertinence for history and which had not been recognised as having any moral, aesthetic, political or historical value

Thus, a change of sensibility is needed, one that is attuned to finer details, material conditions, difference, and transversal connections.

Dualisms that correspond to and naturalise forms of oppressions (e.g. male/female, mind/body, civilised/primitive and human/nature) are rooted in historical processes and are preserved in culture (Plumwood, 1993). In the same way, the art/science dualism, with specific reference to cartography, is a dualism that has been constructed over time. The development of cartography is closely linked to improvements in surveying and mapping instrumentation, and most importantly, accuracy. Accuracy became the primary metric by which progress in cartography was measured. This scientific view of cartography did not always exist. In the supposed march of cartographic progress and with technological improvements, art has been dropped from the definition of professional cartography.

Cartography has seen a change in the *form* of maps – clay tablets, inscriptions on buildings, paper sketches, navigational charts and pixels on a computer screen are all ways through which spatial information has been communicated. Cartography went from being regarded as an art to a science in a period called the 'cartographic reformation'. This was an approximately one hundred year period between 1670 and 1770 which saw the decline in decorative artistry on maps, usually produced by single skilled craftsmen. This was replaced

by neutral white space, produced as a result of large-scale institutional surveys, using increasingly specialised instrumentation (Edney, 2011). Thus the cartographer went from being able to express himself artistically to being part of a specialised production line. Today, national mapping agencies produce anonymous, standardised mapping. J.B. Harley points out that maps are often viewed as models, ways of portraying reality, and are different from pieces of art, like paintings. Harley (1989, p. 4) says that

although cartographers have continued to pay lip service to the 'art and science' of mapmaking, art, as we have seen, is being edged off the map. It has often been accorded a cosmetic rather than a central role in cartographic communication.

One of Harley's most important philosophical insights is that maps help to construct the world, not just represent it. In addition to this, the practice of cartography is deeply implicated in acts of political advocacy, annexation, spatial ordering, and ideology propagation. The scientific view of mapping has given the public the impression that spatial information is "portrayed in a neutral, objective, impersonal, unadorned manner, and that maps disengage us from a personal, subjective view of the world" (Dorling & Fairbairn, 1997, p. 4) but "maps are not independent of the observer: maps are context-dependent, often available only to the initiated, unlikely to be value-free and should be viewed with caution" (Dorling & Fairbairn, 1997, p. 4). I would argue that even the 'initiated', namely students and teachers of mapping sciences, are largely unaware of maps being ideologically-laden communication and ordering devices. This is in part due to the curriculum, which interpellates and orders the student and lecturer, just as maps do. A diffractive analysis shows that environmental and ethical 'blind spots' are aided and encouraged by the promotion of a specific humanist subject through the practice of geomatics education.

It is through a complex interplay of power relations, changes in the environment (natural, cultural and technical), differences and repetitions, that things get produced. These things could be subjectivities, curricula, stories or other practices. The power relations within the schooling system, the academy and industry can be analysed to observe the workings of the relations between actants in the assemblage. The controversial system of Christian National Education (CNE) as implemented by the Afrikaner National Party government had a strong influence on the apartheid education policies that came afterward. The apartheid education system, like the town planning system, had far-reaching influence, and their effects are still observable in South Africa today. The post-apartheid government officially adopted a secular stand, as enshrined in the South African Constitution, yet there is a continuation of the Christian ethos. This is not only a South African phenomenon, and the conflation of secularity and Christianity has been observed since the end of the Cold War. This "myth of secularism" (Braidotti, Blaagaard, de Graauw, & Midden, 2014, p. 6) is based on the underlying connection between humanist values and Judeo-Christian values such as respect for the law, individual worth, autonomy, freedom, and rationality. These values were also most prized and promoted during the period of brutal colonial expansion. It should be noted that racism and colonisation of old is still alive and well in the world today, albeit in the form of neo-imperialism and prejudices towards many kinds of others. The visible neo-liberal agenda in the public sphere (for example the faith in the market economy and promotion of private property rights) produces statements from universities, and in turn produce curricula from geomatics departments. A Foucauldian approach looks at power as both restrictive and productive. Power formations function at the individual and group level; so do narratives, cultural representations and social modes of identification (Braidotti, 2013b, p. 26). For example, the technikon (the predecessor of the university of technology) surveying learning experience (including curriculum, the learning environment, the technology used, the

assessment and the administration) was dictated originally by the government department of education, then power was devolved to the institution, giving the technikon more power. Thereafter, the rise of the Geomatics Council (the statutory body controlling geomatics in South Africa), followed by the domination of the capitalist agenda and the growing influence of the market was, and continues to be, observed.

That dualisms are ideologically questionable is laid bare by Haraway's (1991) analysis of three crucial boundary breakdowns: human/animal, organism/machine, and physical/non-physical. These boundary breakdowns help in the negation of dualisms, and in the development of effective oppositional strategies. These boundary crossings are observed and actively engaged with in my teaching. It is a space where complexity and difference help to open up discussions and learning spaces.

The Storytelling Intervention

Storytelling was introduced in various geomatics courses, and was used in two main ways: stories that were told to the students by me, and stories that the students told.

Stories that I told

For the stories that I told, stories from African history were mainly used. The #feesmustfall student protests of 2015 and 2016 emphasised the need for decolonisation in the South African context. There are many aspects to the ongoing project of decolonisation, and the introduction of African knowledge was meant as a decolonising pedagogy. Each story was told through the lens of GIS, and the links to sections in the curriculum were made explicit. For example, I used maps and spatial analysis to tell the story of Ibn Battuta, the medieval Moroccan traveller who was a lesser-known yet more travelled contemporary of Marco Polo. I also chose to tell some very personal stories. One story focused on my early corporate career working for a large American oil company, and the reasons for my eventually leaving the job. I found that this allowed me to speak from my location, and opened myself up to connections with students that would hopefully enhance their power of being able to act. This ability to act comes from what Spinoza called joyful passions (Deleuze, 1988) and I attempted to form relations that enhance these in my students. The stories needed to grow awareness of alternative points of view, and promote dialogue.

Stories that students told

For GIS students, the climax of the storytelling intervention was the production of their own digital stories in a course entitled 'Spatial Analysis'. The details of the intervention have been reported on previously (Motala & Musungu, 2013). Students were initially asked to produce a professional mapping and cinematographic product that could be uploaded to the World Wide Web, one that they could be proud of. By the fourth iteration toward the end of 2015, the assessment had changed into a task that was more collaborative and focused on taking the students through a series of performances. What follows is an excerpt of the 2015 assessment task:

Tell a story using maps

You are to create a video that tells a story. The story must have a spatial component (you must use maps in telling the story), and must contain numerous spatial analysis techniques. The story could be your story or someone else's story. It could be about a social issue that you are interested in. The script must be written by you.

You may work in teams for this assignment. If you work in a team, do a story on an issue that both of you agree on.

Assignment process

1. *Story circle: This will take the form of a discussion, when each person/group will present their story to the class. You will present the basic idea of the story, the storyline, the main character/s, the maps and the analysis that you will produce.*
2. *Storyboard: You will hand in a storyboard that contains a graphic representation of your story. You must choose 6 (or less) of the most important scenes from your story, and draw it onto the storyboard.*
3. *Conference: You will play the video at a mini-conference for the rest of the class to watch. Your video will contain a narrated story (audio) and still maps (images) or moving maps (videos captured from the GIS). After each video, there will be a short discussion.*
4. *Questionnaire: In the week following the conference, you will be asked to complete a questionnaire about what you learnt during the term.*

Submission requirements

To pass this assignment, you must complete steps (1)-(4), in which case you will automatically get a mark of 50%. The remaining 50% will be based on the mark you obtain for your video submission.

The task had changed from originally placing much emphasis on the technical production of the digital stories, to a focus on process. A centrally important insight from non-representational theory is that representing (like creating a map using GIS) is a performance. Non-representational theory is about movement, it is anti-biographical, concerned with practice, and is experimental (Vannini, 2015). This guided the intervention, which attempted to accentuate and encourage student creativity, deep thinking, celebrations of diversity and connection across difference. A questionnaire (step 4) provided useful feedback on the students' experience of the intervention. Interviews were conducted with students, as well as with some graduates who had been through the intervention and gone on to work in industry.

Student stories

This research focuses on four iterations of the storytelling intervention, between 2012 and 2015. The average class size was 14 students and a total of 54 stories were told. Most students came from previously disadvantaged backgrounds, and experience barriers to success at university. These barriers include language barriers (many students have to communicate academically in their second or third language), financial barriers and other socio-material barriers. This intervention was intended to provide an alternative learning experience that could minimise some barriers.

The themes of the stories were varied, and reflect the diversity of the students. Students were encouraged to explore social issues, and subsequent discussions showed that some were influenced by my choice of stories. Autobiographies and documentaries were common, while some told stories of drugs, crime, disease and terrorism. Others focused on road trips or important personal experiences, such as initiation ceremonies. It should be noted that post-qualitative methodologies have been used in the analysis. A posthumanist data analysis has been described as post-qualitative (MacLure, 2013b) because, unlike traditional qualitative research, it does not consider coding as a fundamentally important method of extracting meaning from qualitative data (MacLure, 2013a). This does not mean that broad themes (such as those mentioned above) are not important. Themes are extracted and used, but this is not where the analysis ends. Just as much importance is given to data that glowed for me – note that this implies some agency on the part of the data. Attention is paid to outliers, my

intuition, differences, affect and movement. Of particular interest to me were stories in which students exhibited boundary crossing, or stories in which the human subject was decentred, or stories that combined critique with affirmation. Almost all digital stories, by their nature, were artistic, since they combined imagery, music, narration and text. The extent to which students allowed themselves to be immersed in the creative process was varied – some combined the elements into beautiful or disturbing stories, evoking affective responses from the viewers; other stories were impersonal, documentary-style and showed a resistance to stray too far from the scientific method. The sharing of personal stories is an exercise in diversity, helping students to connect with each other across difference. The stories themselves have agency and can shape the subjectivities of the humans involved.

Due to space constraints, I can only report in some detail on only one story, produced by an isiXhosa-speaking student who was inspired to trace his lineage back to Central Africa. This story was in part done in response to xenophobic violence that was taking place in South Africa at the time, particularly by South Africans against people from other African countries. The storyteller showed how his ancestors crossed boundaries (physical boundaries then, which would in some cases later become national boundaries) and ended up in eastern South Africa. He ends off the story with the following quote:

“Indeed, I am Xhosa, I am the son of Fikile, grandson of Laqhomfela, grand grandson of Pama. I am Mpodomise. I am Bantu. I am from the Great Lakes. I am originated from Central Africa”

Apart from condensing a large amount of historical research into a short story, the storyteller problematised the violence against people who were seen to be different, and then offered an affirmative take on this difference. It is a story that receives very affective responses from those who watch it, and has found its way into my curriculum. It is an example of students’ subjugated knowledge that can have rich pedagogic potential. The South African higher education system has traditionally been a site for those in power to subjugate certain knowledges, and to privilege others. Access to and success at university is still strongly correlated to social class and race (Badat, 2015).

Responses to this story by others who saw it show an appreciation for the history and difference:

“I also learn from [this] story because [this] story was based on our history of Xhosa people.”

“Other than working together with fellow students, it helped me understand the social issues they face. My topic was very close to my heart, I’ve always wanted to research my heritage, and this project just opened a new door to discovering who I am.”

The storyteller was interviewed after graduating and expressed the positive effect that the story has had – it provided a new set of presentation skills, and also impressed his employers who were able to learn more about him and his abilities. The story, being produced by a human-machine assemblage communicates across multiple temporalities, and makes transversal connections between varying disciplines.

Other performances allowed interesting patterns across difference to emerge in the analysis. The specifics of the phenomenon being investigated are crucially important. As a feminist practice, the importance of creating embedded and embodied knowledge is emphasised. Phenomena like recognisability, ethical practice, knowing, the difference between subject and object, and human subjectivity all emerge out of specific material arrangements (Barad, 2007). With regards to situated knowledge, Hughes and Lury emphasise the methodological

“necessity of articulating dynamic intra-actions between human and non-human forces” (Hughes & Lury, 2013, p. 786). In teaching GIS, the relations between students, computers and GIS software are centrally important for learning to take place. This is one of the reasons that typical written assessments are sometimes unsuitable for use in subjects like GIS.

The analysis of the intervention does not ascribe to standard quantitative or qualitative methods. An over-reliance on codes is eschewed in post-qualitative methods. The storytelling intervention, like the curriculum it is situated in, is in a state of constant becoming, subject to constant change and a range of historical processes. Simple comparison of metrics (such as pass rates across cohorts), and codifying student responses, while useful, does not adequately capture movement. Analysis can show how “discourses and texts materialize and, at the same time, produce subjectivities and performative enactments” (Mazzei, 2014, p. 745).

Conclusion

A critique of this intervention is that, despite its intention to disrupt barriers to success in higher education, it perpetuated some inequalities, specifically around digital ability and access. Varying experience with and differential access to computer facilities (e.g. access to their own laptops) showed in the quality of the final products. This was one of the reasons that the focus of the assessment shifted from the final digital product, to performativity. Subscribing to a process ontology, the storytelling intervention continues to change over time.

While this is not an attempt at a fundamental redesign of the architecture of the curriculum, the storytelling intervention allowed for a part of the curriculum to be dictated by students’ own affects, intensities and flows. It was a micro-instance of critique, flow and activism within the sedimented curriculum. It usefully pays attention to what Braidotti calls “micropolitical instances of activism, avoiding overarching generalizations” (Braidotti, 2011, p. 269).

At a larger scale, what is included (and what is therefore excluded) in the curriculum is a boundary drawing practice (Barad, 2014) which needs to be carefully considered. The surveying worldview is one of boundaries and hard edges, and it is difficult to reconcile liminality. The human surveyor, the land, the surveying technology and the practice of surveying and mapping are co-constitutive and co-evolutionary. A historical lack of interrogation of social and environmental issues in the curriculum has contributed to an inertia of action, a deep-seated unwillingness and inability to conceive of action on these fronts.

In a deliberately playful yet resistant stance, I have chosen to disrespect the boundary between art and science. I have engaged in what Haraway calls art/science activism (Haraway, 2016), using the navigational potential of storytelling to chart a path towards an ethical becoming. This is combined with the analytical potential of diffraction, in which connections are sought out to inspire the navigation.

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Improving employability skills of students through laboratory and practical work

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Abstract

The purpose of this paper is to discuss laboratory work and hands on training that will be offered to students who will be studying a new curriculum, Bachelor of Engineering Technology Degree (BEngTech) in Industrial Engineering Technology at the University of Johannesburg. The university has introduced a new 3 year curriculum, BEngTech, across its Technology based programmes. The new curriculum is going to be rolled out for the first time in 2017. The university is in a process of phasing out the National Diploma and Bachelor of Technology degrees. The new BEngTech curriculum does not have the traditional one year Work Integrated Learning component that used to be part of the National Diploma, hence the need to include new practical based laboratories. The practical work in the new BEngTech degree has been designed to improve the employability of the BEngTech graduates.

The new laboratory and practical work have been designed to include employability soft skills such as teamwork, communication, critical thinking, planning and problem solving. A desktop research was carried out in the Industrial Engineering Department at University of Johannesburg. The research looked at how the new laboratories have been designed, how they will be assessed and in particular how they will fulfill the expected employability skills. The results of the study showed that students will solve real industry based problems. In some of the laboratories students will have to develop a programme, simulate the programme and then download the programme to physical equipment. Some of the laboratories include “noise” factors that are random with systematic errors and students will be asked to remove these noise factors. The impact of the new laboratories will only be evaluated when the BEngTech students graduate and join industry.

Keywords: employability skills, new laboratories and practical work and graduate attributes.

Introduction

The delivery of an engineering curriculum has traditionally been through lectures, supported by tutorial, practical and laboratory work, (Covill et al. 2007). The importance of practical and laboratory work were summarized by (Davies, 2008), as: “they motivate students and stimulate their interest in the subject; they help students to deepen their understanding through relating theory to practice; provide opportunities for students to work together in analyzing and solving engineering problems; develop skills and attitudes that will enable graduates to operate effectively and professionally in an engineering workplace”. Employers expect graduates that have discipline-specific and technical competencies, as well as a broader range of

employability skills, often called soft skills, and these include teamwork, critical thinking, leadership, problem solving, planning and communication, (Lowden et al. 2011) This paper highlights how employability factors have been factored into the laboratory and practical work to be done by students studying towards the new BEngTech qualification.

Literature Review

This paper focusses on the training of professional industrial engineering technologists, . These technologists are expected to play important functions in engineering teams, usually they are involved in manufacturing, planning, maintenance, quality assurance, continuous improvement and supply chain. These activities require graduates who possess employability skills. Industrial engineering graduates are expected to participate and contribute to the South African economy through the use of their skills and knowledge in developing and optimizing factors of production and manufacturing, including service industry, (Zandin, 2001). (Stevenson, 2008), further articulated that industrial engineers focus on business efficiency by optimizing industrial manufacturing and service operations through efficient use of materials, equipment, people, information and energy. (Ngetich & Moll, 2013), identified major industrial engineering disciplines as: Enterprising engineering; Systems engineering; Operations management; Applied industrial engineering and Engineering management. Industrial engineers are employed in the categories: industrial technician, industrial technologist, and industrial engineer, (Nel, 2010).

Employability Skills

Employability skills are the basic skills necessary for getting, keeping and doing well at a job, (Robinson, 2000). Companies hire engineers with technical knowledge, professional skills and good attitude. Engineering Career Services (Engineering Career Services, 2014) summarized professional skills most engineering employers want to see in engineering graduates as: “safety awareness, cultural adaptability, innovation, continuous learning, engineering knowledge, communication, planning, quality orientation, teamwork, analysis and judgement and customer focus”. The new laboratories and practical work done in the new BEngTech curriculum covers some of these competencies. The next section describes some of the soft skills embedded in the new laboratories.

Planning is the starting point in any management process and it determines what an organization wants to achieve and how resources will be deployed in attaining the set goals, (Smit & Cronje, 2007). Planning gives direction to an organization, promotes cooperation among various departments and encourages management to look into the future, (Phan & Matsui, 2011). Normally the planning process has three stages strategic, tactical and operational, (Schniederjans et al. 2006). The planning expected from students when there are running their laboratories and practical work is operational. However when students join industry they will be exposed to all three levels of planning.

Teamwork involves a series of activities where two or more people work together towards a common goal. Smit & Cronje (2007), defined a team as “having small numbers of members with shared leadership and its members perform interdependent jobs with individual and group accountability, evaluation and results”. (Sandler Training, 2015), summarized the benefits of teamwork as that, “ it encourages creativity and learning, increases morale, brings together complementary strengths, builds trust, teaches conflict resolution skills, promotes a wider sense

of ownership”.

Problem solving is a methodological way of finding solutions to challenging issues. There are various approaches that can be used in solving problems, but they must be logical and procedural including investigative and innovative skills, working in a team and good communication, (Ngetich & Moll, 2013). Stages usually followed in solving problems include evaluating the problem, identifying solutions, selecting the best solution and testing and reviewing the solution. In this paper students will be given practical industry based problems that they will be asked to solve in groups.

Leadership initiates change, with a new vision for the organisation, encouraging as well as motivating people to support the new initiatives, (Kotter, 1990). Top management leadership creates goals, values and vision that guide the pursuit of business activities of an enterprise, through the promotion of creativity, (Brake, 1997), developing integrated teams, defining and communicating the shared vision and generating compromise, (Goetsch & Davis, 2006). A good leader creates an enabling environment through their inter-personal relationships and influences others in the change initiative, (Das et al. 2011). Leaders play three roles, namely setting direction, aligning people and motivating and inspiring people, (Kotter, 1990). Of interest in this paper is the leadership traits, (Mills et al. 1998), imparted to students when they are carrying out their laboratories and practical work.

Communication involves the process of transmitting meaningful information. At managerial level communication occurs in three levels intrapersonal, interpersonal and organisational, (Smit & Cronje, 2007). Of interest in this study is the interpersonal communication done by students when they are carrying out their laboratories and practical work. The communication skills imparted to students include both verbal and written technical reports.

Old and New Industrial Engineering Technology Curriculum

The curriculum of the National Diploma, which is being phased out, is that students would complete 26 Academic modules offered in two years, in four semesters known as S1 to S4, and then go to industry to do work integrated learning (WIL), (P1 and P2), for one year. The nature of problems covered by students in the National Diploma are well defined whereas in the new curriculum the problems will be broadly defined. The WIL training served the purpose of relating theory to practice and gave students the much needed industry exposure. On completion of the National Diploma students would then enroll for the Bachelor of Technology Degree, which has 8 modules and normally takes one year to complete. Students exited the National Diploma at National Qualification Framework (NQF) level 6 and the BTech at NQF level 7. The new BEngTech curriculum has a total of 31 modules and a final year Capstone project. The new BEngTech degree will be taught in 3 years. The BEngTech curriculum does not have the WIL component, hence the need for the lecturers to design laboratory and practical work that would expose students to real industry based problems and to enhance the development of employability skills. The BEngTech is at NQF level 7, (ECSA, 2009).

The new curriculum is expected to fulfill a set of 10 Graduate Attributes, prescribed by the Engineering Council of South Africa (ECSA). ECSA is the custodian of engineering teaching and learning standards in South Africa. ECSA accredits all engineering degrees in South Africa and is a signatory to international bodies such as the Washington Accord, Dublin Accord and Sydney Accord, and this makes an ECSA accredited program to be internationally accepted,

(ECSA, 2009).

ECSA Credits and Graduate Attributes

ECSA characterized Professional Engineering Technologists as having, “the ability to apply established and newly developed engineering technology to solve broadly-defined problems, develop components, systems, services and processes”. The new BEngTech curriculum is guided by ECSA’s standards for accrediting a Bachelor of Engineering Technology-type programme. The accreditation criteria is defined in terms of programme design criteria, a knowledge profile and a set of 11 Graduate Attributes, (ECSA, 2009). According to ECSA the new curriculum must have a minimum of 420 credits spread over knowledge areas of Mathematical Sciences, Basic Sciences, Engineering Sciences, Engineering Design and Synthesis, Computing and IT and Complementary Studies. The 11 ECSA Graduate Attributes are:

1. Problem solving
2. Application of scientific and engineering knowledge
3. Engineering Design
4. Investigation
5. Engineering methods, skills, tools, including Information Technology
6. Professional and Technical Communication
7. Impact of Engineering Activity
8. Individual, Teamwork and Multidisciplinary
9. Independent Learning
10. Engineering Professionalism
11. Engineering Management

The new laboratories and practical work designed for the new BEngTech: Industrial incorporates some of the graduate attributes such as problem solving, engineering design, professional and technical communication, individual and teamwork, independent learning and engineering professionalism.

Objectives of engineering laboratory work

Edward, (2010), highlighted that practical work falls into four main groups:

1. Cognitive learning which focusses on the integration of theory and practice.
2. Inquiry methodology which includes hypothesis forming, experimental design and methodology and evaluation of results.
3. Vocational aims which includes awareness of current practice and the inculcation of professional ethics.
4. The development of personal skills such as communication, report writing and team working skills.

The new laboratories and practical work designed by the academic staff focusses on cognitive learning and the development of personal skills. The importance of designing objectives for instructional laboratories was emphasized by, (Feisel, 2005) , who stated that laboratory practical work becomes efficient when it has clear objectives, specific targets and some improvements can be made. Feisel, (2005) presented 13 fundamental engineering instructional laboratories objectives. This paper will focus on the following objectives: data analysis, design,

learning from failure, creativity, psychomotor, safety, communication, teamwork, ethics in the library and sensory awareness.

Research Objectives

The research objective of this paper is to analyze how the new practical laboratory work that has been designed for the new BEngTech curriculum will enhance employability skills of the BEngTech graduates.

Research Questions

How do a laboratory practical enhance understanding of theory and practice?

How do the developed laboratory and practical work offer opportunities to students to develop employability skills?

Methodology

This paper employed a desktop study approach, which involved the gathering and analysis of existing laboratory and practical work designed for the new curriculum. The study was undertaken from February to March 2017 to obtain and examine the new laboratory practical work that has been designed for the new BEngTech degree in Industrial Engineering Technology. The desktop study involved the gathering and analysis of the relevant documents. The main focus of the study was to review how the new laboratory work would address the teaching of employability skills to our BEngTech graduates. The main sources of information were learner guides and laboratory instructional material of selected modules: Facility Layout and Materials Handling, Engineering Mechanical Manufacturing, Automation 3 and Engineering Work Study 1B. The laboratory material was used to explore to what extent the proposed curriculum provides opportunities for students to learn the valued employability skills.

Findings:

This section discusses three laboratories and practical work that will be done by students in the new curriculum, and these laboratories will be known as Laboratory 1, 2 and 3. All laboratories focused on enhancing the understanding of theory and practice as well as enhancing employability skills. The name of the subject, theories taught, sample questions, how the laboratory will be done and assessed will be presented. An analysis on how the employability skills learnt per laboratory and practical work will also be discussed. The final section discusses both students and staff members' comments on the new laboratories.

Mechanical Manufacturing Engineering and Automation laboratories are first simulated in the computer laboratory before students download the developed programme and circuit into a computer attached to the physical equipment. Simulations give students some ideas on how the physical equipment will execute their programme. Students can see if their design is correct through simulation and when their design is wrong they make improvements. This is important because it ensures safety and reduces time taken by students on the actual physical equipment.

Laboratory 1

Subject taught: Mechanical Manufacturing Engineering

Theories taught for this laboratory include material handling and identification which looks at material transport systems, storage systems and automatic identification and data capture. Manufacturing systems theory focusses on single station manufacturing cells, manual assembly lines, automated production lines and assembly systems.

Laboratory Learning Objectives

To foster a deep approach to laboratory learning by encouraging students to take personal initiative (e.g. planning, experimental design, choice of variables, selection of materials and methods).

Students are presented with real life problems including a series of research questions. Suggestions for resource materials and a range of equipment/materials to choose from is also provided to students.

The following ECSA Graduate Attributes are assessed in Laboratory 1:

Graduate Attribute 1: Problem Solving

Graduate Attribute 3: Engineering Design

Graduate Attribute 6: Professional and Technical Communication

Graduate Attribute 8: Individual and Teamwork

An example of a laboratory question presented to students **is the following:**

E.C. Nkosi Precision Engineering, is a company based in Wadeville – Germiston. The company has introduced some automation in their manufacturing line. A component is placed on the conveyor belt by a robot. The workpiece is brought to the range of the machine tool. The workpiece gets machined and afterwards the conveyor moves on. Your focus is on the movement of the workpiece on the conveyor belt and the machining. The number of students in a group must not exceed 4.

Students are expected to:

Design a programme using the Soft-Logo software.

Simulate the programme.

Download the programme into a PLC attached to the physical Fischer Technique equipment that has a conveyor belt with a machining tool.

Run the machine.

Assessment Criteria

Two assessment criteria will be used. Students will assess each other and the laboratory Technician will assess the whole group. The student's final mark will be an average of the laboratory technician's mark for the group and the marks awarded by the student's laboratory group mates. They will be assessed according to the attached marking rubric. Students need to rate their team members' participation and contribution using the following scale of 1 to 5, where 1 is poor, 2 is fair, 3 is good, 4 is very good and 5 is excellent. Individually submit your marks to the laboratory technician.

Student peer-evaluation sheet

Level of quality of participation and contribution.

Aspect	1	2	3	4	5
Planning					
Time management					
Problem solving					
Design					
Teamwork					
Communication					
Report writing					

Figure 1 shows a possible solution that will be presented by the students. This solution will be simulated in the computer laboratory before it is downloaded to the physical equipment. The laboratory technician will check if the solution is correct and award marks as well as give permission for the programme to be downloaded to the physical equipment.

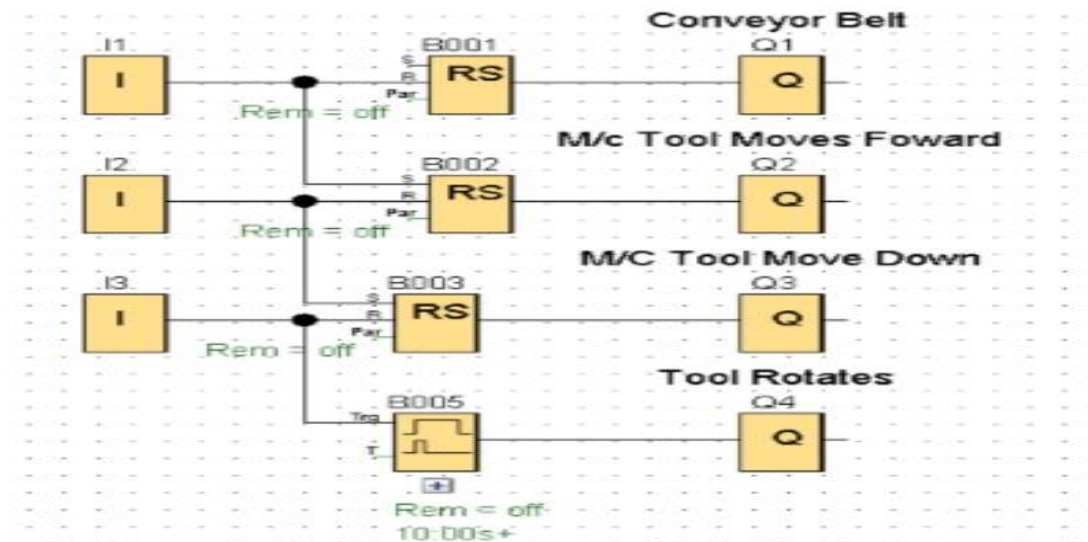


Figure 1. Soft-logo part-programme for a Punching machine with a conveyor belt

Figure 2, below shows the conveyor belt with a machine tool connected to a PC and a Siemens PLC. Once the programme has been downloaded the physical equipment will move according to the programme uploaded and students will be able to simulate an industrial process.



Figure 2. Conveyor belt with a machine tool attached to a PC

The assessment criteria used in Laboratory 1 makes use of the employability skills framework of planning, time management, problem solving, teamwork and communication. It is clear that students rate each other on these soft skills and by doing so they learn the importance of employability skills. Good teamwork results in better planning, communication and improved problem solving.

Laboratory 2

Subject taught: Automation

Theories taught on this subject include automation, industrial control systems, industrial robotics and programmable logic controllers.

Learning objective: After completing this exercise students will be able to implement an AND operation and be familiar with one option for end-position sensing in cylinders. Laboratories are based on Festo Pneumatic and Hydraulic workbooks, Fluidsim software, workbench and equipment. Automation laboratories are assessed individually.

The following ECSA Graduate Attributes will be assessed in Laboratory 1

Graduate Attribute 1: Problem Solving

Graduate Attribute 3: Engineering Design

Graduate Attribute 9: Independent Learning

An example of a question:

A rotary indexing machine is used for feeding workpieces in a production process. The workpieces have to be clamped in the individual workpiece holders for machining. A clamping tool is to be developed and tested by means of a test set-up. This is an individual laboratory exercise.

Students use Festo Fluidsim software in answering the question. Student solutions are as shown in figure 3. The circuit is developed and simulated first and then another electro-pneumatic circuit will be constructed and simulated as well. Some of the exercises will be downloaded into a PC attached to a physical Festo equipment as shown in figure 4. Students will then actuate the equipment using their designed circuits. Some of the practical work involve students constructing and actuating pneumatic circuits on Festo workbenches.

The assessment of Laboratory 2 focusses on the creativity and problem solving skills of an individual student. Independent learning is assessed through the individual assignment that are given to students. These assignments requests the student to automate any process of his or her choice. The submitted assignment reports indicates the use of programmable logic controllers and pneumatic circuits.

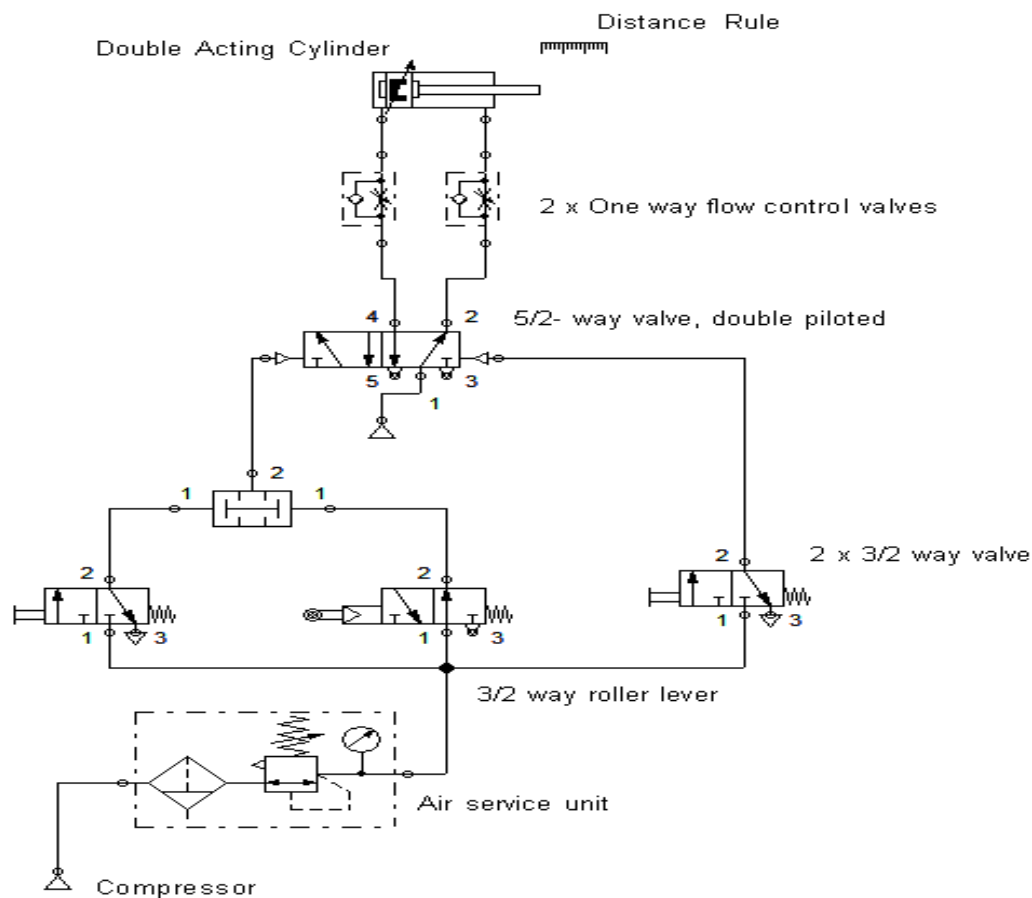


Figure 3. Pneumatic circuit



Figure 4. Festo Pick and Place equipment connected to a PC

Laboratory 3

Subject taught: Engineering Work Study 1B

The theories taught are method study, time study and ergonomics.

ECSA Graduate Attribute 8: Individual and Teamwork, is assessed in this laboratory.

An example of a question: Students are expected to assemble a truck.

Learning objectives are that students will be able to complete a process chart of a real process, be able to use a stopwatch, break a process into elements, understand how rating works and be able to summarise results. Calculate basic time, per element as well as work content.

Students are expected to assemble a truck, shown in figure 5. Students are also given the instructions and guidelines on how to assemble the truck. As part of their planning process students are expected to go through the instructions and come up with a process flowchart. The assembling and dis-assembling of the prototype-trucks gives students some practical hands-on training including the valuable soft skills of planning, communication and teamwork.



Figure. 5 JICA truck used in the Method study and Time Study practical

Instructions for laboratory 3 indicates that each student must have an opportunity to use a stopwatch and record time taken by their group mate in assembling a wheel. As part of their planning process students are expected to come up with a work breakdown structure (WBS) of assembling the whole truck and process chart as shown in figure 6. Laboratory 3 is assessed using the same assessment criteria described under laboratory 1.

Description	Symbols					Remarks
	○	➡	◐	◻	▽	
Pick up machine and wheel holder	○					
Combine machine and wheel holder	○					
Position and screw wheel holder	○					
	○					
Check if wheel are not too tight				○		
Pick up side member		○				
Position side member on panel floor	○					
Pick up assembled wheel		○				
Position assembled wheel	○					
Pick up bolt and washer		○				
Insert bolt underneath and washer	○					
Pick up the M8 nut		○				
Position the nut on the bolt	○					

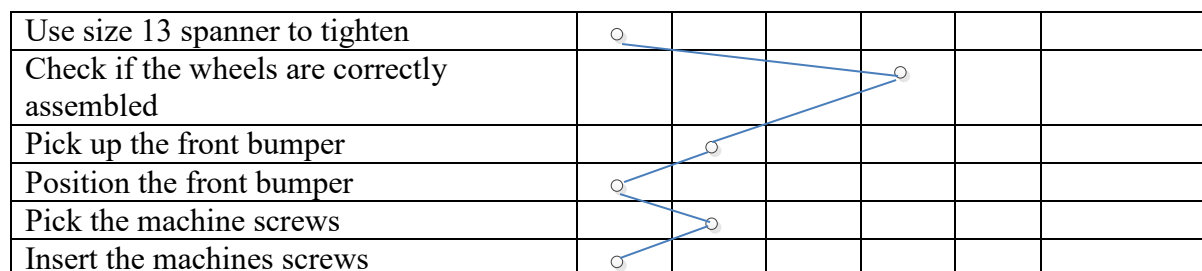
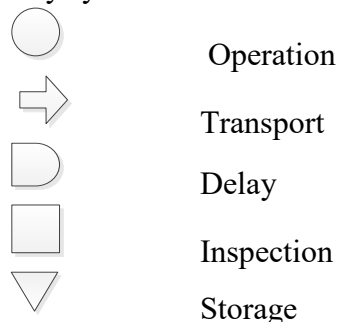


Figure. 6 Part of a Process Chart of assembling a truck

Key symbols



The assessment criteria used in Laboratory 3 is similar to the assessment of Laboratory 1 and makes use of the employability skills framework of planning, time management, problem solving, teamwork and communication. This laboratory emphasize hands-on approach. At the end of the assembly students rate each other on these soft skills. Good teamwork and communication results in better planning, and quicker assembly of the truck.

Student Feedback

The three lecturers who have developed the new laboratories had informal discussion with National Diploma students who completed S4 in 2016 and current S3 students who are studying towards the National Diploma in Industrial Engineering. The 2016 S4 students participated in all the labs and the current S3 students have participated in the work study and time study laboratory, where they assembled a truck. Both groups of students showed that they learnt more by linking theory to practice. In the laboratory, where students assembled the trucks, students identified teamwork, communication and planning as important aspects.

The use of stopwatches in executing time study practical in the assembly of the truck excited most students. Comments written by students on the submitted laboratory reports show that students appreciated the importance of soft skills in a workplace. The teams that finished the assembly of the truck in time resembled good leadership skills, good communication, better planning and strong teamwork spirit. Some teams failed to complete the laboratory in time due to poor planning, weak communication which was caused by one or two individuals who wanted to dominate the team, making teamwork almost impossible. Students disliked disassembling of the trucks and the general up-keep of the laboratory where they are expected to pack all items including the tools that they will have used. Some students complained about the time allocated for the assembly of the truck as being too short.

The Manufacturing Engineering laboratories showed that students were able to solve given problems. Students enjoyed both computer simulations and the physical movement of the equipment from the downloaded programme that students will have developed. However the lecturer in charge of this subject noticed that students took time to come up with a correct solution. This could be attributed to poor preparation and students failing to relate the relevant theory to practice. Students' self-evaluation marks were observed to be rather inflated, that is, students gave each other high marks. The technician's overall mark was then used to normalize the marking scheme.

The Automation laboratories were done individually. Students indicated that they are able to solve problems related to automation. However it was noticed that most students were struggling to construct electro-pneumatic circuits. This could be due to the fact that our students perform badly in the Electro-technology subject offered during their first year.

Staff Feedback

Five staff members, three academics and two technicians were asked to give their feedback on the laboratories that have been conducted so far. Two of the academic staff members had a minimum of 9 years lecturing experience and the third one had 19 years.

The laboratories designed by these lecturers focused on a variety of key factors that include applying theory, enhances student laboratory experience, encourages students to focus on soft skills which are planning, communication, teamwork, problem solving and report writing. Overall the laboratories have been designed to improve the learning experience of students through hands-on approach and working in teams. The lab work integrates theory and practice. The laboratories emphasizes on a hands-on approach where students have to make personal initiatives in planning and coordinating their activities.

Students are given real industry related problems to solve. However the laboratories that have been designed so far does not include the development of inquiry skills which are required for research, but rather they focus more on the preparation of the graduates for professional practice. The staff members believe that the laboratories and practical work will help students to engage with reality while still studying and this will make the students more competitive and employable.

One of the lecturers in charge of Engineering Work Study indicated that industry has mentioned in many of the visits that time study is a skill the students need to practice so that they can apply when they are at work. Laboratory 3 exposes students to time study practical through assembling of a truck and again in another assignment they need to do in industry.

Conclusion

The results of the study show that the Industrial Engineering lecturers have developed a set of modules that incorporate practical work in the form of laboratories and hands on training to improve on the employability of the new BEngTech graduate. Evidence from student marked scripts showed that students were able to design programmes and circuits in solving real industry based problems. Students showed creativity when they came up with different solutions to the same presented problem. Safety issues were improved by simulations before students would make use of the physical equipment. The assembly of the truck practical

showed that students can effectively work in teams, they can allocate each other roles and duties and incorporate their different contributions into the final solution. Student feedback shows that a laboratory can be used to enhance understanding of theory and practice. Group practical work and laboratories teach students the importance of employability skills such as planning, communication, problem solving and teamwork.

The limitations identified in this study were that Industrial Engineering lecturers are still holding workshops on trying to improve on best practices of assessing the 11 ECSA Graduate Attributes. While trial runs of the designed laboratories have been done on National Diploma students, there is need to assess students who will be studying towards the new qualification BEngTech: Industrial Engineering.

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Emerging student-centred perspectives on work placement as a component of mechanical engineering technology education

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Abstract

The paper reports on a qualitative study that explores how work placement experiences of mechanical engineering students affect perceptions of their own competency development. The study focuses on twelve information-rich cases. Data for the study was collected using semi-structured interviews that were conducted with students at the end of their placement period. It was transcribed, coded and analysed. Resulting themes and categories were then compared with the core concepts of social cognitive theory. Seven distinct category themes were identified from the analysis: student work actions, organisational contextual factors, mentorship structure and quality, personal factors, social networks, competency development, and work tasks. Organisational culture emerged as a regulator of the triadic reciprocal causation of learning in the workplace. Two types of organisational culture were discovered in the study: rigid culture and affiliative culture. A rigid culture limits student access to both authentic tasks and appropriate mentoring. The reciprocal effect of students' approach to work solicitation, personal agency and self-efficacy are of lesser strength in a rigid culture. The dominance of organisational culture falls away either when there is a formalised mentorship scheme or in an affiliative environment. It was found that in the latter culture, student approach to work allocation is a major influence on competency development.

Introduction

Since 2014, South African Universities of Technology (UoTs) have had an option of offering a 240-credit diploma which does not prescribe work integrated learning (WIL) that includes work placement or a 360-credit diploma that includes six months of work placement as a component of WIL (Council on Higher Education, 2011a). Availability of the first option was mainly in response to the many challenges around work placement of students. One key challenge faced by the UoTs is the growing resource constraints as there is a dwindling pool of companies that are willing to host an ever-increasing number of students (Council on Higher Education, 2011b). Student headcount in South African public universities is rapidly increasing, with growth by 23% reported between 2008 to 2013 (Council on Higher Education, 2016). The increased enrolments have placed a huge administrative burden on universities to place, monitor, support and assess students. For the second option, the duration of work placement was reduced from twelve months, as is the case in the current diploma, to six months to accommodate new subjects.

WIL encompasses a diversity of curricular practices such as job shadowing, industry based projects, apprenticeships, service-learning, scenario-learning, work placement and others that

share the pedagogical goal of integrating formal learning and workplace concerns (Council on Higher Education, 2011b). For this paper, WIL is limited to work placement. Despite the implementation challenges, WIL is considered to provide substantial benefits to students, universities, and industry (Lock, Bullock, Gould, & Hejmadi, 2009). According to Keleher, Patil, and Harreveld (2011), WIL facilitates the transition from graduate to worker by supporting the development of employability attributes of graduates. In addition, Brooks & Youngson (2014) stated that employers have positive views of graduates that have had appropriate work experience during their studies. Students who have undergone some form of work experience during their studies are more likely to gain graduate level work upon graduation (Brooks & Youngson, 2014).

In a UK study by Lock et al. (2009) on mechanical engineering students' work placement experiences, most of their respondents reported a positive perception of work placement. The students recognised the role that work experience gained during placement was likely to have in enhancing their career progression and post-graduation employment prospects. The students claimed that work placement increased their confidence, maturity, interpersonal skills, and aptitude for learning. These findings were supported by an institutional-wide study at the University of Huddersfield by Brooks and Youngson (2014). While the latter study did not find any statistically significant difference between employment rates of work and non-work placement students, they reported that 80.8% of work placement and only 53.8% of non-work placement students managed to secure appropriate graduate level jobs upon graduation. Similar employability benefits and positive student work placement experiences have been reported in studies from other Organisation for Economic Co-operation and Development (OECD) countries.

A study by Reinhard, Pogrzeba, Townsend, and Pop (2016) claimed that work placement benefits, such as those reported in the Lock et al study, might not be present in South Africa as its industry might not be able to readily provide sufficient opportunities for students. This scepticism is shared by some South African researchers such as Mutereko and Wedekind (2015) who doubt the efficacy of South African industry as learning places. They suggested that since workplace conditions in host companies are not heterogeneous, student placement experiences vary in terms of their educational value and quality. Mutereko and Wedekind (2015) claimed that this diversity in experience undermines the value of WIL as an educational practice. They also reported that there is a perception that South African employers use WIL students as a source of cheap labour. However, other South African studies by Du Plessis (2010) and by Jacobs (2015) have reported positive experiences by work placement students. They reported that South African companies prefer to employ WIL student upon graduation than non-WIL students mainly due to their perceived knowledge of the work environment.

It is evident from the above that there is no consensus in South African literature on whether or how work placement promotes competency development of engineering students. This paper explores this by focusing on experiences of mechanical engineering students during work placement, and how these experiences affect their perceptions of their own competency development and employability. The perceptions of other stakeholders such as employers and academics will be reported on in later work.

Theoretical framework

Martin et al. (2014) claimed that social cognitive theory is one of the most influential theories that are used to explain mechanisms of behavioural change resulting from public health or mass media campaigns. Applicability of social cognitive theory is not limited to the above fields, it can also be used to explain learning within other social contexts such as the workplace (Snowman, McCown, & Biehler, 2012). Central to social cognitive theory is the bi-directional interaction of behavioural patterns, personal factors, and the physical and social-structural environment (Bandura, 1986; Ormrod, 2016). A student's personal factors, behaviour during placement, and organisational contextual factors at a particular workplace interact in a triadic reciprocal causation system for competency development and employability (Bandura, 1986). The bi-directional influence of the above three elements is called triadic reciprocal causation and can be represented as shown in Figure 1. Bandura's triadic reciprocal causation model posits that a person's learning is a result of interactions among personal, behavioural, and environmental factors.

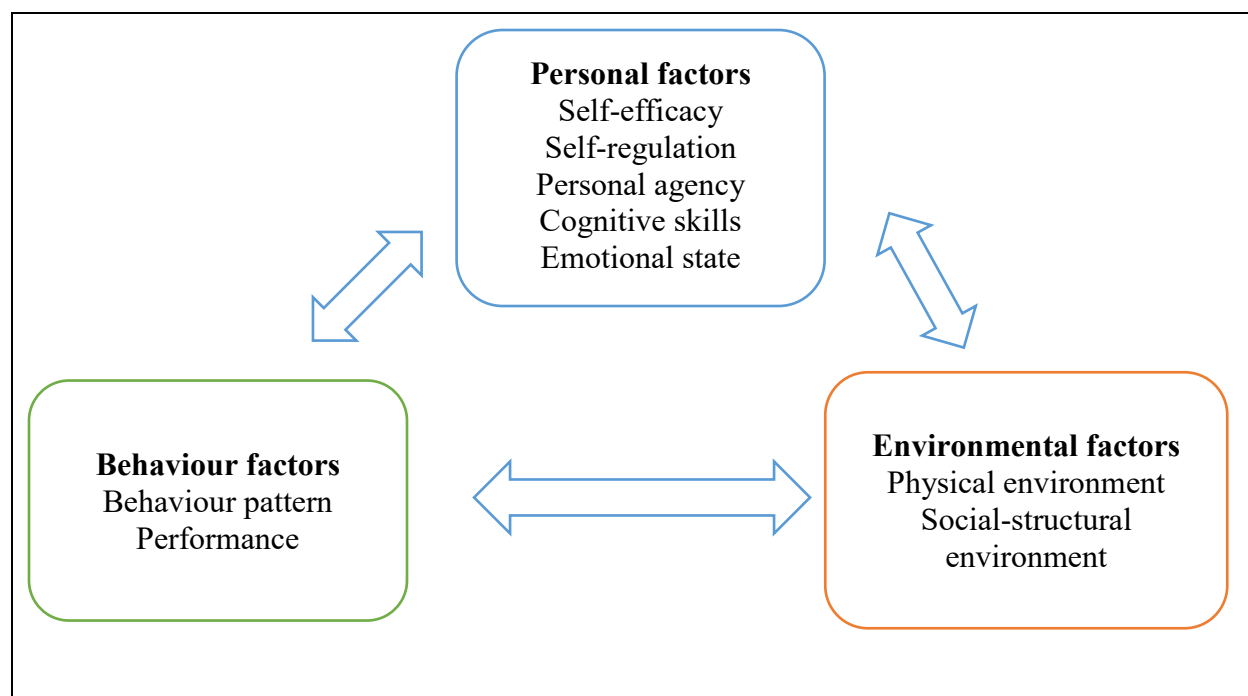


Figure 1. Bandura's triadic reciprocal causation model (adapted from Snowman et al., 2012)

Causal elements in Bandura's triadic reciprocal model do not necessarily exert influence of the same strength (Bandura, 1986; Ormrod, 2016; Snowman et al., 2012). The relative strength of a particular causal element depends on context. Also, the elements do not act simultaneously. It takes time for causal factors to exert influence and to activate reciprocal response from the other causal elements. Bandura's triadic reciprocal causation addresses both the development of competencies and the regulation of human action (Olson & Hergenhahn, 2013).

Personal factors include personal agency, self-efficacy, self-regulation, cognitive skills and emotional states. Personal agency is the capacity for one to exercise control over one's own thought processes, motivation and action (Bandura, 1989). Social cognitive theory provides a framework that recognises that people act as agentic operators in their lives (Bandura, 1986). They are not merely onlookers of brain mechanisms destined to respond to environmental events (Bandura, 2006). Neither are people's actions and behaviour solely the product of internal processes nor are they mechanistic responses to environmental stimuli (Bandura, 1986). Although not autonomous, people are contributors to their own destiny, their thoughts serve a determinative function (Bandura, 1986; Snowman et al., 2012). Social cognitive theory posits that people, and not environmental forces, are the predominant cause of their own behaviour (Bandura, 1986).

Research design

The study focused on twelve information-rich cases that were selected using maximum variation purposeful sampling. Suri (2011) and Benoot, Hannes, and Bilsen (2016) recommended maximum variation purposeful sampling for qualitative studies that seek holistic understanding of patterns and essential features that cut across variations of a phenomenon such as work placement experience. Participants were sampled across nationality, type of host company, prior exposure to work experience, and race. One of the WIL coordinators who is responsible for placing, monitoring, and assessing WIL students served as a key informant for the study and assisted in identifying potential participants who fit the study criteria. An individual student served as a unit of analysis.

Patton (2015) warned that a trade-off between breadth and depth of a study often dictates the smaller sample size for an in-depth study. For studies such as the one reported here, Flyvbjerg (2006) recommended a sample of three to four cases that are different in one dimension or another in order to ensure in depth understanding of the studied phenomenon. The sample comprised one international student and eleven South African students who were enrolled at a single university of technology. Four students had been placed in engineering consultancy firms, two in research institutions and six had been placed in manufacturing companies. Six students were black, five were white and last one was coloured. Two students had prior work experience, one in an administrative role, another in an engineering consultancy while the rest had none.

Data collection was through semi-structured interviews. The students were interviewed on campus after they had completed twelve months of work placement. The data was analysed inductively using qualitative methods of coding to establish categories and themes. These themes were compared with the core concepts of the theoretical framework. Five cases were used to develop themes and categories. Another seven cases were used to check for theoretical saturation (Flick, 2014).

Results

Seven distinct category themes were identified: student work actions, organisational contextual factors, mentorship structure and quality, personal factors, social networks, competency development, and work tasks. Each category theme had subthemes as indicated in Table 1 below. According to social cognitive theory, student work actions constitute behaviour. Mentorship

structure and quality, social networks, and organisational contextual factors are environmental factors. Work tasks are learning activities.

Table 1. Category themes and sub-themes

Theme Number	Category theme	Sub-theme
1	Organisational contextual factors	Inter-departmental mobility Organisational culture Appropriate mentorship Poor mentorship
2	Mentorship structure and quality	Third party mentorship Formalised mentoring scheme Semi-formal mentoring scheme Informal mentoring
3	Student work actions	Approach to task allocation Pattern of working Participation Emotions and perceptions Outcome expectations
4	Personal factors	Self-efficacy Self-regulation Personal agency
5	Work tasks	Non-diploma level tasks Appropriate level tasks Basic training
6	Competency development	Competency gap narrowed Competency gap retained
7	Social networks	Family centred networks University centred networks

Theme 1: Organisational contextual factors

Organisational contextual factors regulate access to learning opportunities during placement. In the study, organisational contextual factors comprised inter-departmental mobility and organisational culture. In some organisations, WIL students were assigned to one department. In others, they rotated amongst the organisation's engineering oriented departments. The departments served as a component of the physical environment. The other organisational contextual factor, organisational culture, was an element of the social-structural environment. Two types of organisational culture were discovered in this study: rigid culture and affiliative culture.

In rigid culture, there was emphasis on standardised procedures and processes, and deviations from norm or mistakes were not tolerated. Performance targets drove operations. In this culture, there was a belief that standardisation, not people, was responsible for meeting performance targets. Rigid culture was often associated with a hierarchical structure. In a hierarchical structure, employees mostly focus on their assigned tasks. In such an environment, mentors and other employees consider student guidance as a distraction. Rigidity in an organisation's culture affects

mentorship and the nature of work tasks that are given to students. In the study, fear of costly mistakes drove mentors to give students peripheral tasks. Mentors often had to balance the time and energy that they spent guiding students and their business-related obligations. Their response to the challenge depended on how the company culture limited their flexibility. A rigid culture limited mentor flexibility. Sometimes mentors responded to the rigidity by either delegating their mentoring responsibility down the company's hierarchy or limiting the time they spent guiding students. As shown in comments below, students experienced poor mentorship in such a culture.

You only have a limited number of questions and everybody is so busy. So, you have to kind of fit your way in. I think supervision was the biggest problem (Student 3).

They will not take you along. They will be so focused on that thing that they'll just get skilled people to fix that thing as soon as possible and they would have you do some other work and stuff (Student 1).

Though I was working with the project engineer. I was not even present at most meetings... (Student 2).

In an affiliative culture, hierarchical boundaries are blurred. Employees often work with others who occupy different positions on the company hierarchy. In such a culture, WIL students have access to people and non-position specific tasks. In this culture, mentors did not struggle to provide appropriate training to students even in the absence of formalised company training programs. Examples of students' positive experiences in an affiliative environment were highlighted in the comments below:

It was a very friendly working environment so you would approach your fellow engineers if you needed information on something (Student 4).

The company suggested that they are going to move me around in the departments and also send me to outside companies to get more training in fields that are more related to engineering (Student 5).

Theme 2: Mentorship structure and quality

Nature of mentoring is sometimes dependent on host company organisational culture. Appropriate mentorship was associated with the existence of a formalised mentorship scheme or an affiliative culture. Poor mentorship was associated with a rigid culture. There was a causal link between poor-party mentorship and third-party mentorship. With third party mentoring, the substitute mentor does not often have access to WIL student learning guidelines. Consequently, the substitute mentor might assign non-diploma level tasks to students unintentionally. Student 2 comment below highlights some of the challenges of third party mentoring.

Most of the time the people who were allocated to us would tell us that you are going to be working with this artisan today. ...the artisans... would just be sending me to places ...I was not really working (Student 2).

Students indicated that the limitations of rigid culture were mitigated by the presence of a formalised mentorship scheme. In a formalized mentorship scheme, students were assigned to departments and given specific performance targets. This facilitated learning although it

compromised the authenticity of assigned tasks. Student 10 and student 11 reported that they spent six months in a formalized mentorship scheme that had an assessment at the end. Renewal of their contracts for the next six months depended on their performance in the assessment. They reported that this eased the transition into the workplace.

Theme 3: Student work action

Student work action comprised student approach to work allocation, nature of participation, and the pattern of working. These elements influenced learning during placement. Some students were proactive in seeking work allocation, while others waited for their mentors to allocate tasks to them. Those that were proactive tended to be more involved in authentic activities and took less time to integrate into the work environment. Even in a rigid culture, proactive students tended to be involved in more activities than those provided by their designated post. In such a culture, students were usually allocated a specific post resulting in limited exposure to position specific tasks only as illustrated below. Requests for access to other tasks were often rejected.

I was responsible for all the testing of materials, welding procedures, the works. I was in the test lab basically... Before I left, I wanted to learn to become a welding engineer, however they rejected my request (Student 3).

The pattern of working influences student learning. Students who worked in a team moved from peripheral to core participation in work activities faster than those who worked mostly alone. Findings from the study indicate that working in a team was influenced by organizational culture, the student's approach to work allocation and personal agency. Proactive students attached themselves to workers whom they admired. A proactive student who wanted to learn non-destructive testing of welds outlined his strategy below:

I built relationships with these people. Probably after the first seven months, we had lunch and coffee together... I asked them if I can do it because it's there. Of course, they will be supervising me. I was just doing it to learn basically so that I have experience (Student 3).

On the other hands, students who preferred work alone took longer to integrate into the work place

Theme 4: Personal factors

Organization context has an affective and cognitive influence on students. Reciprocal students' influence on the organizational context was mostly through the exercise of personal agency. Personal agency is often exercised through intentionality and forethought. Prior to work placement, students developed a mental picture of what constituted the work of a mechanical engineering technician. The resulting mental picture influenced the students' intentions and their expectation-outcome contingencies. The students' intentions resulted in cognised goals and their execution strategies. This affected the students' personal agency. Personal agency was manifested in the way students solicited work tasks. Students with high personal agency actively sought tasks that would assist them in moving from peripheral observers to active core participants in work activities. One such student summarised his goal of achieving core participation below:

I am the type of individual that likes to be involved in major activities. I wasn't comfortable with being below and not knowing the whole picture of what was happening. I wanted to be involved in all aspects of the design (Student 4).

Theme 5: Work tasks

The nature of work tasks that students undertake in the work place has a huge influence on their perceived self-efficacy and perceptions of career prospects. Participation in authentic work activities was associated with high task self-efficacy and narrowing of the student and practitioner competency gap. An authentic activity is one that meets both organisational and student learning needs. For a task to be authentic, it must be like those performed by full-time technicians in the organisation and require using similar cognitive and physical tools. For example, Student 4 comments indicate participation in authentic tasks whereas Student 2 comments indicate use of different tools by practitioners and students.

From the workshop, I was given an office with a computer with drawing software and everything that I needed to start doing some drawing work on concept designs on the projects that were ongoing in the company (Student 4).

Filing a block of metal, carrying a file and filing. The workers there, if they are doing the same thing. They would go about it a much easier way. For example, machine it but us they would want us to file it (Student 2).

Theme 6: Competency development

The employability benefit of WIL is primarily due to competency development during work placement. Students' perception of their employability improves if they think that the competency gap between themselves and practitioners has been narrowed. The students' perception of whether they have narrowed the competency gap was influenced by the nature of the work tasks and their participation in the workplace. They associated task self-efficacy with general career self-efficacy. The students associated the performance of similar tasks with practitioners with narrowing of the competency gap. In the study, all students who thought that their task competency gap had narrowed believed that they were work ready. Student 5 corroborated the above assertion as follows:

If there were projects, they would give me one or ask me to help with a project. We were kind of doing the same things with the engineers who were working full time... Now I am more confident and I know that I can tackle any project that is given to me (Student 5).

Theme 7: Social networks

Students use the social networks to find solutions to their workplace challenges. The students turned to their social networks, family members and university classmates, to solicit for help and advice. The students also used these networks to be linked with industry professionals who might offer insight on their current work assignment or challenge. In doing this, the students learnt the value of professional networks. Student 6 aptly summarized the benefit of social networks below:

I had to consult with my dad to get the number of a mechanical engineer. You do not have contacts in the industry, you do not know where to go in the industry and knowing where to go helps you quite a lot (Student 6).

Another student tapped into his social networks for assistance on how to deal with friction with his mentor.

I did not know how to deal with it...we were not taught to handle conflict...I would have been going out, not knowing what to do....my father suggested that I talk to him [a manager in another division of host company]....he told me to go and discuss the matter with him [mentor] (Student 9).

Discussion

The findings suggest that organisational culture has a dominant influence on learning for competence development during work placement. In a rigid culture, mentor non-availability caused poor mentorship which was associated with third-party mentoring. Student 2 aptly summarised the causal chain when he said, “I had to find my own people.” The prevailing culture influenced the students to seek help from non-technicians who could only provide access to non-diploma level tasks. At the same time, the environment caused students to fear for their career prospects. Fear of ruined career prospects started the push back chain of personal agency exercised through self-regulation. Students actively associated with work colleagues to attempt to remedy the shortcoming. This exercise of personal agency was not always successful. For example, Student 2 grew despondent and had to leave the host company. Thus, personal factors can influence student behaviour. In this culture, students’ behaviour exerted reciprocal influence on personal factors, but it had minimal influence on the imposed environment. Organisational culture’s influence was almost one-directional (see Figure 3 below). Social cognitive theory acknowledges the existence of unequal strength in the causal elements (Ormrod, 2016; Snowman et al., 2012).

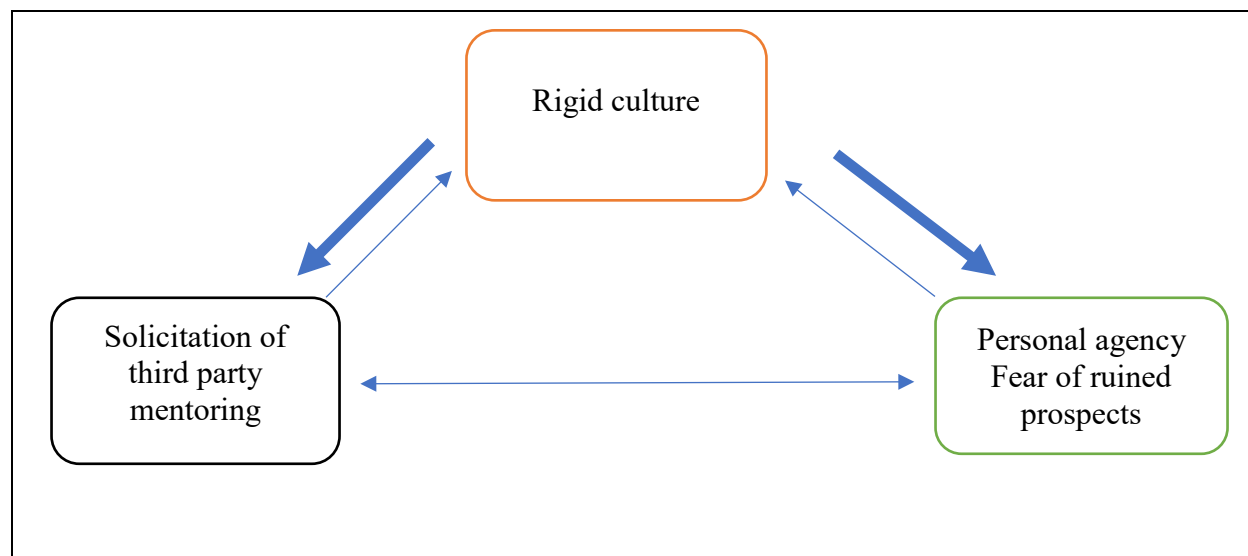


Figure 3. Interaction of causal elements in a rigid culture

Interaction of causal elements highlighted in Figure 3 resulted in the retention of the competency gap mainly due to lack of access to authentic diploma level tasks. Students must participate in authentic work activities that are at an appropriate level for the student-practitioner competency gap to be narrowed (Keleher et al., 2011). Third party mentors who are on lower positions in an organisation's hierarchy are not usually able to provide access to appropriate tasks. Thus, third party mentoring is not usually a solution for poor mentoring. The challenges arising from poor mentoring in a rigid culture can be addressed either by provision of training on efficacious mentorship to potential student mentors or through the development of formalised mentorship schemes.

An affiliative culture provides for reciprocity in causal influence as indicated in Figure 1. Competency development does not solely depend on the existence of an affiliative culture. Personal agency expressed through a proactive approach to task allocation influenced student exposure to authentic work activities. Lock et al. (2009) had similar findings. Students in that study reported that it was expected that students take the initiative in soliciting appropriate experiences in the workplace. Participation in appropriate level tasks promote the development of self-efficacy through the creative influence of performance accomplishment (Bandura, 1997). Presence of a supporting mentor has potential to reinforce a student self-efficacy through social persuasion. Once established, self-efficacy affects students' perceptions, motivation and forethought processes. Students with high self-efficacy are more proactive and resilient in their pursuit of meaningful work experience.

Students who were proactive in soliciting work assignments were exposed to more diploma level tasks than passive students. These proactive students also experienced less challenge in integrating into the work environment at the host company. Even in cases where there were cultural and gender barriers initially existed, proactive students overcame them earlier than students who were passive in their approach to work allocation. It seems that mentors treated proactive students differently. They trusted these students with work activities that required more responsibility and that had more value to the company.

Performance of authentic tasks also assisted students in their self-reflection processes. Sometimes, students' self-evaluation of their capabilities was inaccurate. Participation in authentic activities provided them with opportunities to test the veracity of those self-beliefs. Student 5's comment below illustrates this:

Before in service, I thought I would look for a job and be successful, but when I was doing my in-service I realised that I was wrong (Student 5).

Conclusions

Experiences of mechanical engineering students as they perform work tasks, interact with their mentors and other co-workers and the general work environment affect their perceptions of their own competency development. The study found that student work actions, organisational contextual factors, mentorship structure and quality, personal factors, social networks, and work tasks affect students' perceptions of their competency development. The study also found that organisational contextual factors, particularly organisational culture, regulate access and the triadic

reciprocal causation of learning in the work place. A rigid culture limits student access to both authentic tasks and appropriate mentoring. The reciprocal effect of students' approach to work solicitation, personal agency and self-efficacy are of lesser strength in a rigid culture that does not have a formalised mentorship scheme. The dominance of culture falls away in an affiliative environment or in a rigid culture that has a formalised mentorship scheme. In an affiliative culture, student approach to work allocation is a major influence on competency development. Consequently, the effect of organisational culture, student approach to work placement and social networks on competency development during work placement cannot be ignored.

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“It’s not just working on a plant for 20 years”: Students’ perceptions of engineering professionalism

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This study aims to identify how final-year electrical engineering students at a South African university understand engineering professionalism. In doing so, it adopts a discourse perspective, with particular emphasis on discourse’s dialectical relationship with society, which sees discourse both reflecting and shaping society. Using the concept of engineering professionalism as discourse provides a way to analyse both the current state of the industry (including its history to date) and how the industry may change going forward. As soon-to-be professionals, engineering students are the agents who will shape the industry and understanding their perceptions provides a key for what to expect in the future. For the purposes of this qualitative study, semi-structured focus group interviews were held with twenty students. Findings include: an emphasis on the importance of transferable skills for professionalism; an acknowledgement of the professional engineer’s power to make societal changes and the concomitant responsibility that this entails; and a tension between fitting into the discourse of professionalism and pushing back against it. Within an engineering education context, the study’s findings can be used to develop targeted, impactful learning interventions that encourage critical reflection on and ownership of the discourse of “engineering professionalism”.

Introduction to the study

The Engineering Council of South Africa (ECSA) outlines 11 exit-level outcomes that engineering students must achieve in order to graduate with a BEng degree. Exit-level Outcome 10 refers specifically to “Engineering professionalism”, and requires that students are able to show critical awareness of the need to act professionally once they graduate (ECSA, 2014). Yet, the notion of what constitutes the discourse of “professionalism” within the engineering industry is not without complexity. As this paper argues, the concept has shown itself to be dynamic, affected by shifts in technology, globalisation, social issues, and geographic and demographic contextual specifics.

This study aims to describe how a group of electrical engineering students at a South African university understands the concept of “professionalism” within engineering. It adopts a discourse perspective, drawing on Fairclough’s (1992, p. 64) description of the dialectical relationship between discourse and social structure, which states that discourse both *reflects* and *shapes* the world around it. Thus, while the discourse of professionalism reflects the factors mentioned above, it also shapes the way those entering the industry will go about carrying out engineering work. It is therefore important to understand how senior undergraduate students, who will soon be entering the workplace, understand what being a being a “professional engineer” entails.

The study is based on data generated via focus group interviews of 20 final year electrical engineering students. At the time of the interviews, which were held towards the end of the

first semester, the students were close to writing off most of their course work and were preparing to focus on their theses in the final semester of their studies. By this stage, the students would have completed at least one stint of vacation work during their studies, where they would have been exposed to the practicalities of an engineering workplace. In addition, this cohort of students would have experienced two semester-long Professional Communication Studies courses (one in third year and one in fourth year). These courses aim to support engineering students in developing the oral and written communication skills they will need in the workplace, such as report writing and oral presentations. Moreover, the courses focus on “soft” workplace skills such as teamwork, leadership and ethical behaviour within the engineering industry. As such, these students would have already begun to reflect on what constitutes professionalism within the engineering industry and therefore their contributions are grounded in real experience and considered critical responses thereto.

Profession, professionalisation and professionalism in engineering

In her review of the scope of sociological research into the professions, Evetts (2012, p. 2) explains that three distinct terms have emerged over time: profession, professionalisation and professionalism. This provides a useful framework for unpacking the discourse of professionalism. Evetts’s (2012, p. 2) definition of a profession is “a distinct and generic category of occupational work”. Similarly, Adams (2012, p. 329) draws the link between a “profession” and an “occupation”, asserting that “profession” most often implies a status as expert and extensive education, training and licensing. To this end, in South Africa, the aforementioned ECSA serves as the regulatory body for the engineering profession. The function of the organisation includes the setting and monitoring of standards; registering individuals and thereby certifying their competence; maintaining education standards through accreditation; regulating professional conduct; and encouraging the growth of the profession in the country (“About ECSA - Mission and Vision,” n.d.). There are a number of different disciplines that fall within the umbrella of the “engineering industry”. Some of these are: civil engineering; chemical engineering; mechanical engineering; and industrial engineering.

Evetts (2012, p. 3) goes on to discuss “professionalisation”, which she refers to as “the process to achieve the status of profession”. Again, in the South African context, ECSA plays an important role in consolidating the many different disciplines of engineering practice into one central professional body. Its vision statement is to:

... ensure that South Africa enjoys all the benefits of a strong, competent, growing, sustainable and representative Engineering profession, able to provide all the expertise necessary for the socio-economic needs of the country, and to exert a positive influence in South Africa.

(“About ECSA - Mission and Vision,” n.d.)

In this way, ECSA professionalises engineering practice, articulating its ideal characteristics and situating it as vital to the thriving of the country. Evetts (2012, p. 3) explains that the process of professionalisation aims towards closure of the occupational group and, by doing so, contributes to the maintenance of practitioners’ self-interests in terms of salary, status and power. In addition, professionalisation necessitates boundaries being set up around what knowledge is valued and included and what is excluded from the scope of the profession.

The final theme highlighted by Evetts is “professionalism”, initially thought of as a normative

value within a profession that was understood as worth preserving and promoting by and for industry workers (Evetts, 2012, p. 3). Over time, however, professionalism has been reinterpreted as a discourse, which has added an ideological perspective to that which previously was considered objective and/or neutral. Cheney and Ashcraft (2007, p. 169) emphasise this when they explain that “professionalism has been almost universally valenced as positive, without recognition of its blind spots and associated forms of suppression”. According to Adams (2012, p. 331), professionalism is a disciplinary tool that shapes employees into strategically crafted occupational identities. She argues that professionalism is no longer simply grounded in the workplace (Adams, 2012, pp. 335–336). Rather, she provides examples of how contemporary popular culture like television and movies shapes our notion of professionalism; how professionalism has seeped into realm of the home and child-rearing (here, she provides the examples of “stay at home moms” becoming “household executives” and professional experts like organisers and certified nannies); and how the notions of entrepreneurship and an enterprising spirit have contributed towards a professionalism that is distinctly driven by the neoliberal value of individual gain. Examples such as these, she says, demonstrate the “colonisation of professionalism into non-occupational domains and the insidious structuring of commodified subjectivities” (Adams, 2012, p. 339).

For this reason, she says, it is important to probe how professionalism, made up as it is by an “assemblage of seemingly unrelated concepts” (Adams, 2012, p. 331) shapes how we come to understand the world. In addition, since another function of discourse is to *reflect* the world (Fairclough, 1992, p. 64) (this is discussed in greater detail in the section below), it is necessary to consider the factors that led to the development of the discourse of professionalism through the process of professionalisation. To this end, Evetts (2012, p. 5) distinguishes between professionalisation “from within” and professionalisation “from above”.

In this context, professionalisation “from within” refers to the successful manipulation of the market by the occupational group. It is clearly beyond the scope of this paper to discuss this concept in relation to the full history of the engineering industry, but some key moments are elucidating in this regard. For example, Seely (2005, p. 115) locates the emergence of engineering as a profession around the time of the industrial revolution. At this time, one became an engineer through hands-on apprenticeship at, for example, a machine shop, a factory floor, or a building site. The shift from this method of training to “school culture” (Harwood, 2006, p. 55) in the mid- to late- nineteenth century was driven by leaders in the engineering profession who had “an acute sensitivity to their lack of social position” (Seely, 2005, p. 116) in relation to other professions, particularly the sciences. They believed that a more formal approach to education would lead to greater prestige for engineering professionals. This led to more organised, comprehensive approaches to education (or what Harwood [2006, p. 55] calls “academisation”) and the stipulation that these become a prerequisite for qualification as a professional engineer.

Contrastingly, Evetts’s (2012, p. 5) reference to professionalism “from above” refers to the impact of forces external to the occupational group. Here, a discussion of what Conlon (2008) terms the “new engineer” is relevant. According to Conlon (2008, p. 151), this conception views contemporary professional engineers as broad-based experts who are socially and environmentally responsible. This is because while engineering is a profession that focuses on the solving of problems (Sheppard, Macatangay, Colby, & Sullivan, 2008), the rapid

changes in technology have shifted the nature of the problems to be solved. Whereas previous, more stable systems presented more linear engineering problems, contemporary issues require a “network, web, or system understanding” (Sheppard et al., 2008, p. 4). In contrast to engineers in the past who could approach a given problem in a neutral, objective way, today’s more complex, intermeshed systems require an insider’s perspective that is able to take into account factors such as sustainability, impact of the economy, and social issues when approaching the problems to be solved. Thus, external contextual factors have led to the need for engineering professionals who are more aware of and responsive to the world around them.

It is therefore clear that while professionalism is a frequently bandied-about aspirational value for workers, it is by no means a neutral concept. Both its genesis and its enactment within professions are underpinned by deep ideological strains which play a part in the legitimisation of particular kinds of knowledge, practices and even identities that are deemed acceptable within a particular profession. The brief examples above show that the engineering profession itself has been affected by professionalisation “from within” and “from above”, leading to the emergence of the current norms and standards required of and for engineers. However, Gee (2008, p. 156) explains that discourse is also performative, in that it is about “certain sorts of *whos* doing certain sorts of *whats*”. In this conception, the discourse of engineering professionalism not only shapes the industry, but impacts on all aspects of how an engineering professional should behave. This idea is discussed in further detail in the next section.

Theoretical framework

As mentioned above, this study adopts a discourse perspective. While traditions of discourse theory exist in fields as diverse as information technology, medicine, social sciences and business studies, for the purposes of this study, discourse is understood as language in use (Sawyer, 2002, p. 434). As such, it moves beyond the level of grammar to encompass language in context, and how meanings are manifested in linguistic forms. In this way, discourse reflects forms of social practice (Fairclough, 1992, p. 63). In doing so, it provides a way to focus on how issues are given particular meaning within social settings (Bacchi, 2005, p. 199).

Fairclough (1992, p. 64) develops this idea of discourses as social when he explains that the relationship between discourse and society is dialectical. While discourse is shaped by society so too is it socially constitutive in that it constructs the world through meaning. To this end, he highlights three ways in which discourse is socially constructive. Firstly, it constructs social identities or “types of self” (Fairclough, 1992, p. 64). Secondly, it constructs social relationships between people. Finally, it contributes to constructing systems of knowledge and belief. It does so because its status as institutionally supported and culturally influenced conceptual and interpretive schemas influence the way people understand issues, and the knowledge and beliefs that stem from this (Bacchi, 2005, p. 206).

Thus, while the discourse of the “professional engineer” reflects changes in sectors such as industry, technology, the economy and even geopolitics, so does it in effect transform how this role is carried out. And nowhere is this more of an important consideration than in higher education, where a new generation of engineers are being trained to contribute to society. The students who graduate from South African higher education institutions today will shape how

the industry develops in the coming years. It is therefore valuable to understand how they conceptualise what it means to be a professional engineer in contemporary South Africa.

Research question

How do final year electrical engineering students understand engineering professionalism?

Method of data collection and analysis

As mentioned above, this study's findings and its concomitant conclusions were based on the data generated by semi-structured focus group interviews, which draws on a qualitative paradigm of research. Borrego, Douglas and Amelink (2009, p. 53) explain that the aim of most research in engineering is to determine the cause of outcomes by reducing possible causes to a specific set of variables; quantitative methods, they say, are appropriate for this kind of research. However, they go on to assert that the research approach should be guided by the nature of the research problem, and that the wide scope of the field of engineering education means that different approaches should be represented. Qualitative research has the potential to provide important insights into how learning takes place in the field of engineering that are not possible through quantitative methods (Koro-Ljungberg & Douglas, 2008, p. 172-173).

The sample for this study was drawn from one class of final-year electrical engineering students registered for the fourth-year Professional Communication Studies course mentioned above. In all, 20 students participated in six focus group interviews consisting of four or five students each. The groupings for the interviews reflected the self-selected groups in which students were working on the major course project. The interviews were voluntary, however the groups were finally selected in order to provide a purposive sample that was diverse in terms of race, age and gender. To this end, twelve of the students were male; the remaining eight were female. Note that this does not reflect the gender spread of the full course, of which 130 male students and 18 female students were registered. The focus of the interviews spanned the students' experience as electrical engineering students, their expectations for the workplace and their goals for the future. The interviews were transcribed and then analysed using Computer Assisted Qualitative Data Analysis Software package Nvivo, with Maxwell's (2012, pp. 111–113) organisational, theoretical, and substantive categories used to guide the analysis.

Research findings

The students had a number of different responses when asked to articulate what they understood by the term: "professional engineer". One of the main ideas that emerged was the notion that a professional engineer does not only rely on technical knowledge. As one student explained, engineers in industry are unlikely to be solely focused on technical tasks. Rather, working in a social environment, they are often in a position of management, and as such, it is important that they are cognisant of how they portray themselves to other people. For many students, therefore, the idea of a "professional engineer" conjured up the image of someone who knows how to carry him/herself in a workplace and is aware of how he/she is presenting him/herself to others. This reflects another aspect of professionalism highlighted by the students: that of the importance of teamwork within a professional context. One student explained that in the workplace, engineers are almost always expected to work in teams.

Being a professional means you have to learn to work with other people, in particular be punctual, put in a fair effort, listen to people's ideas and learn how to deliver critical feedback positively.

For the students, therefore, the idea of professionalism within engineering extends beyond the mastery of content. Rather, there is an emphasis on the ability to apply this knowledge in a way that makes it accessible to members of one's team and to the wider society. To support this, one student gave an example of how, while she believes that the role of an engineer in society is to find solutions to the problems that humans face, she is very aware of the fact that some of the issues faced in South Africa – for example electricity shortages – are attributed to failure on the part of engineers. As such, she understands the role of a professional engineer as one that embodies a particular power. Along with this power comes a responsibility to carry out tasks to the required standard. With regards to this, several students highlighted adherence to legal and ethical codes of practice as one of the core markers of professionalism within engineering. This, one student explained, manifests in the application of rational, conscious thought to decision-making.

Several students also mentioned the role they believe dress can play in creating a professional image for an engineer, as contributing to how one presents oneself to society. However, these students also acknowledged that the level of formality of one's attire would differ depending on the context within the engineering industry in which one is working. For example, one student explained that his father ran an engineering business and dressed very casually, which he can do because he does not have a superior to report to. Another mentioned how people in the industry in her home country of Kenya dress far more formally than those in South Africa. Finally, another student proposed that how formally she would need to dress for work would depend on the nature of the engineering work she ends up doing once she graduates. In her understanding, this even extends into how she will be required to carry herself in the workplace. For example, she explains that if she goes into consulting, she will probably be required to be very "serious and professional", whereas if she ends up working in the fields of software and coding, everything will probably be "more chilled", with people "just doing their thing".

This raises a theme that is implicit in some of the students' understanding of what being a professional engineer entails: the distinction between fitting into a preconceived idea of how a professional should be with that of being able to express their own identity as individuals. This emerges, for example, in one student's statement that she does not want the kind of job that will require her to remove her two piercings. She explains: "I don't want to put on this, like, front, just so I can talk to the client". Another student articulates a similar issue:

I don't know where you draw the line between representing yourself the way you are and satisfying all these requirements. I think that was one of the problems. Just, I don't know actually where you draw the line. Even as you look for a job and even as you work. How much of who you really are can you show and how much of the rules do you have to follow? So that one's tricky. That one's tricky.

This was not the only notion of professionalism that was problematic for students. In fact, two of the interviewed students found that, given their limited experience within an actual workplace, they were unable to comment on what constitutes a professional engineer. However, on the whole, the main idea that emerged was that of professionalism consisting of the "add-ons" to the technical knowledge that the students develop whilst at university. As

one student explained, "... there is more to engineering then we think, and that more part is actually not engineering. So a successful engineer is not just an engineer, but it's more a jack-of-all-trades". Some of these "add-ons" include communication skills, particular ways of approaching problems, and commitment to the job. In fact, one student even quantified the weighting of these different facets. A professional engineer, he states, should be 60% content and 40% professionalism, which he defines as consisting of:

...how you present yourself, how you speak, how you make decisions, how you listen to people's ideas, how you give your own input, how you think outside of the box, how you add more outside of your engineering content and all that stuff.

The students interviewed did not question the norms of professionalism that they highlighted in the interviews, and aside from the student who did not want to remove her piercings, these were not challenged. According to their descriptions, a professional engineer behaves in a particular way, and if they, as graduates, are to fit into the workplace, they need to adhere to these norms. One student even linked adopting these modes of workplace behaviour to career advancement, explaining that "you need to have a professional sort of image and skills that help you to sort of get further". However, there was acknowledgement that how professionalism is understood evolves over time. One student explained that this is particularly true in the field of engineering in which technology plays such a big role. He described how a non-engineering friend held the assumption that engineering graduates "just, like, go to the work environment and work on a certain plant for like 20 years". In response, he had told his friend that "there are a million things you can do with an engineering degree" and that the way things are done now are not how they used to be done. One particular theme that emerged regarding the changing nature of the engineering profession related to the expansion of the boundaries of the industry to include the valuing of skills and knowledge from other fields, such as commerce and the arts. Another theme was a growing emphasis on entrepreneurship, and the goal of many of the students to one day own their own engineering-related businesses.

Discussion and conclusion

It is clear that the students understand the concept of a "professional engineer" as extending beyond the mastery of technical engineering knowledge. Rather, it encompasses the ability to apply skills appropriately in context. Most of the skills the students raised in this regard are what are commonly known as "transferable skills" in that they are generic and apply generally to the workplace, irrespective of industry. Some examples of these skills were communication, listening skills, teamwork and problem solving. This shows that, while the knowledge a professional engineer needs to master may be specific to the engineering field, students relate the "how" of the application of that knowledge to more a more generic understanding of professionalism. This is most likely a reflection of the pervasiveness of the discourse of professionalism in society, impacted as it has been by extra-disciplinary elements like media and popular culture. The students did not specify having the ability to "communicate like an engineer" or "problem solve like an engineer". Rather, these skills reflect a professional discourse that is at work to entrench wide societal ideologies such as social stratification and the distribution of power to elites (in this case, engineering graduates) who have had the opportunity to practice these particular skills, through their education, interaction with other professionals or exposure to media. Through their emphasis on transferable skills, the students have articulated the notion of discourse as performative as

discussed above.

This emphasis on transferable skills shows that the students understand the process of establishing oneself as a professional as highly individualised. This is because it focuses on what each individual can *do*. If a graduate feels that she needs to communicate to be a professional, and has poor communication skills, it is up to her to improve in this area. This aspect of individualism is reflected elsewhere in the students' responses to engineering professionalism, particularly in relation to entrepreneurship. This is in contrast to the students' notions of the engineering profession's intermeshed relationship with society, which occurs both on a disciplinary level (in that engineering is impacted by other fields) and through the belief that the role of engineers is to solve society's problems. The interplay between individual and social factors adds to the complexity of the engineering professionalism discourse.

Finally, the fact that the students could describe a professional engineer even though they are still at university shows that they have been exposed to the discourse of engineering professionalism. As mentioned above, most students understood this as something they would need to adhere to once they entered industry. It is clear, therefore, that they have not yet begun challenging the discourse in a way that will reshape it going forward. There are several indications, however, that this is to be expected at some point. Firstly, by acknowledging the dynamism of the profession, the students show an acceptance of the possibility that there may be change in the future. Secondly, the students' understanding that things like dress and manner change depending on context shows that they are aware of the constructed nature of these components of professionalism, which opens the potential for using agency to alter them. Finally, the grappling between conformity and uniqueness as highlighted by some of the students indicates a level of pushback against the current discourse. It is possible that once actually in the workplace, the students will begin to take ownership of the discourse, leading to changes in the way engineering professionalism is practiced in the future.

Future work

There is much scope for future work stemming from this study. One potential angle could be to run a similar study with students from different engineering disciplines to compare and contrast their conceptions of engineering professionalism. This study did not interrogate which (if any) particular teaching and learning interventions during their degree programmes impacted the way the students understand engineering professionalism, and this could be a useful direction for future research in the field of engineering education. Finally, it was beyond the scope of this study to interrogate the ways in which the different focus groups reflected varying findings. A future study could consider the ways in which race, gender and age impacted on the students' conceptualisations of engineering professionalism.

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Students' experiences regarding learning mathematics within the flipped classroom model

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This study explores how first year engineering students experience learning mathematics within the flipped classroom (FC) model. The research design is an exploratory case study design and ninety-nine students participated in the study. The data collection consists of students' written reflections after each FC session as well as an open-ended questionnaire at the end of the last cycle of the research. The students' reflections were analysed using document analysis. The findings suggest that students experienced positive as well as negative emotions regarding two themes: learning experiences and online instruction. Qualitative analysis of the results revealed that overall more students experienced positive emotions towards FC. From the analysis of the open-ended questionnaire, challenges reported are technology, time management, working in isolation, the new strategy, problems with the content, lack of staying focused in the FC and not enough information in the slides. The benefits from learning in the FC are self-regulated learning (SRL), positive emotions, content knowledge gained and, as a result of the SRL, increasing focus, improved time management and better computer skills.

Keywords: Flipped classroom, Mathematics learning, Reflection, Self-regulated learning

Introduction

In South Africa the current teaching methodology for teaching mathematics at higher institutions remains the traditional lecture style. This style focuses on cognitive factors and consists of the transmission of knowledge through lectures with possible additional tutorial sessions. In traditional lecture settings students do not always have the time to understand, critically analyse, apply and reflect on the content presented by the lecturer (Du, Fu & Wang, 2014). The traditional teaching methodology requires a learning environment where both the lecturer and students are present. However, as a result of the "fees must fall" campaign that started in October 2015 at universities across South Africa, classes were disrupted and lecturers were motivated to research other teaching methodologies to ensure that students have access to lectures and continue with their studies outside classrooms.

One approach to teaching mathematics where the student is actively involved in the learning material without the presence of the lecturer is through a "flipped classroom" model. The lecturer provides pre-recorded lectures in the form of podcasts/vodcasts, screencasts, annotated notes and captured videos for the flipped classroom (O'Flaherty & Phillips, 2015) which the students access in their own time. A discussion of problems students experienced while working through the pre-recorded lectures can then take place during class time, and more time is available to involve students actively in group-based problem solving activities. At the heart of the flipped classroom (FC) is moving the "delivery" of material outside of formal class time (through extensive notes, video recorded lectures and other appropriate means) and using formal class time for students to undertake collaborative and interactive activities relevant to that material (Butt, 2014).

This paper reports on how first year engineering students at a University of Technology in South Africa experienced learning mathematics within the FC model. Two research questions guided the research: 1) How do first year engineering students experience learning mathematics within the FC model? 2) What are the perceived challenges and benefits of learning mathematics in the FC?

A brief overview of relevant literature on the use of the FC approach follows.

Theoretical and conceptual framework

The FC is an instructional model (Bergmann & Sams, 2012; Tucker, 2012) where students independently work through the content out of class while doing collaboratively hands-on activities inside class (Chen, Wang, Kinshuk & Chen, 2014). According to a review of previous studies by Chen et al. (2014) the flipped model is still underutilized and underexplored in the higher education context. They argue that research and design models for flipped learning in higher education are also insufficient (Chen et al., 2014). O’Flaherty and Phillips (2015, p. 85) found that there is “evidence of improved academic performance and student and staff satisfaction with the flipped approach, but a paucity of conclusive evidence that it contributes to building lifelong learning and other 21st Century skills in under-graduate and post-graduate education”. In South Africa, only a few studies report on FC teaching and learning. Tanner and Scott (2015) found that the FC approach appeared to have a positive influence on students’ attitudes to learning. However, some students were reluctant to take charge of their own learning (Tanner & Scott, 2015). Thaba-Nkadimene and Thobejane (2017) investigated whether the implementation of School Leadership training programmes in Limpopo integrated FCs and found that these programmes did not promote the use of digital technologies in the classrooms, FCs or virtual learning.

Bishop and Verleger (2013, p. 25) define the flipped classroom as “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom”. For the purpose of this study, we adapted this definition as follows: The flipped classroom is an educational approach that consists of three parts: online learning of content by the student outside the classroom, student-reflection on self-regulated learning (SRL), followed by interactive group learning activities with the lecturer inside the classroom.

These three parts have roots in the social constructivist theory. In this study, students in the FC construct their own meaning to concepts presented to make sense of the mathematical content. Constructivist theories are based on the belief that students construct their own knowledge and conceptual understanding through their own activity (Doctorow, 2002). Piaget’s theories, which underlie much of constructivist thought, imply that it is the teacher’s role to establish a mathematical environment to enable students to construct this mathematical knowledge (Doctorow, 2002). In this environment students have the opportunities to hypothesize, test out their thinking, manipulate materials, and communicate their understanding in order to build mathematical knowledge (Doctorow, 2002).

After the FC sessions, students in this study reflect on their learning and express their experiences in writing. Thoughts on reflection and reflective practice have evolved over many decades, if not centuries, through carefully constructed theory and research applications (York-Barr et al., 2006). Dewey is frequently recognised as the eminent 20th-century influence on reflection in education (Ottesen, 2007; York-Barr et al., 2006). For Dewey (1933), true reflective practice takes place only when the individual is faced with a real problem that needs to be resolved in a rational manner.

During normal class time, the students in this study engage in problem-solving activities interactively within a social setting with the lecturer present. In the sociocultural theory of teaching, it is the role of the teacher to influence students' thinking, in order to move that thinking into the realm of more scientific, conceptual understanding (Doctorow, 2002). This is in line with Bandura's (1977) social learning theory, which focuses on the learning that occurs within a social context. It considers that people learn from one another, and includes concepts such as observational learning, imitation, and modelling.

Figure 1 illustrates how these three constructs fit into the design of this qualitative study.

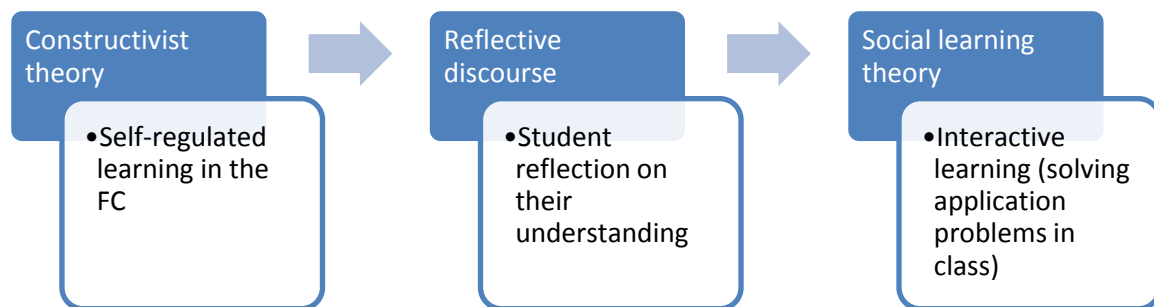


Figure 1: The theoretical and conceptual framework

The methodology used for this research follows.

Methodology

Research design

This study investigates a group of first-year engineering students' experiences learning mathematics in the FC. The research design is an exploratory case study design within a qualitative approach.

Participants

Ninety-nine first-year students enrolled in the Engineering Extended programme participated in the study. Students placed in these programmes do not meet the minimum requirements for direct entry into diploma courses and normally have deficiencies in terms of background knowledge and skills, especially in mathematics and science.

Procedure

The students have 3 one and a half hour sessions of mathematics per week. Because most of our students do not have reliable access to internet or computers at home, we decided to use the weekly lab session for the FC. During this session, students engage with new mathematics content in a computer lab where they work independently through power point presentations with voice recordings, without assistance from the lecturer or teaching assistants. At the end of the session, they complete a short test on the content and write a reflection on their experience of learning the content on their own. The lecturer marks the tests and analyses the reflections directly after the lab session. She makes a list of problems that students experienced, and discusses and resolves these during the next in-class session. During the third mathematics session, the students solve engineering application problems (EAP's) cooperatively in groups with assistance provided by the lecturer and teaching assistants. Figure 2 illustrates this cycle of learning in the FC and in-class.

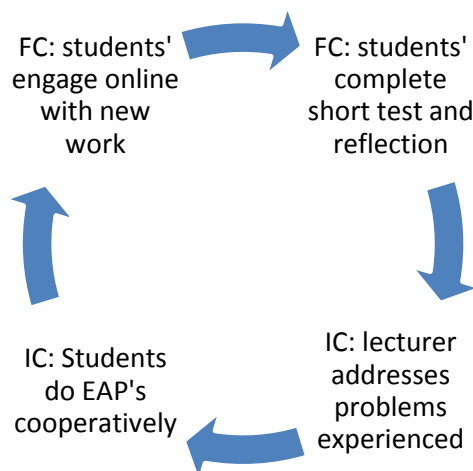


Figure 2: The cycle of learning mathematics in the FC and in-class (IC)

Figure 2 illustrates the cycles of students' engagement with new work in the FC, their reflection on their learning and their solving of engineering application problems (EAP's) in-class. Students completed five cycles in the FC during the first term of 2017.

Research questions

As previously mentioned, the two research questions that guided this study are: 1) How do first year engineering students experience learning mathematics within the FC model? 2) What are the perceived challenges and benefits of learning mathematics in the FC?

Data collection

The researcher collected students' written reflections after each session to establish their experiences of working through the slides on their own without assistance from the lecturer. The following questions channelled their reflections: *What problems did you encounter while working through the material? What did you like about this session? What did you dislike? What did you learn about yourself as you worked through this session? What would you like to improve upon now that you have worked through the session?*

Students also completed an open-ended questionnaire at the end of the fifth cycle to explore the perceived challenges and benefits they experienced. They wrote freely answering the following two questions: *What challenges did you experience? What did you gain?*

Data analysis

The students' reflections were analysed using document analysis. Document analysis is a systematic procedure for reviewing or evaluating documents. Data is examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Corbin & Strauss, 2008; Bowen, 2009). The analytic procedure entails finding, selecting, appraising, and synthesising data contained in the documents (Bowen, 2009). As a research method, document analysis is particularly applicable to qualitative case studies. According to Bowen (2009), document analysis requires skimming (superficial examination), reading (thorough examination) and interpretation.

In this study, we followed this approach to organise the information elicited from the students reflections into categories related to the two research questions, using content analysis. We also used thematic analysis, which according to Bowen (2009), involves a careful, more focused re-reading and review of the data to uncover themes pertinent to the research questions.

Because one of the researchers of this study is the mathematics lecturer of the students, we had to guard against researcher bias while analysing the data. The students wrote their reflections anonymously and as a result, the researcher was unaware of their identities and could therefore interpret and respect their individual meanings without bias.

Results and discussion

The qualitative coding of the data revealed that the students experienced emotions regarding two different themes: learning experiences and the online instruction methodology. A discussion of each of these themes follows.

The students' reflections after the FC sessions, as well as their written responses to the questionnaire, revealed that they experienced positive and negative emotions regarding their learning in the FC. The positive emotions that students revealed in their reflections are feelings of satisfaction, enjoyment, motivation and pride. The negative emotions are frustration and boredom. The students voiced their emotions as revealed in Table 1.

Table 1: Students emotions regarding learning experiences

Positive and negative emotions	What students say (Verbatim)
Satisfaction	I have learned that I can work on my own To figure it out by myself is a challenge that I enjoy and after I have figured out how to do it makes it more satisfying
Enjoyment	The task was good and I enjoyed doing it on my own. I tend to understand better when I struggle first I enjoy it and look forward to using it practically
Pride	The computer environment makes me more engaged. It allows me to work through the topic in my own understanding rather than adjusting my understanding and logic to align with the teacher's It helps me go through the work at my own pace and I learned to think for myself and solve problems on my own
Motivation	It has motivated me to work a little harder and understand more and also induce more brain activity, which makes one more efficient It was a good motivation for me to push myself and work harder to be more committed to my work and studies
Frustration	I had to go ask for help in each and every problem which made me feel stupid Going through the slides on my own makes things harder for me
Boredom	Sometimes I relax too much and start to not pay full attention to what is being said

The students in this study expressed their feelings of enjoyment, satisfaction, pride and motivation regarding their SRL during the FC sessions. Research has shown that self-regulation

is critical in determining students' successful learning experiences in an online learning environment (Cho & Kim, 2013). However, some students reflected on feelings of frustration and boredom. According to Pekrun et al., (2010), self-regulated learners experience both positive and negative emotions. The positive emotions often include hope, enjoyment, and pride in learning, whereas the negative emotions include anger, anxiety, boredom, and frustration (Pekrun et al., 2010). The findings of this study therefore match previous research results about self-regulated learners.

The second theme we identified deals with the online instruction methodology. Once again, we read and re-read the students reflections in our analysis of the data and listened to their individual voices. Table 2 illustrates students positive and negative feelings about the online instructional method used in this study.

Table 2: Students positive and negative experiences with the online instruction

Positive and negative experiences	What students say (Verbatim)
Online instruction	I like to be taught verbally by the lecturer. This makes me understand quicker Because the classroom is not formal, I feel free and more relaxed compared to the traditional lessons. It make it easy for me to be able to listen in class It helped me to see how much I understand on my own and how far I can go on my own without the lecturer's help In the flipped classroom we focus more on computers, not learning
Technology	Some of the power points don't have enough information to make me understand I don't like to work through the slides without voice recording I have a challenge using the computer system as I come from a rural development area, I did not use a computer before I learn more from the slides with voice recordings because I realised that I recall sound more that written material
Time management	Things look new and if it looks new and no one told me about it I take more time to understand the work Grasping the work took a bit longer but it was more rewarding The assessment that we have to complete in class and hand in for marks it is usually too long

From the table it is clear that some students still prefer the traditional method of instruction instead of working through the content using power point slides. The students received slides with voice recordings in three of the five sessions and they agreed that it is more beneficial than using slides without voice recordings. They criticised the power points dealing with rational inequalities and expressed views that those slides did not have sufficient information. According to Bishop and Verleger (2013), general reports of student perceptions on the FC are relatively consistent. Opinions tended to be positive, but there are invariably a few students who strongly dislike the new FC approach (Bishop & Verleger, 2013). Students' time management seems to be problematic, especially for those students who are not used to

computers. They had to submit a written assessment after each session and some complained that they failed due to lack of time. O’Flaherty and Phillips (2015, p. 89) argue that “the introduction of a FC approach requires clear expectations to be given to students to reduce their frustrations regarding the time taken to do the pre-class activities”. They remark that “both staff and students depend on the lecture method because it is familiar, comfortable, instructor centred and requires little active student participation” (O’Flaherty & Phillips, 2015, p. 89).

The content analysis of the open-ended questionnaire revealed challenges and benefits that students experienced in the FC. These challenges and benefits relate to the two themes that emerged from the analysis of the reflective writings after the FC sessions. Nearly a third of the students perceived the self-regulated learning in the FC as a challenge. It seems that some students find it difficult to work independently through new content on their own. They complained that they lose focus while working through the content without the guidance of the lecturer. Other challenges mentioned relate to using the technology required to access the power point slides through blackboard, dealing with new mathematics content on their own and poor time management. Chen et al. (2014, p. 26) argue that “some students have difficulty adapting to this novel approach because of their residual passive learning habits from the traditional classroom, where learning requires less proactive effort”. The literature cautions about the limitations and pitfalls of flipping the classroom (Phillips & Trainor, 2014), and challenges mentioned mirror those that students of this study reflected on: technology issues, increased responsibility on students to regulate their own learning which may leave some students feeling uncomfortable or abandoned, and the culture shock for students accustomed to rote, lecture-style learning.

Students also reflected in the open-ended questionnaire on benefits of the FC. Nearly two thirds of the students reflected on their ability to work through the slides on their own (SRL) and expressed positive feelings such as pride, motivation, satisfaction, enjoyment and confidence about their achievements. A quarter of the students reflected on increased levels of content knowledge, while the rest felt that they have gained focus, time management skills and computer skills because of their SRL. The literature mentions benefits of the flipped classroom strategy, which concurs with the findings in this study. For example, there is increased time for engaging instruction (Milman, 2012); students can study at their own time and pace rather than listen to a lecture on a topic that they already understand and can view lectures on mobile devices whenever they are ready (Steed, 2012).

Reflections and recommendations

The results revealed several challenges that students experienced in the FC, for example dealing with technology. We intend to employ more student assistants in the computer lab to support those students who have problems with technology. Some students felt that the slides did not provide sufficient information on new topics and additional videos with interactive elements will be prepared to support them. As far as students’ self-regulated learning is concerned, we realise that students need to be motivated that they can succeed, and the lecturer will assist individual students in this regard. Furthermore, students need well-defined instruction regarding the time taken to complete tasks in order to manage expectations in this regard.

We recommend that future studies include reflection activities as a regular part of the classroom culture to make the implementation of the FC more effective. The students’ reflective writings not only provide guidance for the lecturer to plan for the in-class learning and teaching, but also allow the students to think about some of the questions posed, and come to class with questions of their own.

In this study some students experienced problems with the mathematics content in the FC, for example, understanding how to complete the table of signs to determine the solution of rational inequalities. However, they reflected positively on their learning of Cramer's rule and Gaussian elimination and preferred these methods to the matrix inversion method of solving systems of equations. Future research should focus on the conceptual challenges students face with regard to learning mathematics content in the FC. It would be interesting to determine which concepts students find most problematic and how a FC approach can facilitate improved learning of these concepts.

Although the present study revealed an overview of students' positive and negative experiences within the FC as well as challenges and perceived benefits they mentioned in their reflective writings, the effect of the FC on their performance in mathematics was not examined. We recommend that future research should employ controlled studies that objectively examine student performance throughout a semester within both traditional and FC teaching approaches.

Conclusion

In this study the constructivist and social learning theories provided a backdrop for students' SRL in the FC, and from their reflective writings at the end of each FC session they derived meaning about their learning of mathematics. Changing the teaching methodology from the traditional teaching approach to the FC approach meant a change in learning experiences for the students participating in this study. Students had to work through first year mathematics content independently without the assistance of the lecturer and some reflected negatively on the experience, with specific reference to problems with technology, time management and understanding the content. However, most of the students experienced feelings of empowerment and expressed positive emotions regarding their learning experience. Students also felt more prepared for the in-class face-to-face sessions with the lecturer. This study therefore revealed that the majority of the students experienced the FC positively. In addition, the reflective writings of the students and the short tests they wrote after the FC sessions provided guidelines for the lecturer to assist them with specific problems they experienced with the content during in-class sessions. More time was available for solving engineering application problems during class time and students had the opportunity to be involved in the learning process and take responsibility for their learning in a safe environment while the lecturer became the guide and facilitator. Based on the feedback of the students the FC model seems to be appropriate for use within the South African context, provided lecturers guide them to overcome challenges with the online instruction and their SRL.

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School-leaving and university entrance assessments in explaining performance in Engineering studies

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Only about 40% of South African first-time entering Engineering cohorts graduate within five years. An argument has been made that selection mechanisms will be needed to identify students who have the prior knowledge and ability needed to succeed in regular programmes and that selection tools such as Grade 12 results and other nationally or locally designed placement tests, such as the National Benchmark Tests (NBTs), be used for this purpose. The NBTs are a set of optional standardised tests that assess whether first-time applicants to South African universities are ready for the academic demands of tertiary education. The contribution of the NBTs to admission and placement has been investigated by a number of authors who have examined their effectiveness at forecasting success and for determining the need for additional academic support. None of these studies have focussed on Engineering or used dominance analysis as a method. This study focusses on cohorts from the Engineering and the Built Environment Faculty at a South African University. It uses linear regression and dominance analysis as well as categorical methods to investigate the contributions made by the national assessments in explaining higher education performance to inform Engineering admission, especially placement, policies as well as curriculum practices. The value of this information has significant potential to enhance retention and graduation if used appropriately. If South African universities are to continue to provide access, redress and success, particularly to students from socio-economically disadvantaged backgrounds, they should consider not only students' school-leaving performance but also their strengths and weaknesses as diagnosed through the NBTs.

Introduction

Throughput rate, or successful completion of university degrees in South Africa, has long been a concern for academics and society at large, and has been discussed by various authors (inter alia, Case, 2013; Du Plessis and Gerber, 2012; Frith and Prince, 2016). The issue of access and success is complex and this study does not attempt to deal with all of the complex factors.

While access to higher education has widened in recent years, many students fail to successfully graduate. In 2014, the number of students enrolled in South African higher education institutions was close to a million (CHE, 2016: p.3), while the overall throughput rate for three-year degrees was 54% (ibid, p.62).

The ratio of engineers to population in South Africa is very low compared to other countries: 1:3166, compared to 1:389 in the USA and 1:130 in China (Grayson et al, 2013: p.343). This is of concern, given the lack of high-level skills in the South African engineering field and the need for engineers in order for the country to achieve its development goals. A study in 2009 by the Council for Higher Education showed that only 54% of South African Engineering students who were first enrolled for a professional Bachelor's degree in 2000 graduated

within five years (CHE, 2009: p.36) and referred to a “growing gulf” between enrolment and graduation in Engineering between 1989 and 2010. In a further study in 2013 by the Council for Higher Education it was shown that only 41% of the 2006 first-time entering Engineering cohort graduated within 5 years (CHE, 2013: p. 47). This is substantially lower than what it was for the 2000 first-time entering cohort and it is imperative that a means should be found to determine which Engineering study, regular or extended, is most appropriate for which students. “The mainstream degree programme is designed to take four years, assuming students do not fail any courses along the way. Selection mechanisms will be needed to identify students who have the prior knowledge and ability needed to succeed in this programme. Selection tools may include Grade 12 results (currently the National Senior Certificate) and other nationally or locally designed placement tests, such as the National Benchmark Tests (NBT)”. (CHE, 2013: p.183)

This study investigates the contributions made by a South African school-leaving assessment (the National Senior Certificate) and a university entrance assessment (the National Benchmark Tests) in explaining performance in the Professional Engineering degree – a four-year post-school qualification – in an Engineering and Built Environment Faculty at a traditional, public South African university.

This investigation should inform admission and placement decisions to address the low throughput rate of Engineers.

Two first-time entering student cohorts - a total population of 697 students - were studied and tracked for four years. By applying multiple linear regression and dominance analysis using grade point average as the target variable, the study reveals two things: that there is a complementary relationship between the two assessments and that the university entrance assessment makes a clear contribution to explaining variation in grade point average. The assessment is shown to have value in assisting universities to make selection and placement policy decisions in Engineering and in choosing appropriate teaching and learning interventions.

Background and Literature review

The two assessments under discussion in this paper are the National Senior Certificate (NSC) and the National Benchmark Tests (NBTs). First written in 2008, the NSC, commonly known as the matriculation certificate, is a statutory South African school-leaving certificate which is conferred at the end of Grade 12. The NSC has four pass categories: basic (no access to tertiary education), access to Higher Certificate study, access to a Diploma, and access to a Bachelor's Degree (Umalusi 2013: p.13).

The qualification under discussion in this paper is the Bachelor's pass, which requires a learner to achieve 30% or more in the language of learning and teaching of the higher education institution, and 50% or more in four designated subjects (Umalusi, 2013: p.14). The National Benchmark Tests (NBTs) were piloted in 2008 after being commissioned by Higher Education South Africa (HESA), now called Universities South Africa (USAf). These are a set of standardised tests that assess whether first-time applicants to South African universities are ready for the academic demands of tertiary education in three areas: Academic Literacy (AL), Quantitative Literacy (QL), and Mathematics (MAT) (Griesel, 2006). Griesel (2006) outlines the four-fold purpose of the NBTs:

- To assess entry-level academic and quantitative literacy and mathematics proficiency of students;

- To assess the relationship between entry level proficiencies and school-level exit outcomes;
 - To provide a service to HE [higher education] institutions requiring additional information in the admission and placement of students; and
 - To inform the nature of foundation courses and curriculum responsiveness.
- Performance on the NBTs is classified according to three benchmark levels: Proficient, Intermediate, and Basic. Table 1 shows the levels of success that these benchmarks explain:

Table 1 Benchmark levels

	Challenges students may experience
PROFICIENT	Performance in domain areas suggests that academic performance will not be adversely affected in cognate domains. If admitted, students should be placed on regular programmes of study.
INTERMEDIATE	Challenges in domain areas identified such that it is predicted that academic progress in cognate domains will be affected. If admitted, students' educational needs should be met in a way deemed appropriate by the institution (e.g. extended or augmented programmes, special skills provision).
BASIC	Serious learning challenges identified. Students will not cope with university study.

It has been found useful to use the arithmetic mean to split the Intermediate band into two bands: Intermediate Upper and Intermediate Lower.

The contribution of the NSC and the NBTs to admission and placement has been investigated by a number of authors who have examined their effectiveness at forecasting success (Allers, et al, 2016; Jacobs et al, 2015; Rankin et al, 2012; Du Plessis & Gerber, 2012; Case et al, 2013; Cliff, 2015).

Some studies have found that particular NSC examinations, such as Mathematics, and the NBT domains (that is: AL, QL or MAT) have more predictive power in specific contexts than others. Allers et al (2016), for example, compared the NSC results and NBT results of second-year Physiology students in 2011 and concluded that achievement of high marks in the NSC subjects, English and Life Sciences and the NBT Quantitative Literacy test were predictors of success in Physiology. The NBT, according to these authors, "could have some value in predicting the success of candidates in their second year of study" (p.83).

Jacobs et al (2015) also found that both the NSC and the NBT Mathematics test have predictive value. Their study investigated the predictive power of the NSC Mathematics results and the NBTs for success in first year university science courses and they recommended a strategy for post-admission placement of students that includes the use of the NBT scores.

Other studies (Rankin et al, 2012; Du Plessis and Gerber, 2012) have found that the NBT scores overall were a predictor of success in specific university courses and that combining them with the NSC scores improved predictive ability:

In examining the predictive ability of the NBT and the NSC at two South African universities for success in an identical first-year Economics test in order to determine whether NBT scores should be used as a determining factor in university admissions, Rankin et al (2012)

concluded that the NSC marks on their own were better predictors of success in the Economics test than the NBT scores on their own, but that combining the scores improved the tests' predictive ability: "...a combination of NSC Mathematics marks and the full set of NBT scores improves the predictive power [of the NSC] significantly" (p.579). They also found that the NSC marks were not good predictors of success for students who obtained close to the minimum requirement (60-69%), and recommended that the NBT scores should be used in these cases.

Du Plessis and Gerber (2012) examined the recommendations of the NBT Project that to be successful in university-level Mathematics students' NBT scores should place them in the Proficient category. Their data showed that students whose scores placed them in the Basic category were not able to succeed in their university Mathematics modules. Their conclusion was that higher NBT scores were necessary for success in university courses such as Actuarial Science and Mathematics, but they were not necessary in courses such as biological, earth, and agricultural sciences.

Other studies have focussed on the ability of the NBTs to assist in the development of teaching and learning interventions. Case et al (2013) argue that in general, NBT results show that most students are under-prepared for university study and that therefore, placement in extended curriculum programmes would be appropriate, while Cliff (2015) argues for the use of the NBT AL test scores to determine the level of preparedness of first-time entering university students and to assist in developing teaching and learning interventions that could help improve students' performance.

The current study builds on the foregoing research and focusses on cohorts from the Engineering and the Built Environment Faculty at a South African University to investigate the ability of the NSC and NBT in explaining subsequent performance in Engineering studies.

Methods

Student performance in higher education is often measured through academic standing (AS), which describes the academic progression or exclusion status of the student at the end of every term or academic year. This university uses a variety of codes to indicate the overall academic performance of students. For the purposes of this study, the fourth-year academic standing codes were grouped into three main categories: Fail (FAIL), Continue (CONT) and Qualify (QUAL). The academic status of a student is represented by a single categorical variable showing the overall academic standing.

The Fail category consisted of students who were academically excluded during the four-year duration of their studies. This exclusion could have occurred at any time between the first year of study and the final year. Students who withdrew from their studies in good academic standing and those who transferred to other institutions were excluded from this analysis. The CONT category consisted of students who were still in the process of studying towards their degree after the fourth academic year. In most cases, these are students who would have failed at least one course which prevented them from graduation. The QUAL category consisted of students who graduated from university in the minimum time allocated - i.e. - four years.

Students who were enrolled for an extended degree program were excluded from this study. In this context, an extended degree program in Engineering and Built Environment Faculty

takes a minimum of five years to complete.

In addition to the academic standing, fourth year grade point average (GPA) was used to assess student performance. Fourth year GPA is defined as the percentage that represents the aggregate of the student's grades and course credits over their academic career. Charts showing the means with 95% confidence intervals were used to compare fourth year GPA, NBT and NSC by AS categories. We are 95% confident that the mean will fall within the confidence interval. The mean is known to be affected by outliers in a dataset. For the purposes of this study, 40 outliers were not included in the analysis.

The Multiple linear regression method was used to determine the relationship between the fourth-year GPA, the dependent variable, and the aggregate NSC and NBT scores, the independent variables. Multiple Linear regression (MLR) is a statistical technique which investigates the linear relationship between a continuous dependent variable and multiple independent variables. The independent variables can be continuous or categorical. In this study, two main continuous independent variables were used: (i) NSC Aggregate (i.e. - the score for the best six NSC subjects out of 600) (ii) NBT Aggregate (i.e. – the total score for the three NBTs out of 300). Linear regression requires that each independent variable should not be a linear function of the other. Multicollinearity causes an inflation of standard errors for the regression coefficients. For this study, using the variance inflation factor function in STATA multicollinearity was found not to be a problem.

Finally, dominance analysis was used to determine the relative importance of the independent variables used in the linear regression models. Dominance analysis is a statistical method applied to multiple linear regression models to determine the relative importance of the independent variables used in the MLR model (Azen & Budescu, 2003). Dominance analysis works by separating the contributions made by each predictor variable to the R-squared statistic in the model. The R-squared statistic shows the amount of variation in the dependent variable that is explained by the regression model. Dominance analysis results in a classification of each predictor variable into one of the three distinct levels of dominance i.e. general, conditional or complete dominance. Within this study, the regression models compared the dominance of NBT and NSC in explaining the variation in fourth year GPA.

Results

The analysis was based on the performance of the 2011 and 2012 first time entering (FEN) student cohorts, who are students enrolling in university for the first time. The sample used consisted of 697 students. The two cohorts were tracked for four academic years.

Descriptive statistics

Table 2 shows the demographic description of the sample used in this study. 77% of the sample was male while 23% was female. The white population group at 38%, was the largest, followed by the black population group at 30%. The Chinese population group was the smallest at 2%. The Unknown population group at 9% included international students as well as those who did not state their race.

Table 2 Demographics

Gender	N	%
Female	160	22.96
Male	537	77.04
Total	697	100
Population Group	N	%
Black	208	29.84
Chinese	15	2.15
Coloured	64	9.18
Indian	78	11.19
Unknown	64	9.18
White	268	38.45
Total	697	100
First Year Registration	N	%
2011	321	46.05
2012	376	53.95
Total	697	100

Table 3 shows the summary statistics of the NSC aggregate, NBT aggregate and the fourth-year GPA scores used in the regression analysis. The difference between the total number of scores for the NSC and NBT Aggregates is due to the fact that international students do not write the NSC.

Table 3: Descriptive Summary Statistics

NBT Test	N	Mean	SD	Minimum	25th Percentile	Median	75th Percentile	Maximum
NBT Aggregate	682	209	34.26	100	188	215	233	271
NSC Aggregate	616	488	37.13	303	466	490	514	573
Fourth Year GPA	701	65	9	26	59	65	72	90

The majority of the students included in this study had an NSC aggregate of more than 400 points out of 600. The distribution of the NBT aggregate scores were moderately negatively skewed.

Academic Standing

Table 4 shows the overall academic standing of the students in this sample. The results show that 45% of the 2011 and 2012 First Time Entrants (FENs) to the Professional degree qualified, while fifteen percent (15%) 'Failed' and 40% were still studying at the end of minimum time (4 years). Overall, these results indicated that more than half of the students failed to graduate in minimum time.

Table 4: Overall Academic Standing

Academic Standing	N	Percent (%)
FAIL	106	15.2
CONT	277	39.7
QUAL	314	45.1
Total	697	100

As expected, students who qualified had a significantly higher mean fourth year GPA compared to those who either failed or were continuing with their studies (Figure 1). This result suggests that fourth year GPA is a good indicator of student performance.

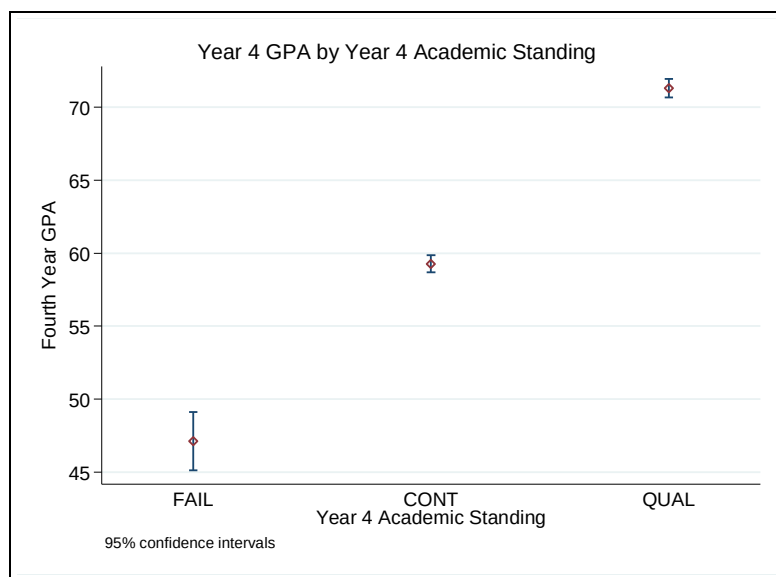


Figure 1 Professional Degree - Year 4 GPA by Year 4 Academic Standing

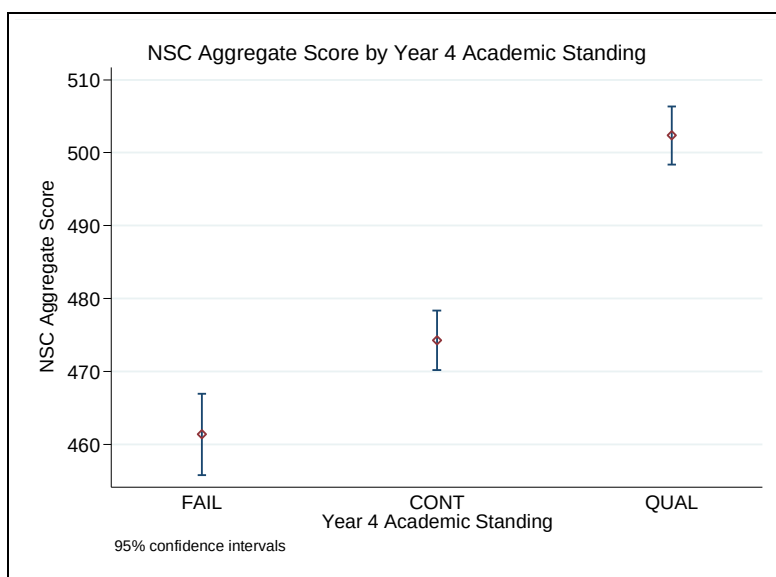


Figure 2: Professional Degree – NSC Aggregate Score by Year 4 Academic Standing

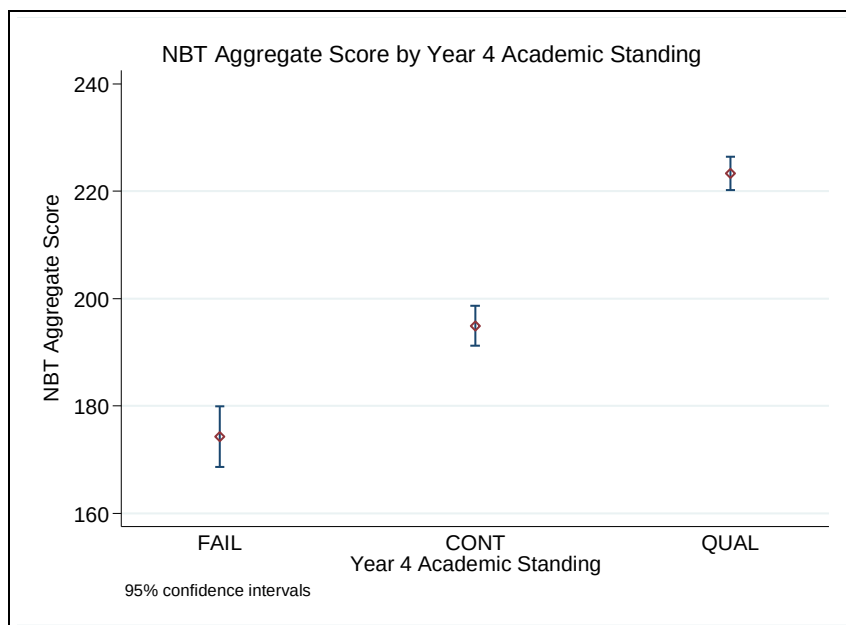


Figure 3: Professional Degree –NBT Aggregate Score by Year 4 Academic Standing

The focus of this study was to determine which of these two predictor variables contributes more to the variation in student performance (GPA) in the fourth academic year. The following section begins to address this through linear regression analysis conducted using the GPA as a dependent variable.

Linear regression using fourth year GPA

The results in the previous sections showed that both the NSC and the NBT Aggregates differentiate well between students in terms of their academic standing. However, it is further necessary to understand the relative importance of each of these two predictor variables in explaining the variation in student performance.

In this section, linear regression analysis is used with the fourth year GPA as the dependent variable which represents student success. In the first instance the linear relationships between the the NSC Aggregate and the NBT Aggregate is assessed and then the linear relationship between Fourth Year GPA, the NSC Aggregate and the NBT Aggregate respectively is assessed.

There is a weak positive linear relationship between the NSC aggregate and the NBT aggregate, with a pearson correlation coefficient of 0.32 (Figure 4).

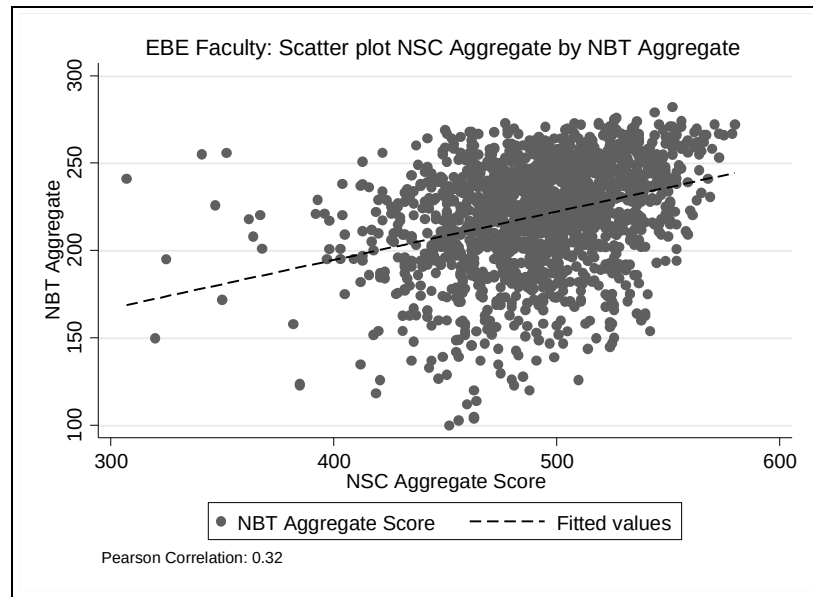


Figure 4 NSC Aggregate by NBT Aggregate

The fourth year GPA has a positive linear relationship with the NSC aggregate score, with a pearson correlation coefficient of 0.47 (Figure 5).

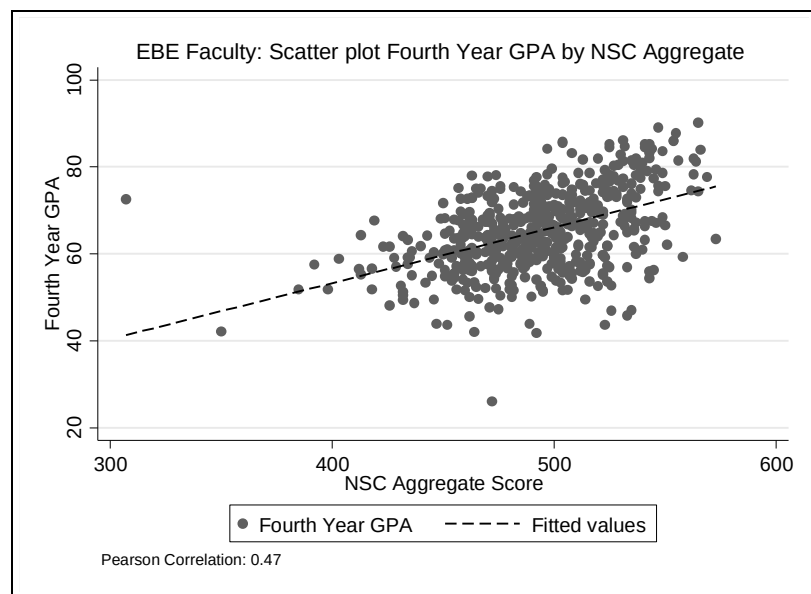


Figure 5 Fourth Year GPA by NSC Aggregate

The fourth year GPA has a positive linear relationship with the NBT aggregate score, with a pearson correlation coefficient of 0.48 (Figure 6).

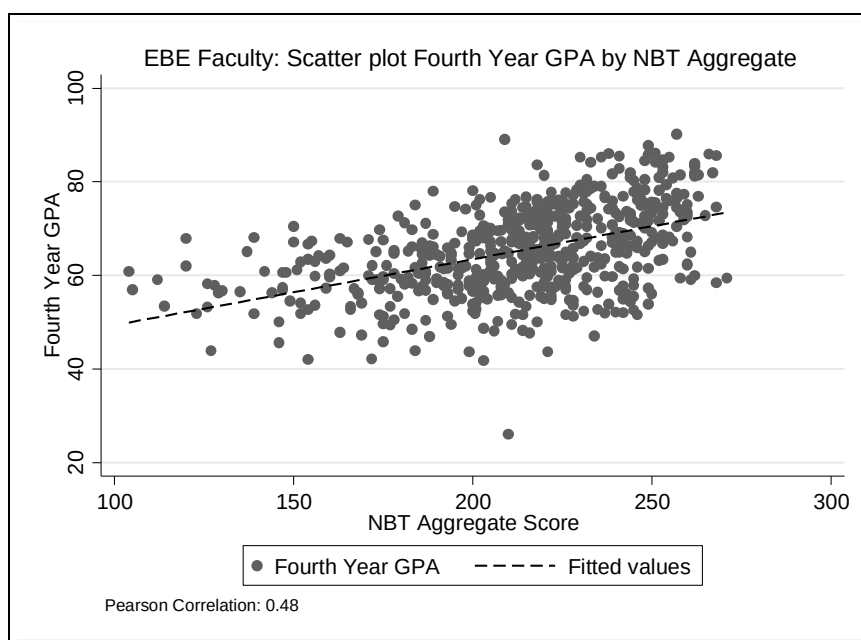


Figure 6 Fourth Year GPA by NBT Aggregate

The linear regression analysis showed that both the NSC and NBT aggregate score had a positive linear relationship with final year fourth year GPA (Table 5). For instance, for every 1 unit increase in NBT Aggregate, there is a 0.108 increase in fourth year GPA while holding NSC Aggregate as a constant. The linear regression model explains 30% of the variation of fourth year GPA.

Table 5: Linear Regression Output

Variables	Regression Coefficient (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$)	Standard error	Other statistics
NBT Aggregate	0.108***	0.0117	
NSC Aggregate	0.0702***	0.00925	
Constant	7.579*	4.334	
Observations			516
R-squared			0.30

Dominance Analysis using Fourth Year GPA

The next step was to determine the extent of the contribution made by each of the independent variables to the overall 30% variation explained by the model. The results (Table 6) showed that of the 30% variation explained by the linear regression model, the NBT Aggregate contributes 56%, whilst the NSC aggregate contributes 44%. Overall, the NBT aggregate completely dominates the NSC Aggregate in explaining the variation in fourth year GPA.

Table 6: Dominance Analysis

Variable	Dominance Statistic ($r\text{-squared}=0.30$)	Standardised Dominance Statistic	Ranking
NBT Aggregate	0.17	0.56	1
NSC Aggregate	0.13	0.44	2
Dominance conclusion	<i>NBT Aggregate completely dominates NSC Aggregate</i>		

Academic Standing and NBT proficiency levels

This section focuses on the performance of students based on the categorical grouping of NBT scores. The NBT performance is first stratified as either proficient or not proficient. The results show that most students obtained a proficient score in NBT AL and NBT QL. However, fewer than 50% of students obtained a proficient score in NBT MAT.

Table 7: Proficiency Levels by NBT Test

NBT Test	Proficient		Not Proficient		Total	
	n	%	n	%	n	%
NBT AL	526	77	156	23	682	100
NBT QL	454	67	228	33	682	100
NBT MAT	317	46	366	54	683	100

NBT Proficiency and Academic Standing

This section looks at how the academic standing compares between the proficient and non-proficient groups across all the NBTs. Figure 7 shows that the Academic Literacy proficient group was twice (52% vs 21%) as likely to graduate in minimum time compared to the non-proficient group. On the other hand, the Academic Literacy non-proficient group was three times (34% vs 10%) as likely to fail to graduate compared to the proficient group.

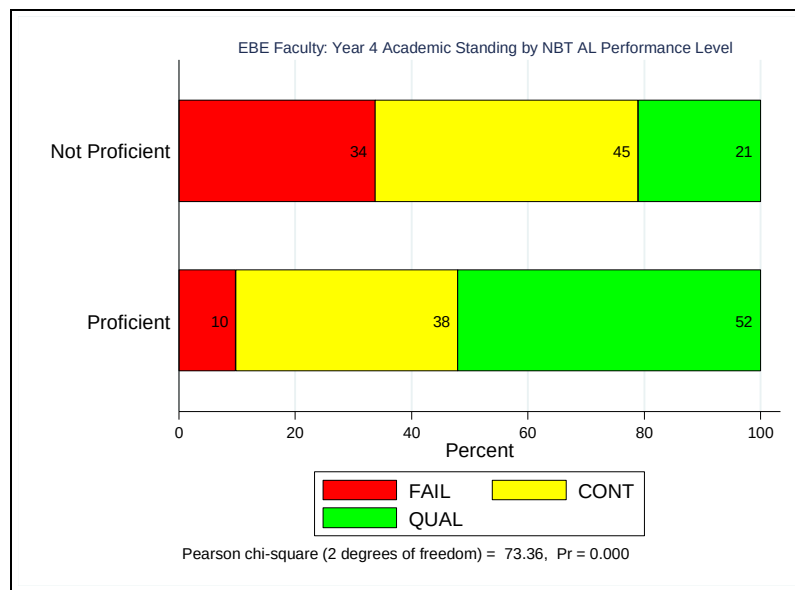


Figure 7: Fourth year Academic Standing by NBT AL Performance Level

Figure 8 shows that the Quantitative Literacy proficient group was twice (54% vs 27%) as likely to graduate in minimum time compared to the non-proficient group. On the other hand, the Quantitative Literacy non-proficient group was three times (27% vs 9%) as likely to fail to graduate compared to the proficient group. The performance trends are consistent with the observations made earlier using NBT AL.

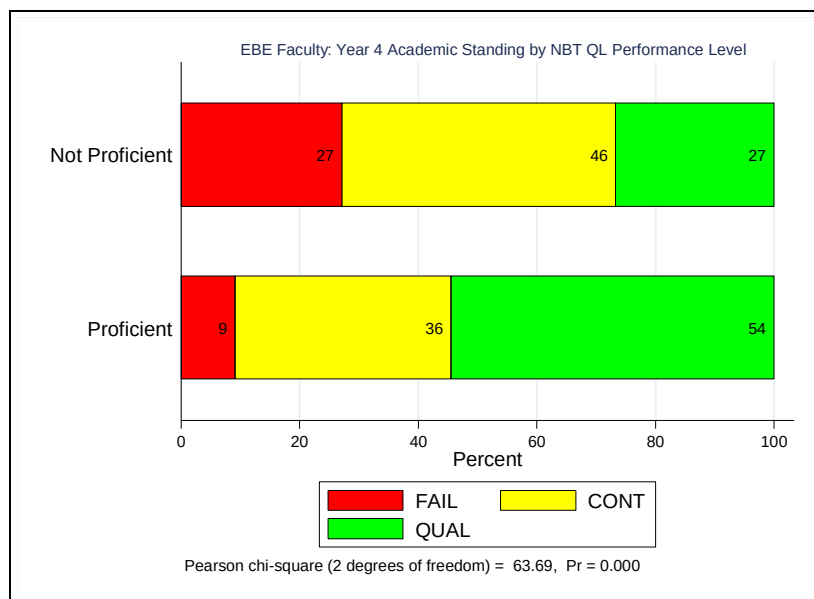


Figure 8: Fourth Year Academic Standing by NBT QL Performance

Figure 9 shows that the Mathematics proficient group was twice (60% vs 32%) as likely to graduate in minimum time compared to the non-proficient group. On the other hand, the Mathematics non-proficient group was nearly three times (21% vs 8%) more likely to fail to graduate compared to the proficient group.

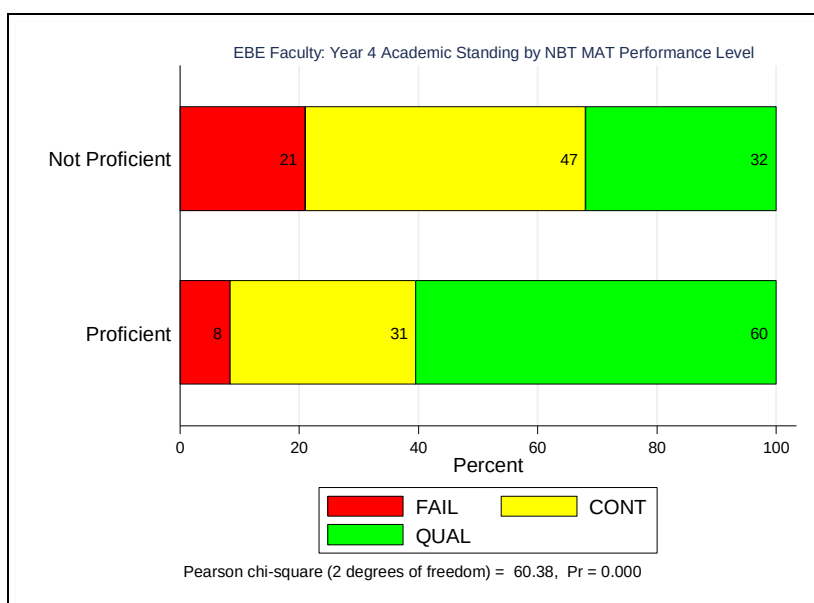


Figure 9: Fourth year Academic Standing by NBT MAT performance

Discussion and conclusion

In this study, both fourth-year Academic Standing and fourth-year GPA was used as outcome measures to investigate how these relate to the NSC and NBT aggregate scores. Given that the NBT aggregate score completely dominates the NSC aggregate score, how the NBT proficiency levels relate to fourth year Academic Standing was further investigated.

The results in this study reveal that both the NSC and NBT aggregates individually explain

fourth year GPA and that together they explain 30% of the variation within the fourth-year GPA. In addition, the evidence shows that the NBT aggregate, in this case, completely dominates the NSC aggregate in explaining the variance in fourth year GPA.

It is recommended that, due to the clear contribution which the NBT aggregate score makes in explaining subsequent performance, the NBT aggregate score could be used in addition to the NSC aggregate score for selection and placement.

Furthermore, the results in the study show that the NBT proficiency categories clearly identified those students who are likely to qualify in minimum time and those who are likely to fail. It is worrying that even though the NBTs had identified those students, who needed either extended degree programmes or additional support, these were not provided and that these students consequently did not fare as well as they might have had this information been taken into account.

Overall, this study showed that the NBTs contribute significantly to predicting the performance of students in the Engineering Faculty at this university. This information would be useful when Engineering Faculties are considering selection and placement policy decisions, as well as choosing teaching and learning interventions, particularly given the changing higher education landscape.

The value of this information has significant potential to enhance retention and graduation if used appropriately. If South African universities are to continue to provide access, redress and success, particularly to students from socio-economically disadvantaged backgrounds, they should consider and be responsive not only to students' school-leaving performance but also their strengths and weaknesses as diagnosed through the NBTs.

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Student perceptions of transformation and belongingness in engineering programmes at a South African university

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Abstract

The 2016 protests and shutdowns at South African universities highlighted how transformation in higher education has become a focus point. The extent of the impact of protests and shutdowns on students needs to be explored, shared and understood so as to better enable planning, designing and delivery of curricula and systems. The aim of this paper is to surface perceptions on transformation within the university context from engineering students whose first year experience included the 2016 disruptions. This initial study, part of a longitudinal study, used second year engineering student voices from an anonymous online questionnaire and in-depth interviews.

Students echoed established principles of transformation in South Africa, describing transformation at university as making all students feel included, having more black lecturers, developing a more Afrocentric culture (in displayed art, building names and choice of engineering problems), and the empowerment of students to speak to lecturers and challenge practices they feel are not inclusive. Student responses aligned with three pillars from a framework of inclusiveness: recognition, mutual understanding and trust. Recommendations for practices that promote inclusiveness in engineering education are given.

Introduction

The promotion of transformation is an explicit part of the mission of many South African universities (e.g. University of Cape Town, 2017; University of KwaZulu-Natal, 2017). To transform is to move from one state, composition or structure to a better one (Harvey & Knight, 1996) and can be characterised by the question “Where would we like to be?” In South African institutions, transformation means moving towards non-racialism and democracy, the redress of demographics to correct past injustices, the encouragement of intellectual diversity, the recognition of African voices, the enhancement and empowerment of participants, and being enabling rather than authoritarian (Badat, 2010; Waghid, 2002; Carrim, 1998).

Scott (2017) emphasises that access to higher education does little to meet the goals of transformation if incoming students only have a 50% chance of graduating. The importance of a sense of well-being and belongingness to student success at university is widely acknowledged (Kuh, Kinzie, Schuh & Whitt, 2011; DeBerard, Spielmans & Julka, 2004). A better understanding of students may help university staff to provide the academic and non-academic support that can lead to greater throughput rates. Greater throughput is central to the mission of transformation in higher education.

While much has been written on facets of transformation in South African institutions, we are interested to know, particularly after the 2016 protests at South African universities, to what extent the issue of transformation is important to engineering students and how engineering students perceive transformation and belongingness.

Belongingness, according to Levett-Jones and Lathlean (2008), is a personal and contextually mediated experience which includes feelings of secureness, being accepted, included, valued, connected and respected by a defined group holding similar values. Belongingness may be passive, in response to the actions of a group, or active, through an individual's actions. Maslow's (1954) hierarchy of needs includes belongingness as a necessary prerequisite to achieving a personal sense of meaning in work that is directed to the greater good.

A culture of inclusion can be defined as all students having equal opportunities to learn and experience personal success (McCann, Lacy & Miller, 2014). Pless and Maak (2004) provide a framework of inclusiveness containing five 'pillars': recognition, mutual understanding, multiple standpoint perspectives, trust, and integrity. These pillars can be used to identify barriers to inclusiveness.

Using Levett-Jones and Lathlean's (2008) and McCann, Lacy and Miller's (2014) definitions of belongingness and inclusion, and Pless and Maak's (2004) framework of inclusiveness, the following research questions will be explored:

- 1.) What barriers to inclusiveness and belongingness were experienced by students whose first year experience included the 2016 disruptions?
- 2.) How did the 2016 protests and shutdowns impacted on the lives of these students?
- 3.) What are students' perceptions and hopes for personal and institutional transformation?

Research design and methods

In conducting this research data were gathered in two ways. Firstly, three hundred and twenty five second year engineering students were sent a link to an anonymous online questionnaire of eight open-ended questions on transformation and four likert-style questions relating to Levett-Jones and Lathlean's (2008) definition of belongingness (Appendix A). Students were asked what transformation means to them in the context of their engineering classes, what events have made them feel included or excluded, how often during 2016 they felt safe, valued, connected and respected, how the protests and shutdowns on campus in 2016 affected them and what transformation they would like to experience at university. Only seven students responded to the anonymous questionnaire over a two week period in the first term in 2017. Due to the low response, quantitative analysis was not possible. Rather than discarding all the questionnaire data, the qualitative responses were included in the set of qualitative data for analysis as a way to hear the voices of students who did not want to be interviewed. Figure 1 depicts how the qualitative survey data was used as additional data for analysis as well as to reflect and potentially add to the interview questions.

Secondly, we conducted in-depth interviews with six students. Students across all races were invited to participate in the interviews, but only black students availed themselves for the interviews. Three were South African (one female and two males) and three were male international students from Southern African Development Community (SADC) countries. A South African male and female pair chose to be interviewed together, as did two international male students. The interview questions asked students to share their views on transformation in a university context with a focus on how the protests in 2016 affected the way they prepared for examinations. The interview protocol is given in Appendix B.

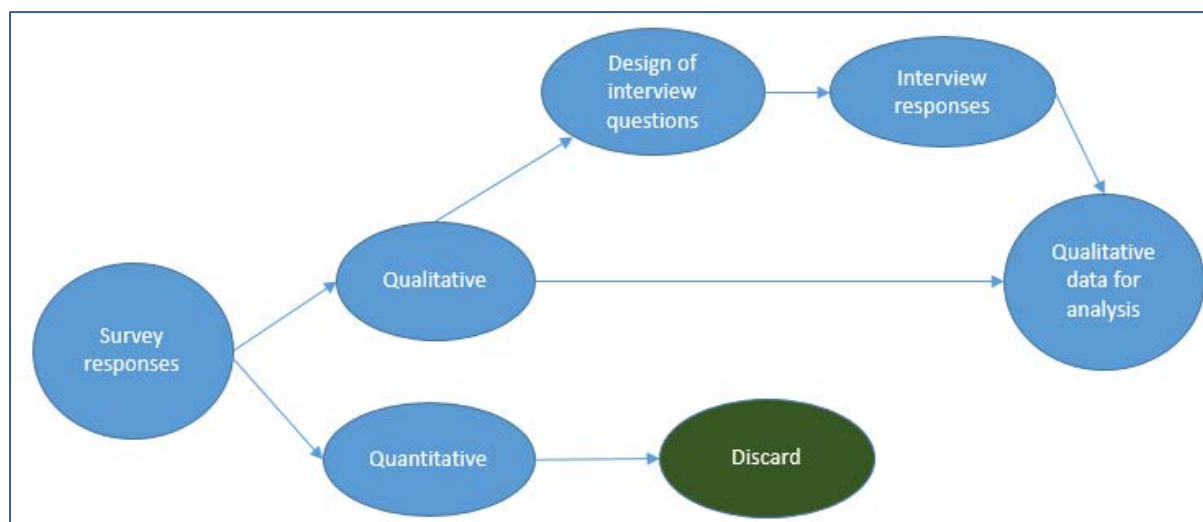


Figure 1: Use of qualitative and quantitative data from the survey responses

Findings

Student responses were grouped into themes related to each of the three research questions.

Barriers to inclusiveness and belongingness

The barriers to inclusiveness mentioned by students in the interviews and questionnaire responses relate to two pillars in Pless and Maak's (2004) framework of inclusivity: a lack of recognition of the differences between students with different backgrounds, and a lack of mutual understanding. The barriers experienced by this small sample of engineering students appear to be systemic, likely to occur across South African higher education institutions.

A critical barrier to inclusion is seen by the interviewees as socio-economic.

Student M: "We, as black children, have so much riding on us - financially."

Student S:

"I first hand experienced someone getting financially excluded and literally, she's gone and there's nothing anyone could do about it... a nineteen year old, ...and then a letter from attorneys asking to arrange payments for R55 000 back. Where are they gonna get that money from?"

Student G: "there's a huge gap between the difference races and the way they are living."

Student S further expounded on the need for financial stability. He explained his government bursary only paid after July, and this year, as happened last year, they still haven't paid. As a result he was always thinking about when his next meal would be. He needed money to eat and for stationary. "Hungry all the time, can't study, it's easier to sleep through the days... but we soldier on. What else can you do?"

Student S explains that coming from a previously disadvantaged background, students lack certain prior knowledge:

"I think you have to realise the challenges, when we come (to university), that we face, given our background. Even if it was a normal year, no strikes, maths and physics, those two courses can crush you. It's like starting the race late, where most people are like 200m ahead. But in other courses, we at the same level, you don't see much difference."

Student S also highlighted that lecturers needed to deliver content that was accessible to students from previously disadvantaged background, by using examples and questions that

have meaning to them. “They must not just assume everyone knows the practicalities of, for example, a plane and swimming pool.”

The socio-economic status of a student appears to be a key factor for inclusiveness and belongingness. The student voices above relate family pressure to graduate, financial pressures and academic pressures (feelings of starting university with deficient prior knowledge and cultural capital) to socio-economic status.

Impact of the 2016 protests and shutdowns on students’ lives

Students reported positive and negative effects from the 2016 protests and shutdowns, with strong emotions leading to difficulty with studying but also developing a sense of agency. The protest action created an opportunity for some South African students to reflect on race-based or class-based inequalities in South Africa and unfairness in life. Student G talked about the emotional turmoil and how it affected her: “It brought out anger in me...how is life so unfair...we can have democracy but there’s still a huge gap between the different races and their way of living.”

A respondent in the questionnaire: “it added a lot of stress to my first year studies ..., but at the same time opened my eyes to the many issues face in South Africa that I might not otherwise be exposed to”. Another questionnaire respondent shared this dual-perspective view: “I was very terrified ... and I saw there are lots of problems here. That affected me academically...”

Student L talked about his motivation to be part of making the lives of others better but ended with a sense of overwhelm: “I can’t see everyone in my township having a house, there are so many people.”

Student G further emphasised the tension and struggle within her when deciding whether or not to join the protest:

“I do understand what they’re saying and I can relate to in so many ways...should I join the protest, should I not? Cause, if there’s a chance I might lose my scholarship...or get arrested ... that won’t be good for me for when I do internships or go to work.”

Student S confirmed his difficulty to study:

“One month of no study and then I was just in the crowd...if you were to ask any black students how they feel about the strike...even if you are not part of the strike, it affects you...on the many things that are said, on social media, the reaction of the institution, your lecturers,... so it’s difficult to sit down to study because you can open your twitter account and check what’s been said ... someone has been arrested now ... it’s a national thing. People who have my same colour and same ideological belief were affected like that.”

A middle-class, mature, international black student, Student M, trusted the system and experienced the shutdown period very differently from the South African students:

“I missed the whole strike thing. I trusted the system fully ... the structure of the system [the 5-year program], I knew I wouldn’t fail ... I trusted the lecturers so much.”

He believed that working throughout the year would have prepared him for exams as he had fully participated in academic work and was minimally affected by protests. He agreed with the cause but was very upset by the disruptions as he had responsibilities that were affected by the uncertainty brought about by the shutdowns.

Student S also had another view, describing how he had been positively affected by the protest and disruptions. He felt the protests gave confidence to students like himself from “disadvantaged communities” to “challenge power” and speak up when they feel things should be different. For example, “standing up to lecturers, telling them ‘I’m not feeling good of how

you explained this” and when a lecturer expected a student to do an assignment using Skype when the student had to go home for a religious ceremony, making the assumption that the student had a computer and internet access capable of making a Skype call. “From now on, when you see something, you can stand up and challenge it.”

It is argued that the protests may have given students more awareness of where they belong socially, that their lives might be considered more disadvantaged than they had previously thought. For a majority of respondents, they are at a crucial age for reflecting on their identity and how society sees them (Luckett & Luckett, 2009).

Perceptions and hopes for personal and institutional transformation

Several student perspectives on institutional transformation emerged. A central point was that all the interviewed students identified with the issues raised by the #FeesMustFall movement but were wary of being part of the protest action due to either losing bursaries or study permits. From the questionnaire responses, hopes for transformation included creating a more Afrocentric university culture by employing more black lecturers, displaying Afrocentric art and clothing, naming buildings after African role models, the use of curricula with African-based engineering examples that address problems in townships, and the improvement of infrastructure to promote social and environmental sustainability.

Questionnaire responses and interviews identified student-student and student-lecturer interaction as having the potential to cause transformation at a personal and institutional level, a finding that resonates with literature on student success (Kuh, Kinzie, Schuh & Whitt, 2011). Communication should not assume that all students have shared knowledge but common ground would be found through “free, open spaces for dialogue” and “some discussion of one’s personal experience to understand each other’s cultures and religion to close the gap for ignorance.”

Students who worked well in groups when preparing for end-of-year examinations had worked alone when preparing for their mid-year examinations because they had not yet formed friendships with classmates. Questionnaire responses suggested that inclusiveness could be improved by having events to “force people to interact with each other” and by “students interacting more with other students and lecturers in tuts and other forms of learning.”

Student M questioned the structure of the norm of a 4-year versus 5-year programme in engineering. (At his university, after the first term tests, under-performing students are advised to choose to move to a 5-year programme.) He argued for the 5-year programme to be the norm as failing tests “traumatises students” and that the extended time of the 5-year programme allowed the content to really be understood - he was “not here to simply pass.” Before moving to the extended program, Student M reported:

“Literally, we had depression. We saw the environment killing us” [whereas moving to the 5-year programme] “changed everything. ... Weighing up pros and cons to moving [to the 5-year degree programme], there’s so many pros ... why isn’t this the first option?”

Another perspective highlighted the transformation challenges and social concerns in student residences. Student K related a series of incidents where due process was hindered due to demands of the student movement Patriarchy Must Fall (PMF). A house committee member in a male residence was accused of sexual harassment and PMF protested at the residence until he was removed from office. Some student residents were not happy that their elected member was removed and this caused tension, a “civil war at residence, some saying they voted for the

removed house committee member and don't want him to step down" despite sexual harassment allegations.

Student K further related that the student left the residence but still probably holds the same views. The lack of due process may have removed the chance of 'rehabilitating' or transforming the house committee member's personal views. The polarisation caused by protest groups had the effect of silencing voices.

Student K: "As a man, I don't feel I can say anything [to PMF]."

Student G described, in her view, that some movements have a 'cause' "for example, the LGBTI aims to have no gender bias", but others are about challenging rules but doing so without following procedures. She gave an example of when the issue was raised informally in a house-committee meeting rather than being raised through "proper structures," it led to an inappropriate remark from a sub-warden, resulting in tension around engaging with the sub-warden. Transforming rules is complicated when "some people only want to change the rules to benefit themselves" yet "other rules are outdated" and should be changed.

Both students, K and G, further expound on the complexities of transformation. Student G:

"We're trying to redefine things and we're still stuck trying to find what should be implemented. ... A university will never be fully transformed. There has to be someone to allow transformation to happen. Not everything is beneficial and good. There will have to be rules and authority. Some forms of transformation are necessary."

Student K: "You won't always win. Some people won't accept that."

Feelings of rejection and unworthiness during the protests and shutdowns were reported by a student who witnessed their race as associated with academic and financial exclusions. During the shutdowns there were instances where engineering departments held open forums that were welcomed by one of the participants in the questionnaire, who described an instance of feeling included in the civil engineering forum: "It felt like we were looking to each other for help...being listened to."

Conclusions and recommendations

While there were only seven responses to the survey and six students interviewed, the views shared provide a rich perspective on transformation and belongingness from students who were in their first year of engineering studies during the 2016 protests and disruptions. The low response to the survey and interviews suggests that in the semester following the 2016 disruptions, transformation was not an issue that second year engineering students wanted to discuss, at least not with researchers. Returning second year students may not want to jeopardise their studies by reflecting on unsettling issues around transformation. Students with an advantaged socio-economic status may find it too discomforting to discuss transformation when it highlights their position of privilege. More research is recommended to confirm or dispute these claims.

Students echoed the principles of transformation in South Africa established by Badat (2010), Waghid (2002) and Carrim (1998) when they described transformation at university as making all students feel included, having more black lecturers, developing a more Afrocentric culture (in displayed art, building names and choice of engineering problems), and the empowerment of students to speak to lecturers and challenge practices they feel are not inclusive.

The impact of the 2016 protests on students who were in their first year appears to have been greater for South African students, who have witnessed peers being financially excluded from

higher education and who feel the unfairness of financial inequality that is largely race-based. The international students interviewed who lived off-campus appeared to have been less affected by the disruptions than South African students who stayed in university residences. The uncertainty of not knowing when the university would reopen and the fear of losing the year made it difficult to focus but ultimately there was a benefit for the international students from the extra time that they could put into studying for their exams.

The three South African students who spoke of their homes in townships felt aligned to many of the issues raised in the protests. They found the protest and shutdown time very emotionally challenging. When deciding whether or not to join the protests, a dominant consideration was the awareness of the importance of their sponsorship which they did not want to risk losing. Two South African students did not take part in the protests although they supported the ideas of the protests, while the third South African student, whose government sponsor only paid mid-year in 2016, did actively take part in the protests.

Inclusiveness can be built through three ‘pillars’ from Pless and Maak’s (2004) framework: recognition, mutual understanding and trust. Improved communication between students and lecturers may help lecturers to *recognise* students from marginalised communities. An emphasis on developing *mutual understanding* could encourage students to suggest examples of engineering and social problems that could be used in teaching. Structures that provide students with sufficient time to deeply know the concepts they are learning can develop *trust* in the system that can reduce anxiety associated with high-stakes assessment.

Suggestions on improving inclusiveness emphasised the importance of student-student and student-lecturer relationships. Working relationships between students could be developed by requiring more group work on inspiring activities in the first semester and encouraging participation in after-hours review workshops where students work collaboratively around large whiteboards. Faculty-wide weekly debates could raise awareness of different ways of thinking and give students a shared experience.

An acute awareness of the differing circumstances that impact on students’ lives can help to answer the question of how to strengthen student support and teaching-and-learning strategies to improve student success and throughput rates. For example, if a lecturer knows that students with limited access to food may compensate for low energy levels by sleeping long hours, resulting in reduced time on task and academic under-performance, then they may be more inclined to support students by actions such as pointing students in the right direction to obtain funding, providing further opportunities to learn or catch-up the material, and protecting students’ identities when displaying marks publically. Although easy solutions at a large scale may be difficult to implement, having advisers and resources to help these students already in the system will go a long way towards transformation, belongingness and overall student success.

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Appendix A: Online questionnaire

Transformation and Belongingness in Engineering Degrees at UCT

The aim of this research is to share student opinions with engineering lecturers in South Africa and internationally through conferences and publications. Thank you for sharing your valued views.

This questionnaire is completely anonymous. Participation is entirely voluntary. You may leave out questions you don't want to answer.

1. Within the context of your classes, what does transformation mean to you?
2. Was there a time when you felt that not all views in a class were being heard or some people were excluded? If yes, give details.
3. Have you been in a small group when you felt that not all voices were being heard, or some people were excluded? If yes, give details.
In your 2016 classes, how often did you feel ...
 4. safe?
 5. valued?

6. connected?
7. respected?
8. Describe events in your university experience that made you feel included.
9. What can a student do to feel more included at university, and what can a university do to make students feel more included?
10. In an ideal world, what would your future university experience look like?
11. How were you affected by the shutdowns and protests on campus in 2016?
12. Who in your family has attend university?

Appendix B: Interview protocol

Consent form to be given to interviewees

- *The purpose of this research is to listen to second year engineering students' views and experiences relating to transformation and belongingness at UCT.*
- *Your identity will be kept anonymous in any research outputs, e.g. conference talks or journal articles.*
- *Your participation is voluntary and will not affect your course marks.*
- *If you agree for the interview to be recorded to help with our note taking, we will not record your name and will not make the recording publically available. The recording will be deleted after we have made notes.*
- *If you prefer not to answer interview questions, you are free to do so. If you wish to withdraw from the research project you may do so by contacting ...*

I understand that this interview is voluntary and anonymous, that I may leave at any time and that I may later request that my interview data not be used in this study.

Signed: _____ Date: _____

Sample Interview questions

The sample interview questions below may be adjusted to probe responses arising from the online questionnaire. Questions 1 to 4 explore whether safety and security concerns significantly affected the interviewed students. In questions 4 to 7 we want to explore, without leading students, whether there is a view that disruptions are or are not acceptable or necessary in order to achieve transformation.

1. How did you prepare for the exams in November 2016 and January 2017?
2. What are the conditions under which you learn best? (If necessary, ask about emotional conditions.)
3. How did your experience of mid-year exams compare with end-of-year exams?
4. How did you perform in exams?
5. What do you think is meant by transformation in a university context?
6. How can a university be transformed?
7. What are your views on the recent protests and disruptions on campus?
8. How were you affected by the disruptions?

An investigation into the impact of changes in assessment practice in a mass transfer course

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The study presented in this paper focuses on a third year course in chemical engineering on the topic of mass transfer operations. Historically, the students taking this course have performed poorly and pass rates have been unacceptably low – between 31 and 66% over the period 2012 to 2014 (before the results of supplementary examinations are considered). A modification to the assessment system first implemented in 2015 has resulted in a dramatic improvement in pass rates which has been sustained at over 80% since its introduction. The study investigated the reasons for the improvement and demonstrates the efficacy of a continuous assessment strategy and how a relatively simple research approach can provide appropriate evidence-based information that can usefully inform the design, implementation and evaluation of course delivery and pedagogical interventions.

Introduction

A dramatic improvement in pass rates in a third year chemical engineering course on mass transfer operations prompted the study presented in this paper. The improvement followed a modification in the assessment system used in the course and the study aimed to establish the extent to which the improvement could be attributed to that modification or to other factors. The study was carried out by the course coordinator in collaboration with a colleague experienced in educational research who acted as a ‘devil’s advocate’ in the investigation.

Prior to the modification, the mass transfer course was a fairly typical teacher-centred engineering course delivered in a ‘traditional’ manner over a single semester – two double lectures per week with an afternoon tutorial every second week. The course content was organized in a conventional manner covering the key topics in the subject and, in each case, progressing from the fundamentals to the more complex concepts and applications. A range of recommended readings for each topic in the course were provided in the course outline and students were provided with sets of notes prior to engagement with each of the course topics. In some topics, practical demonstrations were done in class to facilitate deeper understanding. Application across a variety of contexts and scenarios within the field was provided in terms of practical, numerically based problems presented in the form of tutorial questions, some of which were worked in class to demonstrate the relevant problem solving and application issues.

Initially, the assessment practice in the course involved a mid-semester test and a final examination contributing 20% and 80% respectively to the final mark. Some formative assessment was provided in the form of short, open-book ‘tut tests’ in the tutorial sessions. During these tests, the students were free to discuss among themselves and also to consult the tutors and the course coordinator. The tests were marked and discussed during tutorial and

lecture periods as was appropriate. Solutions were posted on the noticeboard within a day or two of the tests. Marks for these tests were communicated to the students as soon as possible, usually in the lecture or tutorial following the test. However, the marks did not contribute to the final course mark.

Given the level of planning and care which had gone into the course design and delivery, it was both disheartening and perplexing for the course coordinator that pass rates in the course were consistently poor over the period 2012 – 2014; details are given shortly. Reflecting on this problem, the coordinator arrived at several possible reasons: poor lecture attendance; an apparent negative attitude among students towards the course based on its historic high failure rate reinforced by comments from the relatively high proportion of repeat students in the class; students' apparent lack of engagement in critical course content and concepts; and failure on the part of many students to adequately prepare for assessments and examinations. The course coordinator concluded that one of the ways in which these problems might be resolved was to change the assessment system in the direction of continuous assessment with emphasis on formative components. Before presenting details about the changes that were made and discussing their implications, it is appropriate to review briefly the literature relevant to assessment practice and its impact on student learning and academic performance. Thereafter, the investigations that were carried out are presented along with their findings.

Assessment practice and student learning: A brief review of the literature

Felder et al. (2000), in their article entitled "Teaching methods that work", make the claim that "although we might wish otherwise, for many of our students, tests are the primary motivation to study". From an academic perspective it is therefore appropriate to view assessment as central to student experience (Brown & Knight, 1994). The role of assessment practices in higher education as an indicator of student learning has been well documented, (Biggs 2003; Black and William 1998; Gibbs 1999; Gibbs 2006a; Gibbs et al. 2003; McDowell and Sambell 1999; Ramsden 2003; Rust 2002) and the research clearly indicates that assessment has the potential to frame learning experience (Biggs 2003; Bryan and Clegg 2006; Heywood 2000; Ramsden 2003). However, there is a difference between student learning as a means of obtaining optimal marks in an examination, and student engagement with content in a learning environment.

Discourses and the vocabulary of assessment in higher education differ according to discipline and field. However, modularization of courses, bringing with it the opportunity for mark allocation for both examinations and coursework, introduces the notion of continuous assessment as a viable practice in motivating students to learn on a continual basis (Trotter, 2006). Despite the acknowledgement of assessment as a tool for promoting student learning, multiple research into the use of assessment practices in higher education settings suggest that for most academics who use continuous assessments in their teaching, the use of assessment for summative purposes can diminish student motivation to engage with learning material and reduce the effectiveness of feedback strategies that are intended to assist the students' learning (Heywood, 2000; Isaksson, 2007; McDowell et al. 2005; Trotter, 2006; Yorke, 2003).

An additional research-based argument has also been made that grading or marking shifts attention away from actual learning and engagement amongst student cohorts and that in general, assessment as curricula change is not usually effective in creating an environment for student engagement with the learning process and makes little impact on learning (Crisp 2007) because students tend to note the mark or grade and ignore formative feedback (Sadler, 1989; Taras, 2005; Yorke, 2007). Assessment theory indicates, therefore, that changes in the assessment scheme and mark allocation are not enough to promote improvements in student learning unless those changes are purposefully structured to promote appropriate changes in student engagement and in their learning practices and are effective in doing so (Bishop, 2004; Black & William, 1998; Brown, 1999; Carless, 2007; Gibbs et al., 2003; Joughin, 2004).

Investigating the reasons for the improvement in student performance

Prompted by this review of literature and by the nature and context of the modifications to the assessment system, the study aimed to establish the extent to which the improved pass rate and the apparent improvement in student learning could be attributed to the change in assessment system or to other changes, intentional or otherwise, that occurred concurrently, or to a mix of these factors. To address this main question, the following secondary questions were framed.

- 1) What was the exact nature of the improvement in student performance from 2014 to 2015?
- 2) In what ways did the course and its delivery change from 2014 to 2015?
- 3) To what extent might factors other than the change in assessment practice have contributed to the improvement in student performance in the course?
- 4) To what extent was the new assessment system directed explicitly or implicitly towards enhancing student engagement with the topic or changing their learning practices? To what extent did students perceive any such links between assessment, engagement and learning practices and respond to them as intended?
- 5) What were the students' reactions to and experiences of the changes in the assessment system introduced into the course in 2015?

To address these questions three investigations were carried out. These are described next along with their findings.

Investigation 1: The improvement in student performance

To address question 1, pass rates from 2012 to 2015 were compared as shown in Table 1. Several conclusions can be drawn from the table. Firstly, the improvement in academic performance from 2014 to 2015 was dramatic. The pass rates (before supplementary examinations are considered) jumped from 31% to 85%. The marks for the tut tests and assignments were above 80% and so lifted the final marks considerably. So, for a fair comparison, the impact of this enhancement needs to be ignored by using the same basis for calculating the overall results before and after the change in assessment, i.e. by weighting the marks for the mid-term test and the exams by 20% and 80% respectively. On this basis, the pass rates from 2014 to 2015 jumped from 31% to 65% and the average marks from 43% to 56%. The improvement in performance was sustained into 2016, as is shown by the metrics

for the period 2012 to 2014 when compared to metrics for the period from 2015 to 2016. Pass rates jumped by 20% and the average marks by 5 to 10%.

Table 1: Comparison of the Academic Performance of the 2012 to 2016
(This data does not include the results from supplementary examinations.)

Year	Number of Students	Mid Term Test		Final Exam		Overall	
		pass rate %	average mark %	pass rate %	average mark %	pass rate %	average mark %
2012	115	40.7	44.8	49.6	50.9	47.8	49.6
2013	119	66.4	54.8	65.6	54.8	66.4	54.8
2014	153	32.0	42.0	29.4	43.9	30.7	43.5
2015	148	71.6	61.5	60.1	55.1	85.1 (64.9)*	63.4 (56.3)*
2016	158	56.3	52.5	76.6	62.1	81.6 (72.2)*	62.0 (60.2)*
Summary							
2012 to 2014	Before the change	46.4	47.2	48.2	49.9	48.3	52.6
2015 to 2016	After the change	63.9	57.0	68.3	58.6	68.5*	58.2*

* Pass rates/average marks based only on mid-term/final exam results (weighted 20% and 80% respectively)

Investigation 2: Changes in the Course and its Context

The explicit modification of the course consisted of two changes in the assessment scheme: bi-weekly assignments were introduced into the course in 2015; and the marks from tut tests were used summatively as well as formatively instead of just formatively as they had been prior to 2015. To establish whether or not these were accompanied by any other changes, intended or unintended, the course content and structure before and after 2015 were examined carefully and an extensive interview with the coordinator was undertaken. The possible impact of contextual and other factors were also considered carefully. The findings from these studies were as follows.

a) *Aspects of the course and its delivery that did not change*

The structure of the course did not change: 2 double periods per week for 1 semester with an afternoon tutorial every second week. The conceptual design of the course and the way topics were phased in remained the same. There was no discernible change in the teaching style or language use, or in the way the lectures were presented; the same 'traditional', teacher- and lecture-centred approach to course delivery was employed before and after 2015. The practice of providing a set of notes prior to engagement with each of the course topics and giving practical demonstrations in certain topics remained the same. The tutorials, tutoring and the tutorial system did not change.

b) Mid-term tests and the final examination

These were closed-book summative assessments with an emphasis on the application of principles, engineering calculations and analysis. They were set in such a way that students should not pass the course unless they had developed an adequate understanding of the relevant fundamental principles and an adequate level of proficiency in solving problems that required the application of those fundamentals. There was no discernible difference in either the level of the tests and examinations or in the standard of marking.

The only changes that were made were in the weightings of the contributions to the final mark for the course. Prior to 2015 the mid-term test contributed 20% and the final examination 80%. From 2015, this was changed to 30% and 50% respectively, the balance coming from the tut tests and assignment marks as explained next.

c) Tut tests

The practice of setting and marking tut tests – i.e. spot tests during the tutorial sessions – did not change from 2014 to 2015 and beyond. These were open book, 45 minute tests given at the beginning of a tutorial session, in accordance to what had been negotiated with the students. The tut tests were marked by tutors and the marks were given to the students as soon as possible after the tests, usually in a lecture period. The solutions were posted on the noticeboard the day after the test. Students were free to consult the course coordinator thereafter if they needed clarity about the solutions or the marking of their test. Feedback from the tut tests was provided primarily in the lectures and tutorial periods as appropriate. What did change from 2015 with regard to the tut tests was a shift from being purely formative in nature to being both formative and summative; from 2015 the tut tests contributed 10% to the final mark for the course.

d) Take-home Assignments

This component of the course was first introduced in 2015. It involved take-home assignments that were given towards the end of a topic, i.e. usually bi-weekly, and consisted of problems that were similar in form to tutorial problems, but also included aspects that were more conceptual and qualitative in nature. The problems were based on the topic being addressed at the time, but also included a question on an upcoming topic with the expectation that students would undertake some pre-reading and research. The assignments were handed out prior to the introduction of a new topic and contributed 10% to the final mark for the course. The system used for communicating marks, solutions and feedback to the students and for returning the scripts was the same as for the tut tests.

e) The intended impact of the change in the assessment system

The intention behind the changes in the assessment system was to ‘encourage’ students to engage appropriately with the topic on a regular, weekly basis. The change from the tut tests being purely formative to being both summative and formative in nature did not involve any change in the time allocation for the course as the tut test system was already a well-established feature of the course. The intention behind this change was to ‘encourage’ students to prepare more diligently for the weekly tut tests (and the tutorial

sessions) by having the marks for the tut tests ‘count’. In contrast, the introduction of the take-home assignments did constitute a formal addition to the work load for the course, amounting to one or three hours every second week, which, however, was well within the notional hours allocated for the course. Nevertheless, as the additional work involved reinforcement and revision of aspects of the course, it did not in principle add to the overall number of study hours required to achieve the intended learning outcomes. It does seem, from the student feedback discussed in the next section, that, from 2015 onwards, students did spend more time on the course, certainly weekly, than they had done in 2014. More certain is the conclusion that the pattern of their study time was different. However, on both counts, the change was a direct consequence of the change in the assessment system rather than being an independent contextual influence.

f) Other factors

The investigation concluded by considering a number of additional factors that may have influenced the students’ performance. Firstly, there was the possibility that there were subtleties about the nature of the course that may have been influential. Nothing of this kind was found. Like most of the Chemical Engineering courses taken by the students, the focus of the course is the application of relevant conceptual fundamentals and of the associated mathematical models to relevant industrial situations. Assessments are well aligned to this focus in that the students’ understanding of the concepts and their calculation skills were evaluated primarily by means of numerically-based problems, an approach shared by the majority of the other third year engineering courses taken by the students. The problems set in tests, tutorials, examinations and in the take-home assignments were diverse in nature, and no particular disparity in the level of difficulty was evident. Tests and exam questions were always ‘fresh’ in that ‘standard’ or recurrent questions were avoided. The course coordinator stated categorically that there was no intention to ‘teach for the exam’, either from 2015 or before, and no evidence of this was found.

The possibility that contextual factors may have contributed to the improvement in the students’ performance was also considered. None were found. Compared to previous years, there was no discernible upswing or down swing in the general level of marks and pass rates in the other courses the students took. There were also no changes in the programme or curriculum structure. Furthermore, there was no evidence that any extra time spent on the course impacted negatively on time spent on the students’ other courses. Compared to students before 2015, students did not appear to be advantaged by other factors not yet mentioned such as for example, the posting of test solutions on noticeboards; there were no changes in these systems that could be discerned.

The conclusion from this investigation was that the only discernible change in the course was the change in the assessment system and the impact of this shift on students’ engagement and study practices. To confirm this conclusion and to obtain deeper insight into the impact of the change in the assessment system, an investigation into the students’ experiences of the course was undertaken.

Investigation 3: The students' experience of the course and of the changes made

This investigation addressed the research questions from the perspective of the students by conducting surveys of the 2014 and 2015 cohorts. The questions in the survey were designed so as not to overly emphasize or expose our interest in their experience of the assignments and tut tests. The questions were as follows.

- 1) What was your overall impression of the course and your experience of it?
- 2) Please tell me about any features or aspects of the course that you found to be particularly helpful or unhelpful?
- 3) Please think about the tutorials given in the course. How did you find these? Were they helpful or not and in what way?
- 4) Please think about the assignments given in the course. How did you find these? Were they helpful or not and in what way?
- 5) Please think about the spot tests given in the course. How did you find these? Were they helpful or not and in what way?

It is unfortunate that only 7 students in the 2014 cohort, i.e. a 5% of the class, returned the questionnaires. This means the returns from that cohort are not representative and were probably from among the more conscientious students in the cohort. It also meant that there was no reliable base line for making a longitudinal comparison of students' experience from 2014 to 2015. However, some interesting insights were forthcoming. One student indicated that the tut tests had encouraged them to 'keep up' with the pace of the course; this was even though the tests were not 'for marks' – "the tut tests were helpful because they made the students get in the habit of reviewing the material learned in class regularly". Two other students hinted at the formative value of those tests. "The spot [tut] tests were helpful because they tested the key concepts/units of the given chapter such that if you pass the tests you know you are on the way to proper understanding." "They were good for practice and better understanding of the course. And one could monitor [one's] progress and understanding of the content."

Little more that was relevant to the research questions emerged from these returns, although there were some negative remarks regarding the lecturer with respect to "just reading from the [powerpoint] slides" and that there were "a large number of slides/content covered in one day".

Of the 148 students in the 2015 cohort, 68 completed the questionnaires, i.e. 46% of the class. These returns showed that the objective behind the shift towards continuous assessment, i.e. to 'encourage' greater engagement with the content and to encourage students to 'keep up', had been achieved. Thirty eight returns stated this explicitly in one way or another with remarks such as "I found the spot [tut] tests and assignments helpful because they made sure that we are always up to date with the content". "Submitting assignments every week was very helpful and also the tut tests pushed me to study frequently for this course." "They were helpful in the sense that one had to keep up with the course content in order to successfully get through the spot [tut] tests/assignments." "The tut tests kept me on my feet and helped ensure that I always engaged with my work after class and at home." "They forced me to look at course content

ahead of time.” “They guaranteed that I did not fall behind with the work as the course progressed.”

The returns also gave some insights into how students experienced other aspects of the course in 2015. Some aspects, namely the practical demonstrations in class and the practice of providing lecture notes before the lectures, attracted some positive comments. The lecturer’s performance as a teacher received both positive and negative remarks, while several students made negative remarks about the lectures in general, i.e. lack of clarity, too few worked examples in class, and the lack of interaction in class. Two students commented that the tut tests tended to become “partial group discussions” and 6 stated that these tests took up too much tutorial time.

With regard to the research questions, several conclusions can be drawn from the surveys. The mode of teaching in lectures appeared to be quite traditional in nature – teacher centred, little class interaction, heavy usage of powerpoints, and limited working of examples in class. Practical demonstrations and the provision of course notes were viewed positively. The mode of delivery impressed a few students but not others, and most students who commented on the lectures indicated, in the helpful-not helpful terminology of the questionnaire, that lectures had not been ‘helpful’. With regard to whether or not there was a change in these aspects of the course delivery, very little can be said although the two remarks about powerpoint usage in 2014 give hints that perhaps little had changed from 2014 to 2015.

It is very clear from the students’ comments that the shift towards continuous assessment in 2015 achieved its intended objective of ‘forcing’ them to engage regularly with the course content and to ‘keep up’. While student comments indicate that continuous weekly assessments were not generally liked, the entire 2015 cohort of students endorsed both the tut tests and the assignments as a means of enabling them to keep up with the pace of work, to engage with the course material productively, and to obtain a good understanding of the concepts taught in the course.

Discussion

The motivation for this study was to establish as clearly as possible whether or not the dramatic improvement in students’ performance could be attributed to the implementation of a continuous assessment system and whether or not there were any other mitigating or influential factors. The literature suggested that a change in assessment system would not necessarily be expected to improve student learning unless that change was purposely structured to foster deeper student engagement with the topics being assessed. It is clear from the study findings that the shift towards continuous assessment was the only significant change that was made, that this shift was intentionally structured to enhance student engagement, and that the changes made succeeded in doing that. No changes in the context of the course were found and the changes in the way students used their study time was a direct result of the modified assessment system. Therefore, it can be concluded that the noted improvement in student performance can be attributed to the shift towards continuous assessment that was implemented. Further, this accords with expectations from theory, and the study provides further support for the efficacy of continuous assessment that is appropriately designed and implemented.

There is more, however, that can be learned from this study. Firstly, the particular format of continuous assessment that was implemented deserves comment. It had two components that had both similarities and differences. They were similar with regard to being designed to foster deeper and ongoing student engagement in the course content, and in the kind of rapid feedback given to the students once the work was marked. In addition, both components were based on the kind of problems used in tutorials and found in tests and examinations. In this regard they not only fostered student engagement, but worked with the tutorial system in helping students to become familiar with the kind of questions to expect in summative tests.

The two components were also different in several respects. The assignments were take home exercises intended as individual work. They also included a question on the next topic so that students had to read ahead. The tut tests were open book tests conducted in a tutorial session in a context where consultation with peers and tutors was allowed. Accordingly, the two components were complimentary but provided different kinds of learning environments and hence different perspectives on what was being learned. These are all positive points about the design of the assessment system.

There were, however, some less positive features. Some students complained that too much time was spent in the tutorials on the tut tests, and that there were too many assessments. Furthermore, the lectures were somewhat teacher-centred, not very interactive, and found by many students to be not very 'helpful'. In short, it seems that the overall teaching and learning environment was not exemplary in all respects. This point is made because it highlights that even in non-exemplary teaching and learning environments the implementation of appropriate continuous assessment can have a significant impact on student learning, pass rates and the students' academic performance in general.

A final point worth discussing is the magnitude of the improvement in students' performance that was achieved. The pass rate, before supplementary examinations are taken into account, more than doubled from 2014 to 2015 even though the level of the tests and the standard of marking did not change. The study has shown that this improvement can be attributed to deeper student engagement in the course. However, the idea of 'deeper student engagement' is rather general in nature. What kind of engagement are we talking about, and why did it have the kind of impact it did? Could it be that all that was required was that students got down to serious study on a continuous basis, or was there something about the kind of activities engendered by the tut tests and assignments that were particularly effective in promoting student learning? Put another way, were there aspects of the teaching and learning environment, non-exemplary though it was, that had particular pedagogical 'bite' that only became effective when the students engaged more seriously and continuously in the course? These are questions that cannot be answered reliably from the data at hand. However, given the previous points that have been made, they do raise the possibility that appropriate implementation of continuous assessment may activate the 'pedagogical bite' of aspects of the teaching and learning environment that wouldn't otherwise be activated.

Conclusion

The study reported in this paper investigated the reasons behind a dramatic improvement in students' performance in a third-year course in a chemical engineering programme. The only significant factor that could be found to explain the improvement was the introduction of continuous assessment components that were aimed at fostering deeper student engagement in the topic. In this regard, the findings accord with indications from the literature. In addition, the study found that the improvement in student performance occurred in the context of a teaching and learning environment that was fairly typical of traditional, teacher-centred approaches to teaching. As such, the efficacy of continuous assessment is demonstrated even for teaching and learning contexts that are not exemplary in nature.

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Cognitive demand across an engineering degree programme

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The modern engineering workplace requires graduates that are able to handle cognitively demanding tasks. However, evidence from the literature suggests that employers are often critical of graduates for lacking higher-order problem solving and critical thinking skills. This paper examines gains made on the part of first, second and fourth year students within an engineering degree program with respect to their ability to handle assessment tasks of varying cognitive demand. Assessment tasks were classified according to Biggs' Structure of the Observed Learning Outcome (SOLO) taxonomy. The results indicate that while fourth year students displayed greater facility with calculation-type questions, they performed worse than their first and second year counterparts on questions that required higher-order thinking and reasoning.

Introduction

The university engineering curriculum should prepare students to meet the cognitive demands of the workplace. Today's engineering workplace is characterized by high cognitive demand, complexity, multidisciplinary and teamwork. Too often, university curricula focus on routine operations and low cognitive demand tasks that are not representative of the types of tasks graduates are likely to encounter in the workplace (Paul, 1995; Stewart, 2012). This paper explores the extent to which a specific engineering degree program is preparing students for high cognitive demand tasks. It does this by comparing first, second, and fourth year student performance on test tasks of ranging cognitive complexity. Cognitive demand was determined using Biggs' Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs, 2003). In particular, the researchers sought to investigate whether or not final year students were better able to successfully answer test questions of high cognitive demand than their first and second year counterparts. This paper is structured such that it begins with discussion of the importance of cognitive demand in engineering degree programs. Thereafter, it provides brief discussion of the SOLO taxonomy. The research design is then laid out, before the results are presented and discussed, and conclusions drawn.

Importance of Cognitive Demand

The demand that students engage in 'higher-order thinking' tasks is not just about appropriately challenging them. Instead, it is about developing the cognitive skills required by today's engineering industries. Higher order thinking has been defined in myriad ways. Whereas lower-order thinking involves activities such as observation, measurement, collection and recording of data, higher-order thinking is made evident in tasks such as interpretation and analysis of information and the exercise of judgement (Lewis & Smith, 1993; Hagerty & Rockaway, 2012). We define higher-order cognitive thinking as occurring "when a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations" (Lewis & Smith, 1993:136).

Higher-order cognitive demand, as defined herein, is important in engineering education for two reasons. First, it prepares students for employment in engineering. Engineering activity involves evaluating and solving problems rather than memorization and deployment of algorithms (Marshall & Horton, 2011; Dunne, 2015). Hutchins (2015) argues that engineering students are too often required to plug variables into equations, as per the so-called ‘plug-and-chug’ model. This does little to prepare students to solve open-ended, complex problems, which are the kind of problems that graduates will be required to solve in the workplace. It is for this reason, perhaps, that studies show that employers increasingly report that graduates entering their employ lack critical thinking and problem solving skills (Dunne, 2015).

Second, higher-order thinking tasks help students from an educational perspective, in that they enable students to see how concepts inter-relate and facilitate a deeper understanding of learned material. This is important within individual modules as well as across entire curricula (Marshall & Horton, 2011; Toledo & Dubas, 2016; Dresner *et al.*, 2014). Higher education institutions should be encouraging deep learning, rather than shallow learning on the part of students (Marton & Saljö, 1976; Biggs, 2003), as a deep understanding of material facilitates achievement of activities such as analysis and evaluation (Jensen *et al.*, 2014). The task confronting engineering degree students should not be one of memorizing masses of information, but one of accessing, structuring and using information (Benjamin, 2008). Evidence from the literature suggests that students that regularly engage in higher-order assessment tasks gain a deeper understanding of curriculum content (Jensen *et al.*, 2014).

Integrating Cognitive Demand into the Curriculum

Often, there is resistance to curricular change as lecturers feel that they cannot make significant changes to content. However, incorporating higher-order thinking does not necessitate major alterations to curricular content. Instead, it requires that greater thought be given to the presentation of course content and, crucially, greater innovation regarding assessment. Assessment is of particular importance because it always involves the development of some set of skills. Students regularly given multiple choice assessment tasks learn the skill of answering multiple choice questions, in the same way that students regularly required to write essays learn the conventions of essayist literacy (Lillis, 2001). Assessment, therefore, should be aimed at developing the kinds of skills that are useful in today’s economy.

These skills are determined by the fact that the modern world is increasingly complex. Learners, in engineering and elsewhere in the academy, need to know how to integrate, evaluate and apply information (Evers *et al.*, 1998). The concepts with which they work are “dynamic, multiplex, often poorly structured and highly interconnected” (Stewart, 2012:350). To develop these skills requires assessment methodologies that are fit for this purpose.

To this end, Felder (1982) posits that open-book examinations might be better able to overcome the problem of memorization in that they more accurately simulate real world tasks. Students should also be encouraged to engage in concept mapping, as this may also promote higher-order understanding, particularly in the engineering sciences (Stewart, 2012; da Silva *et al.*, 2015). Other assessment strategies that can be used to develop higher-order thinking, include promoting creativity by setting problems that are ill-defined, open-ended and that require students to draw information from complementary disciplines (Marton & Saljö, 1976; Felder, 1982). Finally, self-reflection is a critical component in integrating higher-order thinking into the engineering curriculum, as it develops engineering judgment and professionalism (Bulleit *et al.*, 2015).

In order for such gains in understanding to be fully realized, higher-order assessment tasks should be built in across the curriculum, rather than in one or two isolated modules (Marshall & Horton, 2011; Toledo & Dubas, 2016; Dresner *et al.*, 2014). In this way, the curriculum ‘scaffolds’ the development of higher-order thinking abilities. A well-planned, scaffolded curriculum improves students’ ability to engage in higher-order thinking tasks (Dresner *et al.*, 2014). However, scaffolding of higher-order cognitive demand tasks must also be aligned with the outcomes to be achieved, assessment methods and classroom practice (Toledo & Dubas, 2016; Jensen *et al.*, 2014; Fazey, 2010). This means that attention should also be given to scaffolding concepts such that important concepts are introduced multiple times, both structuring student learning and providing opportunities for learning to be applied across modules and contexts.

Students “develop in a cumulative fashion as they progress through their courses and other experiences at their institutions, so the first goal is to determine the degree of improvement of those skills in the course of students’ entire baccalaureate education” (Benjamin, 2008:53). Despite this, in an American study similar to the present one, it emerged that after two years of university study, nearly half of the students displayed no improvement with regard to higher-order thinking (Dunne, 2015). It is thus important that greater explicit attention be given to the development of such higher-order cognitive thinking on the part of engineering students.

SOLO Taxonomy

In this paper, Biggs’ SOLO (Structure of the Observed Learning Outcome) taxonomy (Biggs, 2003) is used to measure cognitive demand. The SOLO taxonomy is a framework for analyzing assessment outcomes and expectations. Such taxonomies are not only useful as research tools, but they can also play an important role in the design of scaffolded curricula (Toledo & Dubas, 2016; Tekian *et al.*, 2001). The SOLO taxonomy examines the kinds of understanding that students display (or are required to display) in undertaking an assessment task.

The taxonomy includes five levels of understanding. In the first of these, prestructural understanding, students display little to no understanding of content. By demonstrating unistructural understanding, students demonstrate understanding of terminology, but little more. Students that demonstrate multistructural understanding display understanding of concepts but can only engage in so-called ‘fact-telling’. In the penultimate level, relational understanding includes situations where students can do more than list facts, demonstrating ability to relate points to one another. In the final level of the taxonomy, extended abstract understanding includes instances in which students are able to generate abstract conceptualizations and apply knowledge to new contexts.

The first three levels of the taxonomy represent an increasing quantity of knowledge on the part of students, while the final two levels represent enhancement in the quality of knowledge that students demonstrate. Figure 1 illustrates the various levels included in the SOLO taxonomy and provides indication of the kinds of assessment tasks representative of each level. As can be seen in Figure 1, different assessment tasks require students to demonstrate different types of understanding.

It is important to note that the SOLO taxonomy is not a hierarchy in which the initial levels are ‘bad’ and the latter levels ‘good’. Instead, the taxonomy represents a progression where students move from one level of understanding to the next. That is to say, students need to acquire unistructural understanding before they can acquire multistructural understanding, and so on. It is also important to note that students are unlikely to be motivated to move through all

the levels of understanding if the curriculum, assessment, and classroom practice do not require of them to do so.

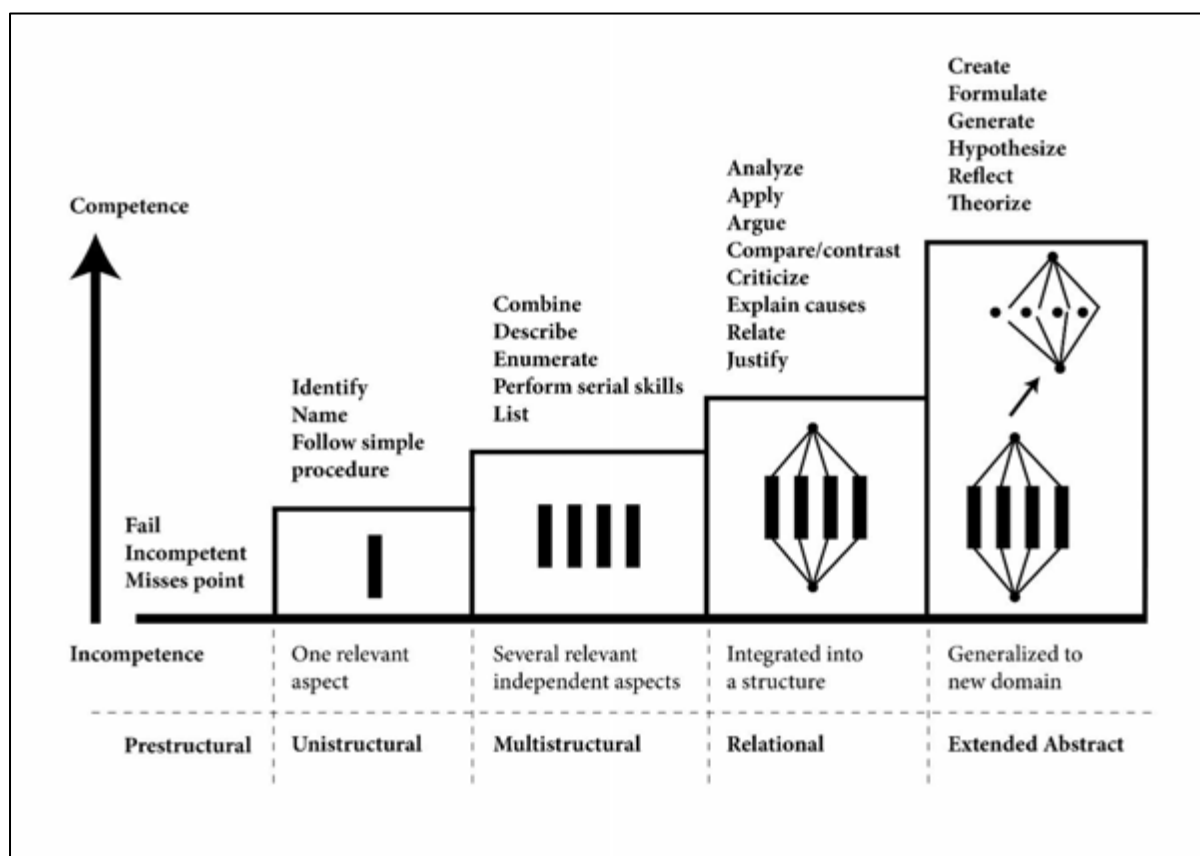


Figure 1. SOLO taxonomy (Biggs, n.d.)

Research Design

This research was undertaken within the context of a civil engineering degree program offered at a large public university in Johannesburg, South Africa. The program is a four-year degree program accredited by the Engineering Council of South Africa, a signatory of, amongst others, the Washington Accord. The program aims to deliver graduates that are able to work internationally across various fields within the broader civil engineering discipline.

For the purposes of this paper, three modules were selected, one each at first year (second semester), second year (second semester) and fourth year (first semester) level. These modules were selected on the basis that they included a range of content types, ranging from 'theory' to 'calculation' to 'application' types of questions. Therefore, it was possible to design the tests such that comparison of student performance on like-for-like questions could be undertaken across the various years. The number of students in each module was: 49 in the first year module, 107 in the second year module, and 43 in the fourth year module.

In each of the modules, the first major test was selected for analysis. This is because past experience (Simpson & Bester, 2017), and the literature (Jensen *et al.*, 2014), showed that, after the first test, students tend to adjust their study habits in line with their experiences from the first test. These tests, in each case, covered a block of course material in a summative way. Each of the tests was designed so as to include three types of questions: low cognitive demand,

high cognitive demand, and questions requiring mathematical calculation. This was done on a like-for-like basis in that the low demand questions were similar to each other across the three years, and so on. Low cognitive demand questions were questions that required uni- or multistructural understanding as per the SOLO taxonomy, while high cognitive demand questions required relational or extended abstract understanding on the part of students. Questions requiring mathematical calculation could also be said to require either low or high cognitive demand. However, the questions of this type included in this study were all deemed to be straightforward, low-cognitive demand questions. That is to say, all the questions required use of basic formulae and concepts such as area, volume and proportion.

In the first- and second year tests, the ratio between the different question types was roughly one-third each. However, in the fourth year test, there was a lower proportion of calculation-type questions. This was due to the nature of the module, which lent itself better to theory- and concept-based questions, rather than calculation-type questions. In the fourth-year test, there was a roughly even split between low and high cognitive demand questions.

Of course, classification of questions according to such taxonomies always involves some degree of subjectivity. Furthermore, these are not mutually exclusive, monolithic categories and there is some degree of overlap between them. As such, a check as to the validity of the question classification was undertaken. Across all the year groups, the students performed better in questions identified as low cognitive demand questions, than they did in those identified as high cognitive demand questions. This suggests that the question classification was undertaken in a valid and reliable manner.

Results

Figure 2 shows the students' performance on low cognitive demand questions across the various years of study. As can be seen, the second year student cohort outperformed their first and fourth year counterparts. The fourth year student group performed better on low-demand questions than the first years, albeit marginally.

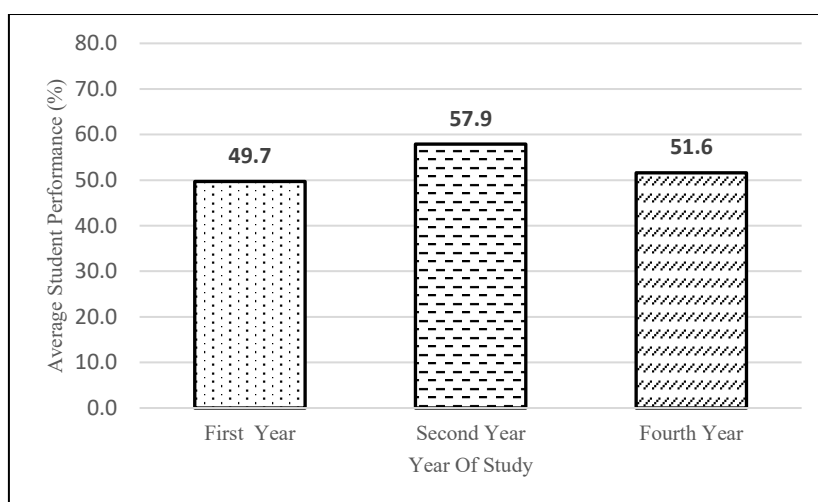


Figure 2. Average student performance on low cognitive demand questions

Similarly, Figure 3 summarizes the performance of the students on high cognitive demand questions. It can be seen that there is little difference in the performance of the first and second year groups with respect to high cognitive demand tasks. Of note is the fact that the fourth year

student group demonstrated worse performance on these questions than the first and second year students.

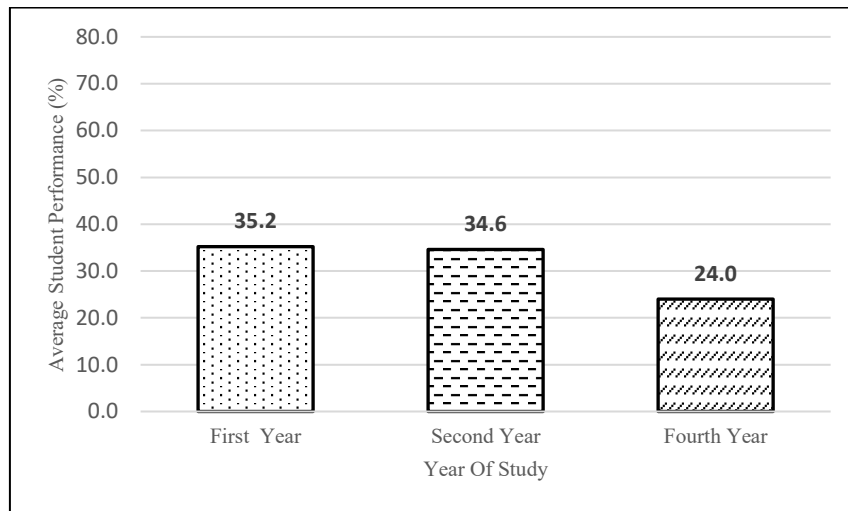


Figure 3. Average student performance on high cognitive demand questions

Finally, Figure 4 shows the average student performance across the three years of study on questions that required mathematical calculation. In all the modules concerned, the mathematics required was of a basic nature. As can be seen in Figure 4, there was steady improvement in the students' abilities to undertake calculative tasks, both from first year to second year, and on to fourth year. In fact, where calculation-type questions were a significant stumbling block for first year students, the final year students showed significant facility with this type of question, obtaining an average score of approximately 75%, and performing much better on these questions than they did on the other question-types.

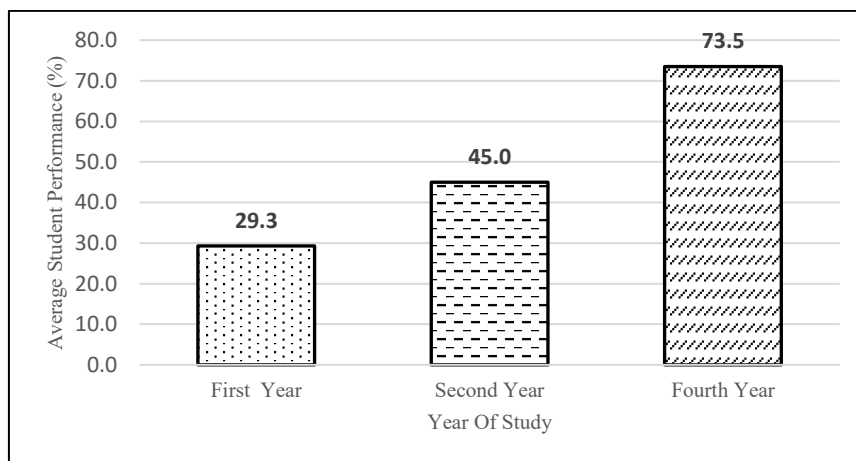


Figure 4. Average student performance on calculation-type questions

Discussion

The results presented in the previous section show how three cohorts of students, in three different years of study within a civil engineering degree program, performed in assessment tasks. These assessments were designed so as to include various question types: low cognitive

demand questions, high cognitive demand questions, and questions requiring mathematical calculation.

As can be seen in the results, there is little difference between the three cohorts' ability to engage in low cognitive demand activities. All three cohorts were able to obtain an average score of approximately 50% on such questions. This indicates, unexpectedly, that low cognitive demand questions are not a significant stumbling block to student success.

However, this is not the case with regard to high cognitive demand questions. Such questions represent a significant barrier to student success. All three cohorts achieved an average score on high demand questions of 35% or lower. And, more crucially, the first year students outperformed their second and fourth year counterparts on such questions, with the fourth year students lagging behind, with an average score of only 24%.

As already mentioned, previous assessment experiences create expectations for future assessment (Jensen *et al.*, 2014; Simpson & Bester, 2017). These results suggest that the civil engineering curriculum has perhaps not adequately served to develop higher order thinking skills such as critical thinking, analytical thinking, hypothesis generation and synthesis. Instead, students, as they progress through the program, seem to show little gain in their ability to handle cognitively demanding assessment tasks. This may be because, as they acquire assessment experience, they come to learn that they can 'get by' without engaging with course content at a high level of complexity, but it is more likely to be because the curriculum is not adequately scaffolding the development of higher-order thinking.

Where the curriculum *is* fostering strong development on the part of student ability is in the area of mathematical calculation. Questions requiring (basic) mathematical calculations proved to be a major obstacle to success amongst the first year cohort, with students obtaining a mean score of less than 30% for such questions. However, the second year cohort showed some improvement in handling such questions, achieving an average score of 45%. The final year cohort showed greatly improved ability in this regard, achieving an average score of almost 75% on such questions. It should be remembered that these questions were all identified as basic mathematical questions, and further research needs to be done to investigate student achievement on higher-order mathematical questions.

This result indicates that the civil engineering curriculum is succeeding at developing graduates that can undertake relatively basic mathematical calculation. In lay terms, the work of engineering is often seen as synonymous with mathematics. However, the profession itself characterizes its work somewhat differently. Although basic sciences (mathematics, physics and chemistry) are important in engineering, the outcomes of an engineering degree program are put forward as related to design and synthesis and problem-solving (Engineering Council of South Africa, 2014; ABET, n.d.). Thus, although engineers (and engineering students) undertake mathematical calculations, what they offer the public is the ability to interpret the results of such calculations and use the results to exercise judgement, make decisions and solve problems.

Biggs (2003) notes that real understanding is developed when students think and act like, in this case, engineers. A curriculum that promotes decontextualized mathematical calculation, without requiring students to engage in high level engagement with the results of those calculations is therefore limited in its ability to develop real understanding of engineering practice. High level engagement with engineering content needs to be scaffolded throughout the curriculum, and it is in this respect that curricula may presently be lacking.

It should be the case that facility in mathematical calculation and ability to engage in high cognitive demand activities such as interpretation, hypothesis generation, and decision-making, rise in tandem. This is because the two are intertwined: mathematical tools and models are applied, within engineering practice, with a view to making decisions and solving problems. The engineering curriculum should reflect this fact and scaffold students' achievement of these dual goals (Deek *et al.*, 1999; Kalman, 2008).

The results obtained in this study show that civil engineering curricula may be developing mathematical proficiency, rather than analytical proficiency (Stewart, 2012; Dempster & Reddy, 2007). The danger of this is that students may be able to succeed despite adopting a surface approach to learning (Biggs, 2003; Marton & Saljö, 1976) in which mathematics is learned as procedural and higher order thinking is replaced by rote memorization. Instead, assessment that develops analytical proficiency should enable students to better engage in analytical thinking, hypothesis generation, problem solving and synthesis. As Stewart (2012:364) notes, "most systems in the natural world are not neat, simple hierarchies of knowledge, but complex, interconnected and interdependent networks where relatively small changes in one system can lead to wide-ranging impacts".

Conclusion

In this paper, we have asked whether students within a civil engineering degree program are being adequately prepared to meet the demands of the workplace, particularly as these demands relate to higher-order thinking practices such as synthesis, hypothesis-generation, decision making and analysis. This was done by analyzing student performance on a series of assessment tasks. First, second and fourth year students were investigated. The results suggest that the curriculum may have done little to scaffold students' ability to engage with high cognitive demand tasks. Instead, the fourth year students seemed to be equally unlikely to be able to successfully engage with high cognitive demand tasks. In contrast, it became evident that the focus of the program was on developing relatively simple mathematical proficiency, for which substantial gains in performance were made across the various cohorts.

However, our position is that the development of mathematical proficiency without the ability to interpret mathematical results and integrate these into higher-order decision-making processes does little to prepare students for their future careers. It also does little to serve society, which requires engineering graduates that can use their technical and mathematical skill to effect sustainable, ethical and effective change in the built environment.

The data set drawn upon herein is limited in size and scope in that it focuses only on one test in one module at each year level. Also, it is important to recognise that test scores are only one among many measures of student achievement. In addition, tests are time-limited and students may perform differently in assessments with fewer such limitations. Nonetheless, the results points to the fact that our engineering curricula may be falling short of the goal of developing graduates with advanced higher-order thinking skills. In recent times, efforts have been put in place to address this, particularly in Europe (de Justo & Delgado, 2015). These efforts represent growing recognition of the fact that society needs engineers that have well-developed abilities to question, evaluate and solve problems. It is important to note that the development of higher-order thinking abilities cannot be relegated to isolated modules within engineering programs. Rather, all modules within such programs should contribute to the scaffolding of these capabilities.

Future research should investigate how questions requiring mathematical calculation can also be classified according to the SOLO taxonomy. Thereafter, attention could be given to how

curricula can scaffold the development of both mathematical and non-mathematical higher order thinking in tandem. In this paper, we've highlighted potential shortcomings in (civil) engineering curricula. Future research may want to test the hypotheses developed herein in a statistically significant manner.

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The literacy of engineering design: Investigation into first year design report writing

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Literacy is ideological, in that it is tied to the values and interests of social groups. Social groups *use* literacy to achieve their particular ends in society. Engineering design is a literacy practice that involves deploying literacy (including multiple forms of meaning-making, such as drawing) in particular ways so as to achieve the particular ends that the engineering profession seeks to enact in the physical world. This paper explores the literacy practices of first year mechanical engineering students as they engage in engineering design. This is done by examining a sample of first year mechanical engineering design reports. These reports were produced in response to an assignment requiring the students to design a passenger vehicle clutch system. The reports were analysed from a multimodal discourse analysis perspective, which involved examination of how various ‘modes’ (language, drawing, layout and so on) were used to construct the argument of each report.

The analysis reveals that many students focused on accumulation of existent literature, at the expense of incorporating their own creative design input. Furthermore, many of those that did produce drawings as part of their design, produced abstract concept drawings rather than usable working drawings. The analysis thus shows that the first year students were still undergoing development of their engineering ‘design voices’. This was borne out too in the language and layout choices the students made. The results are significant because, upon graduation, engineering students are expected to have gained expertise in engineering design, which requires mastery of certain literacy practices. Engineering educators need to play a role in guiding students towards such mastery.

Introduction

Literacy is often seen as singular, autonomous, value-free and identity-neutral. However, literacy scholars have, for a number of decades, argued that literacy should instead be seen as ideological, in that it is tied to the values and interests of powerful social institutions, and that individuals bring with them (or do not bring with them) literacy resources that can both help and hinder their success within these social institutions (Heath, 1983; Street, 1984). Similarly, engineering design is a “socio-material process of observing and inscribing extracted recognitions ... and collecting and combining these recognitions into new recognitions by drawing them together” (Juhl and Lindegaard, 2013: 44). That design is a socio-material process implies that it is impacted upon by social institutions and by access to the material aspects that enable design, including access to the technologies that facilitate design activity.

In this paper, we explore the literacy practices of first year mechanical engineering students as they engage in engineering design. We do so by examining a sample of mechanical engineering design reports. These reports were produced in response to an assignment requiring the students to design a passenger vehicle clutch system that formed part of an introduction to engineering design module. The reports are analysed using multimodal discourse analysis.

This involved examination of how various modes (language, drawing, layout, and so on) are used to construct the argument of the report, that is, how the various modes facilitate achievement of the design process.

Literacy: A multimodal approach

Studies of literacy have undergone various ‘turns’ of focus in recent decades. Notably, the ‘social turn’ in literacy studies led to a plethora of research that debunked the notion that literacy is an autonomous skill (see Gee, 2000, for a fuller exposition of the importance of the social turn). These studies showed, instead, that literacy is practiced in particular ways in particular contexts. An often-cited example of such a study is Heath’s (1983) exploration of the home literacy practices of three communities in the United States, with different economic and social circumstances. Heath shows that the literacy practices of the more affluent communities aligns more closely with the literacy practices privileged at school, giving children from these communities a distinct academic advantage over their peers from less privileged communities. Through such studies, it has become commonly accepted that literacy is an ideological trait of society, and that it is tied to powerful social institutions, including the school and university, and that different groups (whether doctors, engineers, actors or any others) use literacy in specific ways so as to advance their particular social interests.

More recently, however, literacy studies have undergone a ‘multimodal turn’. It is now widely accepted that literacy practices are enacted through deployment of various semiotic resources. That is to say, humans produce meaning through means that extend well beyond language alone (Kress, 2010; Kress and van Leeuwen, 2006). These means, or modes, can include image, diagrams, gesture, facial expression, and so on. The multimodal turn in literacy studies has enabled consideration of how image and writing (and other modes) interact in texts (Lim, 2004; Guo, 2004; Kress and van Leeuwen, 2006), but also of how particular disciplines use language in combination with other representational modes to achieve their goals (Bezemer et al., 2011, for example, show how meaning is accomplished in the operating theatre through modes that include, but are not limited to, the linguistic).

Engineering activity is accomplished multimodally. Engineers, and engineering students, use various ‘representations’ (Johri et al., 2013), including drawings, mathematical notations, tables, graphs and diagrams to achieve their meaning-making goals, and each of these is used in conjunction with language, whether written or spoken. It is for this reason that this paper adopts a multimodal view of literacy. By expanding the concept of literacy in this way, it becomes possible to analyse how first year mechanical engineering students deploy various semiotic modes in service of their design efforts. The design report is, essentially, a written genre. But, its primary goal is the production of a working design drawing. As such, in producing such reports, engineering students (and, indeed, engineers) must move from the written language, through the mathematical notation required for calculation of the design facets, to the production of drawn elements: this process is how we define design literacy in this paper. How students navigate this meaning-making pathway and the practices they deploy while doing so can inform engineering educators about the students’ developing relation to the engineering design process.

Engineering design: A brief overview

In this paper, engineering design is conceived of as a systematic process used in the development of products to address the needs of society, and it is seen as central to the engineering profession, regardless of discipline (Otto and Wood, 2001). Due to the importance of engineering design within the profession, it forms a cornerstone of the engineering

curriculum. In the South African context, the Engineering Council of South Africa (ECSA) prescribes engineering design as an exit-level outcome. Thus, upon graduation, engineering students (regardless of discipline) are expected to have gained mastery of engineering design.

Ayer, Messner and Anumba (2014) argue that mastery of the process (and literacy) of engineering design requires that students develop both creative and analytical skills. In the initial steps of the engineering design process (need identification, problem statement definition and preliminary research), the engineer would use general research skills. Critical analysis of available information and the generation of informed design specifications and criteria are vital in these early stages. Creativity plays a central role in conceptualising potential design concepts or solutions, and analytical skills are required in the detailed design steps later on. Communication skills (oral, written and visual) are required throughout the engineering design process.

It is commonly accepted that the steps in the engineering design process are not independent of each other and do not always follow each other in a linear fashion. The design process is often iterative and the engineer will move back and forth between these steps. This implies that, in order to master the literacy of engineering design, students are required to master an array of skills and are required to shift between these skills in an iterative manner. Engineering design requires critical thinking skills, creativity, and appropriate reporting practices to arrive at effective design solutions. Thus, it could be argued that it is imperative to introduce students to engineering design at first year level so as to develop these abilities.

As such, first-year engineering design modules have become commonplace in engineering curricula (Bazylak and Wild, 2007). Introduction to engineering design modules represent the first engagement that engineering students have with design. Furthermore, as Bazylak and Wild (2007) argue, despite their lower technical proficiency in relation to more senior engineering students, first year students can and should undertake meaningful design challenges. This is because, as Ayer, Messner and Anumba (2014) argue, open-ended creative design problems can assist first year students with the development of engineering design literacy.

Methods: Collection and analysis of data

To undertake this research, a sample of first year mechanical engineering design reports were collected. These design reports were produced in response to an assignment that required the students to design a mechanical clutch for a passenger vehicle. The assignment brief specifically required that students develop at least three concepts and assess these concepts using design criteria of their own choosing. One concept then needed to be selected for detailed design (including calculation of the relevant design parameters as well as appropriate material selection), and a working drawing of the chosen design was to be produced.

The assignment formed part of an introduction to engineering design module that was undertaken in the second semester of the first year of a mechanical engineering degree programme. The module is among the first in a series of modules that aim to develop students' proficiency in mechanical engineering design. As part of the module, students were taught about clutches and, in a module taught in the previous semester, the techniques and requirements for engineering drawings were introduced. The engineering design process, introductory level engineering materials and materials selection were also taught in the previous semester. The students were also given input regarding the preparation of engineering design reports in the previous semester.

All the students in the class (approximately 115 in number) were asked to give consent to their reports being used for this research. There was a low response rate to the call for written

consent, and the reports generated by all students that gave consent were included in the study. In total, 24 students' reports were analysed for the purposes of this paper, representing 20% of the total population. These reports totalled 380 pages and included 180 images, of which just over 60 were drawn by the students themselves, with the remainder of the images being taken from other sources.

The data was analysed using multimodal discourse analysis (MDA). MDA is concerned with how semiotic resources, used in combination, lead to the expansion of meaning-making, where social context is at the centre of such analysis (O'Halloran, 2011). In other words, MDA examines how social groups, however defined, use various semiotic resources in particular contexts to achieve specific meanings.

In the present analysis, three 'passes' of the data were undertaken. In the first pass, the layout and structure of the student reports was analysed. This included examining the headings used, the logic of the report, the positioning of the design drawings, and concluded with consideration of what this indicated about the design process followed by the student. In the second pass, images were analysed in isolation. This included examining image captions, referencing of images, dimensioning of components and labelling of elements. It also involved examining the extent to which students produced their own drawings or relied on images obtained from other sources. In the final pass, the linguistic aspects were analysed, with particular focus on how images and tables were referred to in the text and how the students positioned themselves, linguistically, in relation to the design process.

Discussion: Text, image, layout and the design process

As described above, analysis of the students' written reports was undertaken through multimodal discourse analysis, with a focus on image, language, layout and the integration of these in the design reports. The goal of this analysis was to identify the literacy practices evident in the students' work. It is worth noting, at this point, that the purpose of this discussion is not to criticise the students or identify them as deficient in terms of their design processes. The students are novice designers and their literacy practices reflect this status. Rather, the purpose of analyses such as this is to identify where students' require focused input regarding design literacy, and how the teaching and learning of design can be used to effect positive development in this regard.

Image production

Analysis of the students' written reports reveals that a majority of the students were confident enough to produce their own design images. Particularly noteworthy is the fact that the images produced by the students included both concept sketches and working drawings. These images were hand drawn rather than computer generated (using CAD). Analysis of the concept sketches indicated that approximately half of the sampled reports did not include concept sketches. However, those that did contain concept sketches included three concept sketches, on average. This indicates that the students assimilated the general convention, within the engineering design process, of providing a minimum of three concepts.

A majority of the sampled reports included working drawings. However, by and large, the students' working drawings were, in fact, assembly drawings. Only a small proportion of the students demonstrated awareness of the fact that individual component drawings are required for manufacturing purposes. This shows that the majority of the students are still developing an understanding of the link between design and manufacture, that is, how design fits into the broader engineering process. Furthermore, a third of the students included dimensions in their working drawings. Although, at face value, this may seem a minor point, dimensions are

important for manufacturing purposes and an important cue to the readers of a design report regarding the scale of the assembly. The inclusion of dimensioning is thus an important design literacy.

A balance between images copied from the literature and those produced by the students themselves can be observed in the majority of the sampled reports. In general, images taken from the literature were used to explain facts (in the ‘literature review’) whereas images that were produced by the students were incorporated in the design-oriented sections of the report. This was seen as positive in that students moved from existing knowledge to production of their own designs. There was, nonetheless, a greater reliance on existent design images, and the students’ reluctance to put forward their own design ‘voice’ was also evident in the characteristics of their language use.

Language use

In examining the language use evident in the students’ reports, particular focus was placed on examining the extent to which the students drew on linguistic cues aimed at making the design process explicit, as well as the extent to which the design process was located within a real-world problem or context. In this phase of the analysis, as was the case with analysis of the images used in the reports, the notion of ‘voice’ became important. This was because, in a majority of the students’ reports, there was a particular emphasis on ‘fact-telling’. This was evident in the sentence structures deployed by the students in their reports. Specifically, there was a preponderance of short, declarative statements, written in simple present tense. Such sentences begin with phrases such as: “A clutch transmits power from...”, “It is disengaged by...”, “When the engine is started, ...” and “When there is no pressure on...”. These examples represent the language of textbooks, in which knowledge is often represented as static, and writing often conceived of as transmission of information. It is worth noting that this kind of language use is often accompanied by specific layout choices, particularly by extensive use of bullet point lists, such as in the example shown in Figure 1.

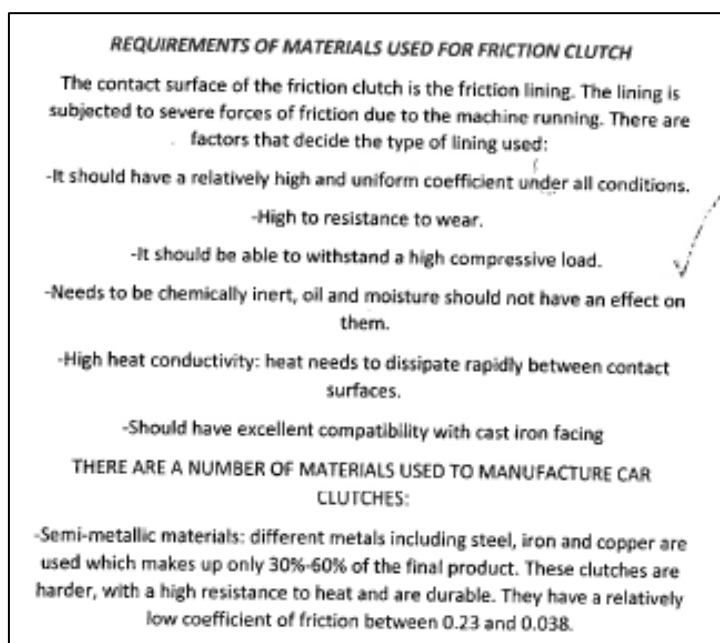


Figure 1. Extract from design report: student relies on ‘fact-telling’ and bullet point lists

In contrast to textbook writing, engineering design is a creative process in which engineers brainstorm ideas, evaluate alternatives, and develop solutions. Although engineering design

builds on knowledge presented in the literature, it should move beyond the reporting of facts and use those facts to make selections and decisions. As such, just as was the case with the students' image use, much of the students' language use demonstrates a preoccupation with 'the literature' (the body of work previously undertaken on a topic), at the expense of 'design' (the use of that work to effect changes in the physical world).

However, there is evidence of a developing design voice in some of the students' reports. Phrases such as the following, although less common, emphasise design as process and the agency of the engineer in that process: "The use of wrong materials was identified ...", "Evaluation of the alternative solutions identifies...", "The design and calculations have shown..." and "It is essential to understand the relationship between...". These examples are often (but not always) characterised by passive voice, and the sentences they form part of tend to be much longer and are discursive, rather than declaratory. They present the author as actively involved in a process of discovery.

Furthermore, the engineering design process takes place within a particular context or in response to a particular problem. In this regard, it was evident that while many students did not situate their design within any social context or problem, there were attempts on the part of some students to do so. For example, some students located their designs in a generic context: "Even the highest quality and most durable clutch is subjected to operational wear and tear". Others took a more creative approach: "A large automobile company has designed a model passenger car but the problem is their clutch system which slips often and also chatters and makes noise and as a junior engineer I am tasked with the design of a more reliable clutch system...". Such explicit reference to real world contexts, whether real or imagined, represents an important shift in the way design work is conceived on the part of these students.

Integration of language and image

Engineers draw on a range of representational resources, and this is particularly so in their design work. Such representational resources include language but also drawings, photographs, schematics, and data tabulations. These were the dominant resources used in the sampled student design reports. Of interest in this third level of analysis were the strategies that students deployed in integrating language and image within their reports. This is important because it speaks to the extent to which a report reads as an assemblage of disparate elements, or the extent to which image, language and tabulation are deployed in service of the achievement of the design goals of the engineer-in-training.

To this end, our analysis reveals that students use one or a combination of four strategies for integrating images and tabulations into their reports. We refer to these strategies as layout, lexis, captioning and reference. In the extract provided in Figure 2, the student concerned has deployed all four strategies. In the case of layout, image and language are connected through their proximity on the written page. In many instances, this was the only strategy deployed by students. In such cases, there is no explicit linkage made between the two modes. In the second strategy, lexis, common terms appear in both the language and the image or tabulation, thus creating a link between the two. In Figure 2, this is evident in the repetition of terms in the figure labels and in the paragraph below it.

When image and language are linked by captioning, figures and tables are given captions that direct the reader as to what meaning to derive from the figure or table. For example, in Figure 2, the caption directs the reader to recognise that the image's function within the text is to illustrate the various components of the clutch, a point already reinforced by both repetition of the component names and the close proximity of the image and associated language

components. Finally, in the case of reference, language is used to direct the reader's attention to, and reading of, the figure or tabulation. This is evident in Figure 2 in the sentence preceding the image.

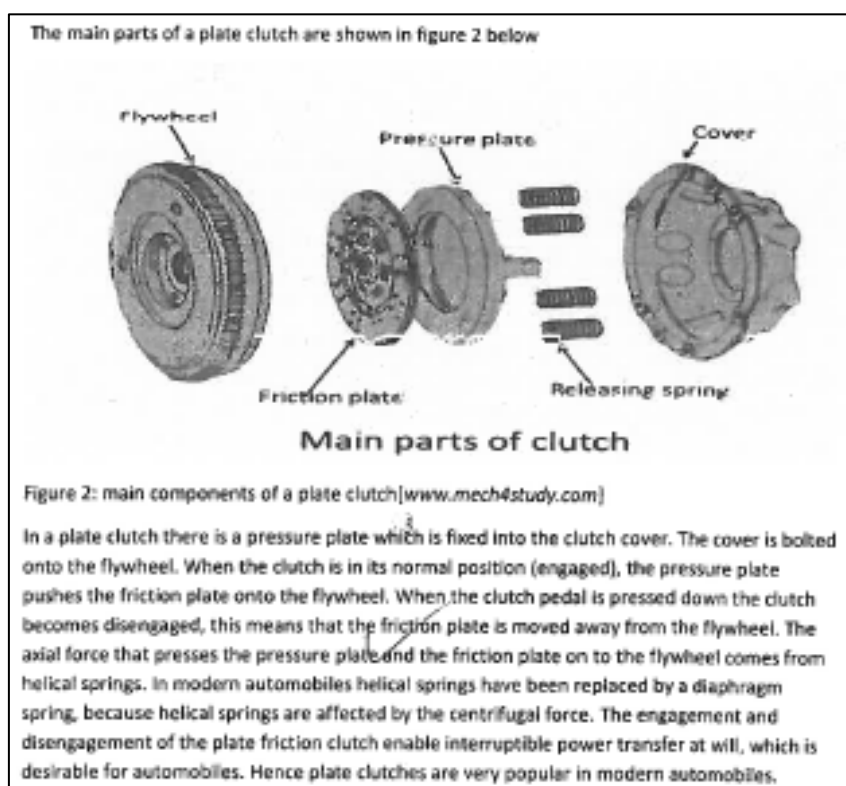


Figure 2. Extract from design report: student uses various strategies to connect language and image

These strategies represent a continuum of the involvement of the designer in directing the reader's attention in specific ways. As students deploy the latter strategies, they take on more authority and cede less authority to the reader. They assume a more powerful position as designer and accord themselves a stronger design 'voice'. In so doing, they also demonstrate more control over their design choices.

Literacy and the acquisition of a design 'voice'

The analysis that emerges from the data strongly centres on students' design 'voice': their positioning of themselves in relation to the task of design and in relation to their readers. We see these first year students as beginning a process of acquiring a design voice and the literacy practices they exhibit represent their attempts at doing so.

However, the students' design voices are inhibited by their lack of familiarity with the technologies of design. As was shown up in the analysis, none of the sampled student reports included CAD-assisted design drawings, with the students instead choosing to deploy the hand-drawing techniques taught in a preceding module on drawn communication. However, this is also positive in that students are applying and developing the critical early literacy of hand drawing. In addition, a large number of students were unable to integrate their design calculations and drawings into the text proper of their design reports, instead relegating these to appendices or separate, hand-produced pages in the report. Such strategies are attempts on

the part of the students to overcome their lack of familiarity with, and access to, technologies for design literacy, such as MS Word, PDF readers, scanners and so on.

Furthermore, the literacy practices that the students deploy demonstrate some level of uncertainty regarding the role of design within engineering activity. The relationship between work with ‘the literature’ and the students’ ‘own work’ was often disjointed, with the literature being given much greater status and attention, an observation borne out in analysis of the language use, image use, and layout choices. This requires consideration because engineering design is not simply about repeating existent solutions through mechanistic or routine procedures, but about solving problems in novel ways using creative methods for doing so. At the same time, there was a further disjoint between ‘design’ and ‘manufacture’, as two parts of the engineering process. Very few of the students whose reports were sampled for analysis produced a final design that could be sent for manufacture based on the drawings produced. This was because the final drawings they produced lacked multiple perspectives, adequate dimensioning and complete labelling. This may indicate that the students have not yet made explicit connections between the content taught in the module on drawn communication and the engineering design process taught in the introduction to engineering design module.

In addition, there was much to be gleaned from analysis of the interaction of language, image and tabulation in the design reports. As previously discussed, few students actively directed the readers’ attention regarding images through captioning and explicit reference. The question of captioning is important as captions offer direction as to how to view an image in that they point to something important in the image and, as such, add to the meaning of the text as a whole (Archer, 2012). The interaction of modes within the reports is important because of the aforementioned purpose of the engineering design report, namely to identify client needs, specifications and constraints, use mathematical methods to determine design parameters, and produce a usable representation of the designed artefact. The design report thus intrinsically relies on the interplay of the various modal resources of language, mathematical notation and image. It is only through such interplay that engineering design can be enacted. Analysis of the design reports indicates that some students are ahead of others in developing control over this interplay.

For example, in many of the students’ reports, the concept evaluation and selection process was undertaken through tabular means. An example of this can be seen in Figure 3. However, in very few of these tabulations is the process of producing the table explained. In the example of Figure 3, there is no explanation given as to why the specifications were ranked in the way they were, how the specification values were determined, what the difference is between the ranking and the specification value, or how the score for each type of clutch was determined. In these cases, the tabular representation exists in isolation from the surrounding text. Although it represents the crux of the students’ design decisions, the substance of these decisions is obscured; in so doing, the students’ design voices are similarly hidden from the report. Part of the job of the design engineer is explicating how and why design decisions were undertaken, and failure to do so may result in the impression that these decisions were undertaken in an arbitrary or uninformed manner.

Conclusion

Multimodal analysis of first year mechanical engineering students’ design reports has shown that the students lack an engineering design ‘voice’. While this may well be because students lack confidence in their own design abilities, or because they lack understanding of what engineering design entails, there is also strong evidence to suggest that it may be due to a lack of access (physical access and epistemic access) to the technological resources of design.

However, there is evidence to suggest that students are in a process of developing such voice, and the practices they deploy represent their initial attempts at doing so. The students are in a stage of what Paxton (2007) calls ‘interim literacy’, in which they move from the literacies of the home and school towards those valued by the university, and the engineering profession specifically.

Rank of Importance	Specifications	Specification Value (%)	Single Plate clutch	Multi Plate Clutch	Conical Clutch	Centrifugal Clutch
1	Reliability	30%	28%	29%	30%	30%
2	Inexpensive	35%	35%	26%	23%	25%
3	Power/Torque	11%	10%	11%	11%	11%
4	Weight	12%	8%	7%	9%	10%
5	Max length=0.1145 Max Diameter=0.28m	7%	7%	7%	7%	7%
6	Noise level	5%	3%	3%	2%	3%
	Total Values	100%	91%	83%	82%	86%

Figure 3. Extract from design report: concept selection table

The students demonstrate a basic understanding of the required design literacy practices, which bodes well for their ongoing development of these practices in the remainder of their studies. Early awareness of these practices provides students with sufficient time and space for such development to occur. Identifying the potential causes for the students’ lack of ‘voice’ in their design reports can inform curriculum development and guide students towards mastery of the literacy of engineering design. A potential intervention in this regard would be to introduce basic design-oriented tasks in lectures and tutorials within the first year introduction to engineering design module. This may provide students with greater opportunities for engagement with the engineering design process which may in turn improve their understanding of what engineering design entails. In addition, it may enhance students’ confidence in their own engineering design abilities.

Studies such as this are important because literacy is practiced differently across institutional and disciplinary contexts (Lea and Street, 1998). One such domain is that of engineering, and engineering design, specifically. Engineers do things with literacy that are different to scientists, historians, educationalists and so on. When students enter into an engineering degree programme, the challenge that faces them is acquiring awareness of, initially, and mastery of, ultimately, the literacy practices privileged within their chosen profession. Within engineering design, engineering graduates need to have gained expertise in understanding client needs, incorporating literature, and turning these into usable representations of a designed artefact. This requires development of a strong ‘design voice’ that is made manifest through the application of particular literacy practices. The more we, as engineering educators, understand this process, the more we can guide undergraduate students towards mastery of the literacy of design.

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Industrial engineering as a career choice at the University of Johannesburg

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Internationally the demand for industrial engineers is growing, due to the economic downturn as well as constraints on natural resources. Yet, at the University of Johannesburg, the majority of students who seek admittance to the engineering faculty do not choose industrial engineering as their first choice. A quantitative study was done by surveying industrial engineering students in the first and second year, to determine the number of engineering students at UJ whose first choice was industrial engineering. In addition the satisfaction with the course of those students who did not choose it originally was determined. We investigated the impact of open days and engineering weeks, as arranged by the University, on pupils' choice of industrial engineering? The study found that a large portion of students did not choose industrial engineering as their first choice and it seems to be due to a total lack of knowledge with regard to industrial engineering. The perceptions of school pupils of engineering need to be changed and issues with the current standard of high school mathematics need to be explored further. The question to ask is: How can we improve the marketing of industrial engineering as a career.

Introduction

The demand for industrial engineers is growing internationally. This is due in part to the economic downturn as well as constraints on natural resources. On the South African scarce skills list, industrial and production engineers are listed eighth (2014). Industrial engineers have a key role to play in economic growth by helping companies to become more competitive and productive. By increasing productivity salaries can be increased without inflation increasing and in this way quality of life can be improved.

The definition of Industrial Engineering according to the South African Institute of industrial Engineers (SAIIE) is "the integration of resources and processes into cohesive strategies, structures and systems for the effective and efficient production of quality goods and services" (SAIIE, 2016). According to the business dictionary the definition of industrial Engineering is "the discipline of utilizing and coordinating humans, machines and materials to attain a desired output rate with the optimum utilization of energy knowledge, money and time. It employs certain techniques such as floor layouts, personnel organization, time standards, wage rates, (incentive payment plans) to control the quantity and quality of goods and services produced." (Business Dictionary, 2016)

It is well publicised that there are serious problems with service delivery in the public sector specifically with regard to the functioning of municipalities, hospitals and clinics. Much research has been done on the role of industrial engineering in the health care sector. Industrial engineering techniques can be applied to improve the balance between resources and service.

Yet, at the University of Johannesburg, the majority of students who seek admittance to the engineering faculty do not choose industrial engineering as their first choice. Students end up

in industrial engineering because they did not gain admittance to the engineering field of their choice and as a last resort they apply to Industrial Engineering provided there are still vacancies left.

No studies were found that addressed attraction to industrial engineering specifically which justifies further research in this regard.

Objectives

Firstly it was important to determine the percentage of engineering students at the University of Johannesburg whose first choice was industrial engineering. Secondly, the satisfaction with the course of those students who did not initially choose industrial engineering was established. The third objective was to improve the marketing of industrial engineering to prospective students in South Africa.

Literature review

Science and Engineering occupations are critical to global competitiveness and for an economy to prosper. Engineering is linked to innovation, jobs and wealth creation. Previous studies have shown that engineering is often seen as a strong profession but few high school pupils have an understanding of the engineering profession (Education and Culture, 2012). In South Africa as in most countries, there is a shortage of engineers in general, and industrial engineers specifically which may be a factor in the slowing of the economy.

Research has been conducted internationally to determine the factors that motivate students to study engineering and how to attract more students to the field (Osborne, Simon, and Collins, 2010). The “educate to innovate” project in the USA was initiated by President Obama (Whitehouse, 2016). The goal of this project is to move American students from the middle to the top of the pack in science and mathematical achievement (Kyoung, Lattuca, and Alcott, 2017). The USA has approached this initiative by: Partnering with CEO’s from over a 100 companies in order to expand proven science, technology, engineering and mathematics (STEM) programs to sites across America. They also created a blueprint for the private sector to develop and invest in STEM programs. Companies that are the largest employers in communities advocate STEM reform in those communities. Their goal is to train 100 000 new and effective STEM teachers in the next ten years. They have raised funds privately and motivated for Congress to fund the rest. They have engaged current talented STEM teachers to assist in this endeavour. They are publicly demonstrating and increasing their investment in STEM as demonstrated in an annual White House Science Fair and lastly they are broadening participation including women, girls and minorities to ensure a more diverse STEM talent pool.

In Europe an extensive study “The Attract project –Enhance the Attractiveness of Studies in Science and Technology” was conducted. This research investigated the perception of engineering in eight European countries. Four specific areas this study focused on were the attractiveness of being an engineer; barriers; attraction and retention (Education and Culture, 2012). It was found that engineering is perceived as a difficult study with a limited outcome which was one of the main reasons for decreased interest in the field. As a career it is seen as a high income and exciting job with high status.

Even though the South African environment is very different from the European and American environment much insight can be gained from these studies as to how to attract more students to engineering in general. Some of these findings and interventions could be applicable to South Africa. Studies have been done to determine factors that motivate South

African students to study engineering. (Jawitz and Case, 1998). Some of these factors are: contact with engineering career, school subjects, socialisers, manual activities, mental activities, career rewards, challenge, variety, and social identity, belief in self, salary and status (Reed and Case, 2003).

One of the common finding in literature is that more women need to be attracted to engineering. The absence of women in the labour market has been associated with lower economic growth and development (Elborgh-Woytek, et al., 2013). The discrepancy between the number of men and women in engineering fields is not because of a mismatch of skills and the requirements for becoming a successful engineer but rather of perceptions about engineering (Marra & Bogue, 2004). Fewer than five percent of female pupils in the Organisation for Economic Co-operation and Development (OECD) countries consider following a career in engineering and computing whereas eighteen percent of male pupils do (OECD, 2012). There seems to be a biased self-concept in female pupils with regard to science (Sikora and Pokropek, 2012). More female students tend to enrol in Industrial Engineering than any other of the engineering disciplines, often because of social reasons (Brawner et al. 2012). It has been recommended that to increase the number of female students in engineering, a way should be found to make physical science a more attractive and pleasant experience. A study by Jawitz et al (Jawitz, Case, and Tshabalala, 2000) showed that engineering was only considered by females who enjoyed physical sciences. (Jarwitz, Case, and Tshabalala, 2000).

It seems that, the South African schooling system tends to reinforce the social and economic marginalisation of the poorest and most vulnerable people (Maree, 2010). Bloch provides the following figures “A small cohort of 20% of South African schools, half of which are former Model C (currently Section 21) schools and the other half well-performing black schools, delivers the vast majority of the country’s eventual graduates” (Bloch, 2009). Most of these schools are quintile 5 schools. According to Vinjevoldt (2009) “Mathematics at school is not studied in-depth, consequently there are gaps in learners’ understanding of the subject when they arrive at university”. Several studies indicate that preparation of mathematics has a direct impact on attraction and retention of engineering students (Hall, et al., 2015). Problems within the schooling system may have an influence on the potential number of applicants to engineering.

There is still a disparity regarding race in industrial engineering in South Africa (Schutte, Kennon, & Bam, 2016). It seems that very few black, coloured and Indian students choose to follow the academic programme for industrial engineering. However there are large numbers of these following the technical programmes.

Methodology

This case study attempts to determine the reasons why students at the University of Johannesburg did not make industrial engineering their first choice. In addition student satisfaction with the course was evaluated as well as methods to attract more students to industrial engineering. A quantitative study was done by surveying National Diploma (NDip) industrial engineering students in their first year, second year and at Bachelor of Technology (BTech) level at the University of Johannesburg.

The purpose of the questionnaire was to determine the percentage of industrial engineering students who chose industrial engineering as their first choice. The questionnaire addressed the following issues: Student’s awareness of industrial engineering prior to commencing with the course. Students were asked if industrial engineering was not their first choice what their first choice was (see appendix 1). Questions about motivational factors that played a role in

choosing industrial engineering were asked. The questionnaire also addressed whether students were satisfied being allocated to industrial engineering (questions 16 to 19 in appendix 1). The students were asked whether laboratories and practical's gave the students an understanding of what industrial engineering entailed. In addition we investigated the impact of career guidance prior to the commencement of their studies, in the form of open days and engineering weeks. Open ended questions in this survey asked students the reason for not choosing industrial engineering and why they agreed or disagreed with the statement that they were now in the right field of engineering. For the close-ended questions a five point Likert-scale was used. Informal interviews were conducted with ten students who had indicated that industrial engineering was not their first choice. These students were asked the reason for not choosing industrial engineering and what their first choice had been. The factors that made industrial engineering enjoyable were determined. They were asked if they had their current knowledge at registration whether it would have influenced their choice. They were questioned on whether they regretted studying industrial engineering. SPSS was used to analyse the data. Of the students surveyed a total of 190 students questionnaires were analysed.

Findings

From the questionnaires analysed, 59% of students indicated that industrial engineering was not their first choice. Only 37.4 % indicated that they knew what industrial engineering was before they started. Responding to the question of whether or not students were of the opinion that they were now studying the right field of engineering, 77% of the group agreed. When asked whether they enjoyed studying industrial engineering 85% of the group agreed with this statement. Only 58% of students found industrial engineering studies challenging. Of this group 88% indicated that they believed industrial engineering was a desirable career for the future. Only 22% of the group ever attended an engineering week and of this group 64% of the students indicated that the engineering week changed their view of industrial engineering and 71% indicated that it was a positive change. A larger group 56% attended open days at a University but in this group only 34% stated that it had changed their view of industrial engineering.

In the informal interviews the students were asked why industrial engineering was not their first choice. According to the students a total lack of knowledge with regard to industrial engineering was the reason for not considering it as a career option. Most students knew about other engineering courses. All the students interviewed had chosen one of the other engineering fields as their first choice.

At the University of Johannesburg in the mechanical and industrial engineering department approximately 40% of our students come from quintile 1 and 2 schools (the poorest schools). As indicated these schools typically do not produce large numbers of graduates and often the mathematics preparation is not adequate.

Enrolments first time undergraduates	Department	2015	2014	2013	2012	2011	2010
Percentage of students from the lowest SA quintile schools (quintile 1 and 2)	MECHANICAL & INDUSTRIAL ENG TECH	43.9%	40.1%	50.0%	46.6%	36.8%	38%

Table1. The number of students from quintile 1 and 2 enrolled at the University of Johannesburg in Mechanical and Industrial Technology programmes

Enrolments first time undergraduates	Department	2015	2014	2013	2012	2011	2010
Percentage of students from high performing schools (quintile 5)	MECHANICAL & INDUSTRIAL ENG TECH	15.3%	15.1%	17.9%	18.8%	18.1%	21.8%

Table 2. The number of students from the best performing schools (quintile 5) enrolled at the University of Johannesburg in Mechanical and Industrial Technology programmes.

Conclusion

Extensive research has been done on how to better attract students to engineering and by implication this can also be applied to industrial engineering. Suggestions have been made that the perception of school pupils towards engineering needs to change. From our study it was apparent that at the University of Johannesburg most students who study industrial engineering had no idea what the course entailed when enrolling.

There are problems in South Africa with regard to our education system especially high school mathematics (Wolmarans, et al. 2010). These factors have a significant impact on preparing possible candidates for successful completion of their engineering studies. There is a need for effective STEM teachers. Potentially this would increase the number of pupils interested in engineering.

It appears that at the University of Johannesburg most industrial engineering students did not choose industrial engineering as their first choice mainly because they have never heard of it. As they continue with the course the students do enjoy their course and consider themselves in the right field of engineering. A large percentage of our students come from quintile 1 and 2 schools (the poorest schools). It would seem that industrial engineering needs to be marketed more effectively to Black, Coloured and Indian learners for academic and technical industrial engineering qualifications.

At the University of Johannesburg, the industrial engineering department has an active student group. They call themselves DIEO (Department of Industrial Engineering Organisation). Of the students surveyed 46% were members of DIEO. The leaders within DIEO have approached the department for funds to visit a number of high schools in order to inform high school pupils of the value of industrial engineering as a profession. They plan to target schools in and around the Johannesburg metropolitan area.

Engineering weeks have a greater impact on perception of industrial engineering than open days at Universities. However it may be difficult for students to attend these presentations due to economic reasons.

In order to attract more pupils to study engineering, universities should develop projects to expose pupils at all school going ages to the fact that engineering can be fun and interesting (Jawitz, Case, and Tshabalala, 2000). Institutions exist with a science focus such as Sci-Enza

and Sci-Bono and it is believed that lessons can be learned from these projects. Perhaps an engineering project can be developed to give "engineering specific" exposure to pupils.

There needs to be a focus to increase the number of STEM teachers. It makes sense to involve private companies to help develop STEM programmes in various communities.

Industrial engineers in industry should become involved by exposing industrial engineering to scholars?

It is recommended that industrial engineers become more involved in social upliftment projects especially at University level. Few industrial engineers are involved in public services (such as municipalities) and it is an area where significant impact can be made. Engineers can change the world and it is believed that more top performers would be drawn to the field of engineering and specifically more women will be interested if they were aware of the social impact industrial engineering can make. This will also assist in decolonising the curriculum as practical examples from South African environment can be used to illustrate engineering concepts.

Industrial engineering is a comprehensive field which includes an understanding of people, machines, processes, information technology and finances. There are many career opportunities for industrial engineers in both the manufacturing and service industry. The researchers are of the opinion that if pupils understand what industrial engineering entails, it would positively impact the intake and retention of students.

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Appendix 1



Industrial Engineering Questionnaire

With this questionnaire we are trying to determine what motivates students to study Industrial Engineering and whether they believe they made the right choice later on.

Mark with a X where applicable.

1. Gender

Male	Female

2. Age _____

3. What level are you busy studying

S1	S2	B-Tech

4. Was Industrial Engineering your first choice when you registered?

Yes	No

5. If yes in question 4 motivated you to choose it?

6. If no in question 4 what was your first choice?

7. Did a parent or family member have any influence on your choice?

Yes	No

8. If yes in question 8 how did they influence you?

9. I understood what industrial engineering was when I started

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

10. I am studying the right field of engineering

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

11. If you agree or agree strongly in question 10 please state why.

12. If you disagree or disagree strongly in question 10 please state why.

13. Laboratories and practicals have given me a better understanding of what I will do in the field?

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

14. If you agree or agree strongly in question 13 please state why

15. If you disagree or disagree strongly in question 13 please state why.

16. I find your studies challenging.

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

17. I enjoy studying Industrial engineering.

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

18. I believe industrial engineering is a great career for the future.

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

19. I believe industrial engineering is a job like any other.

Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

20. Did you ever attend an engineering week?

Yes	No

21. If yes in question 20, you did attend, did it change your view of industrial engineering?

Yes	No

22. If yes in question 21, view changed, was the change of view

Very negative	negative	Somewhat	Very positive

		positive	

23. Did you ever attend an open day at a university?

Yes	No

24. If yes in question 23, you did attend, did it change your view of industrial engineering?

Yes	No

25. If yes in question 23, view changed, was the change of view

Very negative	negative	Somewhat positive	Very positive

26. Are you a member of DIEO?

Yes	No

27. I attend DIEO events?

Never	Rarely	Sometimes	Often	Always

28. When did you decide to pursue a career in engineering

29. When did you decide to pursue a career in industrial engineering

Exploring the effects of multiple intelligence and learning styles on academic performance of students doing construction economics and management.

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Abstract

This paper is based on a study undertaken by an honours research group in the Department of Construction Economics and Management, University of Cape Town.

The purpose of the study was to determine whether multiple intelligence and learning styles are predictors of academic performance of students in the department of Construction Economics and Management (CEM) at the University of Cape Town (UCT). A literature review relating to multiple intelligence, learning styles and academic performance was conducted. Existing multiple intelligence and learning style models that can be used to predict academic performance were reviewed. A quantitative survey based research method was employed using self-administered questionnaires for both multiple intelligences and learning styles. The survey was conducted with 156 CEM students who voluntarily participated in the research.

The results obtained from the questionnaires indicated that multiple intelligence was a predictor of academic performance whereas learning styles was not. However, within the multiple intelligences logical-mathematical was the most significant predictor of CEM students’ academic performance. In addition, the year of study extraneous variable impacts on academic performance but cannot be classified as a predictor of academic performance, it merely shows that the longer a student has been in the tertiary education system the better their academic performance.

Introduction

This study examines the problem which suggests that students have different multiple intelligences and learning styles, which consequently affects their academic performances. In order to explore the problem mentioned above, the study is guided by the overarching question – how do the multiple intelligences and learning styles of CEM students at UCT affect their academic performance?

The purpose of this research is to determine whether multiple intelligences and learning styles are predictors of academic performance. The research seeks to establish the multiple intelligences of CEM students at UCT as well as the various learning styles and the extent to which they are utilised by the CEM students. Furthermore, the study seeks to determine

whether multiple intelligences and learning styles are a predictor of academic performances in CEM students.

The CEM department at UCT is located in the faculty of Engineering and the Built Environment (EBE). Although the CEM disciplines – quantity surveying, construction management and property studies – share some courses with their engineering neighbours, it is generally very different from any of the engineering programmes. The difference is reflected in the delivery methods and assessment of the course contents, and ultimately the way the students learn and apply the content of what is taught. It is therefore pertinent to study the effects of multiple intelligences and learning styles on the academic performance of CEM students as a way of gaining insights into the most important learning style differences among CEM students. The understanding gained from this study will also lay a foundation for CEM educators to formulate a teaching approach that adopts learning styles of all students, thereby improving on the final graduate attribute (product).

Critical Literature Review and Conceptual Framework

Multiple Intelligence and Learning Styles

Studies in the field of intelligence support a general definition of intelligence, which suggests that everyone can learn to become more intelligent through study and practice of appropriate tools that one is exposed to (Perkins, 1995; Perkins, 1992; Gardner, 1983). It has been argued, however, that people have a range of diverse intelligences, thus leading to Gardner's (1983) concept of multiple intelligences (Brualdi, 1998; Oliver, 1997; Gardner, 1983). The theory of multiple intelligences proposes eight distinct components, which defines intelligence. These are linguistic, logical-mathematical, spatial, bodily-kinaesthetic, musical, interpersonal, intrapersonal, and naturalistic intelligences (Gardner, 1983). Sternberg (1997, 1988) supports this concept of multiple intelligences, focusing on three components, which he identified as practical intelligence, experiential intelligence and componential intelligence. It is argued that each person has these intelligences in varying degrees and combinations, working together in complex ways in acquiring and applying knowledge. Perkins' (1992) had also supported Gardner's theory of multiple intelligences, arguing that more applicable teaching can clearly enhance education.

The concept of learning style describes the differences in the process of learning irrespective of the particular combination of intelligences at work, whereas multiple intelligences have to do with the content and outcome of learning (Snyder, 2000; Gardner 1995). There is, however, a correlation between the logical intelligence developed in people and the learning style they take on. Consequently, one of the determinants of students' academic performance is their approach to learning (Baleghizadeh & Shayeghi, 2014; Biggs & Kirby, 1984). The intelligences develop differently depending on the cultural and personal contacts of individuals as they develop (Brualdi, 1998). Therefore educators and educational systems should strive to incorporate as many of the intelligences as possible, and nurture the strengths and weaknesses of students to provide a better learning environment. However, educators arguably only address two out of the eight multiple intelligences, these being linguistic and mathematical (Armstrong, 1994).

Learning styles can be separated into four different distinguished groups: undirected, reproduction directed, application directed and meaning directed learning styles (Busato et al. 1998; Vermunt, 1996). Felder and Silverman's (1988) learning style model was therefore designed to capture the most important learning style differences amongst engineering students and to provide a good foundation for engineering instructors to formulate a teaching approach that adopts the learning styles of all students.

Ramsden (2003:41) suggests that learning should be seen basically as a "change in the way we conceptualise the world around us", asserting that a person's approach to learning reflects a direct correlation between the person and the object of study. This learning approaches paradigm resonates with the four different learning style groups, with undirected learning at one end of the learning style spectrum and direct meaning learning on the other. Parallels may be drawn between this spectrum and Ramsden's (2003) assertion that one's relationship with the object of their study directly influences how they go about learning that subject. The concept of approach learning further entails the learner relating to the different tasks in different ways (Ramsden 2003). The concept of approaches to learning arguably reflects the idea of different aspects of multiple intelligence at play in the learning process. In other words, it describes the structure of the subject of the study.

Research Method

The research method employed involved the establishment of a firm theoretical framework based on a strong critical review of existing literature on multiple intelligences, learning styles and academic performance. A quantitative study was done focussing on the question: "How do logical intelligences and learning styles of CEM students affect their performance?"

Data was collected using questionnaires. The sample was taken from second, third and honours year students who were enrolled and studying in the CEM department at UCT, 156 students in total. Disregarding a few students who were absent on the day the questionnaire was administered, the entire cohort of students from the classes took part in the survey. SPSS version 23.0 programme was used to analyse the data.

Two self administered survey questionnaires were used, firstly a learning style questionnaire adapted from the Revised Two-factor study Process Questionnaire: R-SPQ-2F as developed by Biggs et al (2001) and then a multiple intelligence questionnaire based on Gardiner's research books (2003, 1999, 1995, 1993, 1983, 1975). The questionnaires contained 35 items referring to multiple intelligences and 20 items relating to learning styles.

Research Findings and Analysis

The results obtained from analysing the data gathered indicated that multiple intelligence was a predictor of academic performance whereas learning styles was not. The research also showed that within the multiple intelligences logical-mathematical was the most significant predictor of CEM students' academic performance. Furthermore, the year of study extraneous variable impacts on academic performance, but cannot be classified as a predictor of academic performance. The variable of the year of study merely shows that the longer a

student has been in the tertiary education system the more likely they are to achieve a better academic performance.

The two hypotheses of the study were, firstly – that “multiple intelligence would predict academic performance with a direct, positive relationship expected whereby higher multiple intelligence subscale scores were hypothesised to predict higher academic performance (GPA) scores”. Secondly it was hypothesised that “learning styles would predict academic performance and, based on previous literature, it was expected that a deep learning style would be a stronger predictor of academic performance, and that a direct relationship between deep learning and academic performance (GPA) would emerge.”

A preliminary analysis was done to evaluate both reliability and validity of the questionnaires used in the study, and the main analysis, a multiple regression analysis (MRA), was conducted to test the research hypothesis.

The hypotheses were tested using a hierarchical MRA. Hierarchical MRA was performed to test the model interactions from an organised data structure. Multiple intelligences were positioned first in the model in order to test if it predicted academic performance over and above learning styles, which would suggest that learning styles are innate of multiple intelligences (see Figure 1).

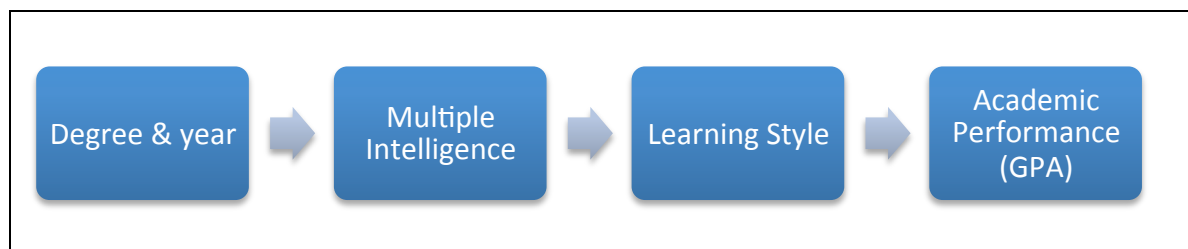


Figure 1. Hierarchical MRA

Multiple Intelligence and Academic Performance

The relationship between constructs such as multiple intelligence and academic performance was investigated. Based on previous literature by Gardner (2006), it was hypothesised that multiple intelligence, which can be divided into seven subscales, would be a significant predictor of academic performance. More precisely, it was expected that a positive relationship between each type of intelligence and academic performance would exist. This is based on Gardner (2006) theory of multiple intelligence, which critiques traditional IQ testing as being too limited, and proposes a broader measure encompassing multiple types of intelligence as a preferred alternative. Preliminary analyses were conducted to examine the reliability and validity of the multiple intelligence measure. This was necessary as Gardner (2006) had argued that it is difficult to fairly test multiple intelligences. However, he believes it could be accomplished only if several measures for each intelligence can be developed, and then make sure that people were comfortable in dealing with the materials and methods

through which each intelligence was measured. The current study depicts the difficulty in fairly testing multiple intelligences as the results of reliability testing and factor analysis indicated that there were problems with the questionnaire. Therefore, the results drew attention to the concerns Gardner (2006) had with operationally defining and fairly testing multiple intelligence. Although these problems may be attributed to short subscales, item-response bias whereby fatigue effects and time constraints encouraged students to repeatedly choose the same response option regardless of the item. Therefore, fatigue effects and time constraints should be taken into consideration when interpreting any further results.

Gardner (2006) found that neurological evidence supports the particular intelligences that he described and provides evidence of the finer structure of such capacities as linguistic, mathematical, and musical processing. Due to the fact that intelligence (IQ) is traditionally associated with higher academic performance, it was logical to assume that a similar relationship would exist between multiple intelligence and academic performance. The results of this study supported this hypothesis as overall scores for the multiple intelligence measure were positively correlated with academic performance (see Tables 1 and 2). In addition, multiple intelligence was a significant predictor of academic performance upon running MRAs. However, further inspection of the results demonstrated that only one of the subscales (logical/mathematical) was contributing to the significant predictive ability of the multiple intelligence questionnaire. Therefore, although multiple intelligences may exist, logical/mathematical emerged as the only relevant multiple intelligence sub-scale in predicting how students perform academically in this specific university environment (see Tables 1 – 3 below). Houdé (2004) provided evidence that logical and numerical capacities are cognitively and neurologically distinct from the other six intelligences. The findings of this study suggest that logical mathematical intelligence is the only significant predictor of academic performance, thereby supporting Gardner's (2006) and Houdé's (2004) findings, which indicated that logical mathematical intelligence was cognitively and neurologically distinct compared to the other six intelligences.

Similar studies, however, found results that contradict Gardner's theory regarding the predictive strength of multiple intelligence. For example, Rahbarnia et al. (2014) investigated the relationship between each of the multiple intelligences and students' mathematical problem solving abilities. The results of Rahbarnia et al. (2014) study indicate that only logical mathematical, spatial visual, intrapersonal, and linguistic intelligences had a significant correlation with students' mathematical problem solving. Whereas, bodily kinaesthetic, interpersonal and musical intelligences had no significant correlation with students' mathematical problem solving. Furthermore, the results of the Generalised Linear Model suggested that logical mathematical, spatial visual and intrapersonal intelligences were the only predictors of mathematical performance in different cognitive processes. Similar to Rahbarnia et al. (2014), this study found significant correlations between logical-mathematical, interpersonal, and intrapersonal intelligences and academic performance (see Table 2). Therefore, there appears to be converging evidence that contradicts the expected relationship between all seven subscales of multiple intelligence and academic performance. Evidence rather suggests that only a small proportion of the subscales may be predictive. In particular, this study proposes that logical-mathematical intelligence is the only robust indicator.

Learning Style and Academic Performance

Furthermore, it was the aim of the study to identify the relationship between constructs such as learning styles and academic performance. Based on previous literature done by Biggs et al. (2001), it was hypothesised that learning style, which can be divided into two subscales (deep and surface learning), would be a predictor of academic performance. While both learning styles were expected to be positively associated with academic performance, it was hypothesised that the strength of this relationship would be greater for deep learning styles (Pintrich et al., 1993).

Research Findings and Implications

The results of this study indicated that learning style was positively associated with academic performance. Additionally, this relationship was stronger for deep rather than surface learning styles. Although such correlations tend towards supporting the hypothesis, they were not significant. Furthermore, learning style did not emerge as a significant predictor of academic performance upon running an MRA and it did not contribute to the broader model. Therefore, the results were not in alignment with the hypothesis (see Tables 1 – 3 below).

Table 1. Repeated measures (ANOVA) statistics for the multiple intelligences questionnaire

(I) Multiple Intelligence	(J) Multiple Intelligence	Mean Difference (I-J)	Std. Error	Sig.
Linguistic	Logical-Mathematical	-2.327*	0.239	0.000
	Musical	-1.314*	0.250	0.000
	Bodily-Kinesthetic	-1.429*	0.281	0.000
	Spatial-Visual	-1.603*	0.268	0.000
	Interpersonal	-2.109*	0.252	0.000
	Intrapersonal	-1.532*	0.222	0.000
Logical-Mathematical	Linguistic	2.327*	0.239	0.000
	Musical	1.013*	0.250	0.002
	Bodily-Kinesthetic	0.897*	0.247	0.008
	Spatial-Visual	0.724*	0.231	0.043
	Interpersonal	0.218	0.231	1.000
	Intrapersonal	0.795*	0.242	0.027
Musical	Linguistic	1.314*	0.250	0.000
	Logical-Mathematical	-1.013*	0.250	0.002
	Bodily-Kinesthetic	-0.115	0.242	1.000
	Spatial-Visual	-0.288	0.231	1.000
	Interpersonal	-0.795*	0.233	0.017
	Intrapersonal	-0.218	0.241	1.000

Bodily-Kinesthetic	Linguistic	1.429*	0.281	0.000
	Logical-Mathematical	-0.897*	0.247	0.008
	Musical	0.115	0.242	1.000
	Spatial-Visual	-0.173	0.212	1.000
	Interpersonal	-0.679*	0.218	0.045
	Intrapersonal	-0.103	0.257	1.000
Spatial-Visual	Linguistic	1.603*	0.268	0.000
	Logical-Mathematical	-0.724*	0.231	1.000
	Musical	0.288	0.231	0.017
	Bodily-Kinesthetic	0.173	0.212	0.045
	Interpersonal	-0.506*	0.229	0.604
	Intrapersonal	0.071	0.260	0.200
Interpersonal	Linguistic	2.109*	0.252	0.000
	Logical-Mathematical	-0.218	0.231	1.000
	Musical	0.795*	0.233	0.017
	Bodily-Kinesthetic	0.679*	0.218	0.045
	Spatial-Visual	0.506*	0.229	0.604
	Intrapersonal	0.577	0.220	0.200
Intrapersonal	Linguistic	1.532*	0.222	0.000
	Logical-Mathematical	-0.795*	0.242	0.027
	Musical	0.218	0.241	1.000
	Bodily-Kinesthetic	0.103	0.257	1.000
	Spatial-Visual	-0.071	0.260	1.000
	Interpersonal	-0.577	0.220	0.200

*. The mean difference is significant when $\alpha < .05$

Table 2. Coefficients

Predictor Variables	b	Std. Error	beta	t	p
Constant	55.181	6.727	-	8.203	0.000
Degree	-	1.099	-0.040	-0.515	0.607
Year	2.918	0.698	0.322	4.182	0.000
Linguistics	-0.302	0.229	-0.114	-1.322	0.188
Logical-mathematical	0.820	0.249	0.267	3.297	0.001
Musical	-0.152	0.233	-0.054	-0.653	0.515
Bodily-kinesthetic	-0.351	0.255	-0.121	-1.377	0.171
Spatial-visual	-0.261	0.252	-0.094	-1.037	0.301
Interpersonal	0.328	0.261	0.107	1.256	0.211
Intrapersonal	0.001	0.265	0.000	0.003	0.998
Deep learning style	0.001	0.091	0.001	0.010	0.992
Surface learning style	-0.106	0.089	-0.094	-1.184	0.238

Similar findings have been recorded by other studies (Biggs et al., 2001; Busato et al., 2000). For example, a study done by Busato et al. (2000) was conducted on “Intellectual ability, learning style, personality, achievement motivation and academic success of psychology

students in higher education". The study aimed to identify whether the first four variables in question could serve as predictors of academic success within the context of higher education. In this particular study, directed (meaning directed and application directed) and undirected learning styles were examined. Directed learning styles were considered to be deep strategies and were hypothesised to promote academic success (Pintrich et al., 1993). However, the directed learning styles did not serve as positive predictors of academic performance and no significant association was found (Busato et al., 2000). Furthermore, the undirected (surface) learning style appeared to be a consistent negative predictor as hypothesised. This study supports the findings of Biggs et al. (2001) and Busato et al. (2000) as learning style was found not be a predictor of academic performance.

Table 3. Repeated measure (T-test) statistics for the learning styles questionnaire

Pair	Paired differences		t	Degrees of freedom (df)	Significance (2-tailed)
	Mean Difference	Mean standard error			
Surface vs deep	3.083	0.783	3.940	155	0.000

This finding perhaps resonates the assertions of Willingham, Hughes and Dobolyi (2015), who believe that although it is argued that the learning styles theories support the idea that a combination of teaching and the student's learning style are essential to student success, there is little scientific support for learning styles theories.

Both inferential and descriptive data statistic tests were undertaken and the results were attained in order to establish whether multiple intelligences and learning styles were predictors of academic performance. Additionally, analysis of the extraneous variables, degree and year of study were conducted as a control for prediction of academic performance. Testing of association between potential predictor and outcome variables in order to establish whether multiple intelligences and learning styles predict academic performance.

This study revealed that only the logical mathematical subscale of multiple intelligences is a significant predictor of academic performance. Furthermore, the 'year of study' extraneous variable was also revealed as being a significant predictor. Contradictorily, the study revealed that the bodily-kinaesthetic subscale of multiple intelligences is significantly and inversely related to academic performance. Both subscales of the learning styles survey (deep and surface) were not significant. Therefore, no significant relationships were indicated between learning styles and academic performance. These findings enabled this study to report on whether the research hypotheses set are accurate or not.

The findings indicate that from the sample of UCT students, two of the multiple intelligence subscales were significantly correlated with academic performance. The logical mathematical subscale was directly associated with academic performance while the bodily-kinaesthetic subscale was inversely associated with academic performance. Therefore, it was likely that scores on these intelligence subscales would emerge as predictors of students' academic

performance (GPA). The beta coefficient for this subscale represented a positive relationship whereby higher scores on the logical mathematical subscale predicted higher GPA scores.

While the overall model including multiple intelligence and learning style as predictors was significant, only multiple intelligence significantly contributed to the effect size. Therefore, the results of the tests supported hypothesis 1, as multiple intelligence did predict academic performance (albeit, only one of the subscales was significant). This effect was seen over and above the effects of potentially extraneous variables (year and degree). The results did not support hypothesis 2 as learning style did not predict academic performance despite the overall model being significant (see Tables 1 and 2).

The study addresses the following question:

How do the multiple intelligences and learning styles of CEM students affect their academic performance?

The research question was addressed by reviewing and exploring the past literature, which included the main variables of our study, namely multiple intelligence, learning styles and academic performance. Other factors that are assumed to have an effect on the research study's underlying dependent variable (academic performance) were also looked at. One of these was teaching styles, which was not researched in detail, but was mentioned as a potential factor and thus a possible influencing predictor of academic performance. Research into the various multiple intelligences was very restricted, and all findings largely related to the same seven multiple intelligences developed by Gardner (1983). Learning styles, on the other hand, varied a lot more in the way in which each individual author described and categorised their perceived distinct learning styles and approaches.

The multiple intelligence and learning style model explains a relatively high portion of the variance in MRA and consequently shows acceptable overall significance. Therefore, in concluding, the model is valid and is a predictor of academic performance.

Limitations to Study and Recommendations

One of the main limitations to this research was the diversity of the sample. The study purely focuses on second, third and honours year students of one department (CEM) at the University of Cape Town (UCT), which means that there is sampling bias. Therefore, the sample is not representative of the population and results cannot be generalised.

Another limitation was the honesty of the students, as some questions required students to disclose certain weaknesses, which may not have been fairly revealed in the questionnaire. Therefore, social desirability bias may have influenced the way participants responded. Lastly, the questionnaires were handed out and completed during the first period of the students' lectures. Consequently, there was a limited time frame to administer and complete

the questionnaires. As a result, some students answered a few of the questions poorly due to time constraints and fatigue effects. The analysis of the data, which comprised 156 students, using the SPSS version 23.0 programme, achieved the objectives discussed above.

Conclusion

Based on the results of this study it could be inferred that programmes that are aimed at adapting students' learning styles for the purposes of improving academic performance may not be beneficial. Considering that learning style is not a predictor, further research should be done to identify alternative predictors of academic performance to facilitate meaningful interventions that could improve academic performance. It should be noted that this study could be improved by addressing some of the limitations highlighted earlier. Firstly, more time should be provided for participants to answer the questionnaires in order to reduce fatigue effects and response set bias. Secondly, instead of using indirect self-report questionnaires, direct measures could be used in the future to minimise social desirability bias. Direct measures are also known to be more reliable and could provide further insight into the predictors of interest. Thirdly, it would be beneficial to recruit a larger sample as the larger the sample size, the more reliable the results. Lastly, a broader sample should be recruited to reduce sampling bias. Rather than using a nonprobability purposive sampling technique, a probability (random) sampling technique should be adopted to obtain a more diverse sample that better represents the population of students.

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Predicting engineering student success using machine learning

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Recent years have seen an increase in the number of students from diverse backgrounds enrolling into South African universities, presenting many challenges. Some students struggle with their academic choices, and universities struggle to understand and address the individual needs of such a diverse student base. Fortunately, vast amounts of student information have been collected and stored, giving an opportunity for researchers in educational data mining to derive some useful insights from this data to help both the universities and students. This research aims to identify factors that contribute to the success and or failure of a student, then predict the future performance of the student at enrolment. By using data pre-processing techniques, the experiments identify the most significant success factors from the data at enrolment time. The most significant factors can then be used to identify students who may need extra support, and the nature of those factors can help determine the manner of support needed. This study implemented and evaluated the effectiveness of the most commonly used and new machine learning algorithms in predicting student performance on a sample of 1366 engineering students. The results show various degrees of success in predicting student performance, and it is hoped that these findings will guide the selection of machine learning algorithms for future studies.

Introduction

South Africa needs engineering graduates. The government of South Africa issued calls for engineering graduates to increase the infrastructural development of the nation thus the demand for engineering professionals is extremely high (Case, 2006). However, the throughput rates from engineering programmes at academic institutions are still low. As reported by Lawless (2005), annual graduations in engineering for 2005 were approximately 2000 and about 3000 qualifiers from programmes at universities of technology. By 2002, there were approximately 12 000 students in the university system and just over 2000 graduated that same year (Lawless, 2005). These figures are significantly low for huge a nation which has such a high demand for the engineering skill.

Most studies of student performance focus on western settings (Poh & Smythe, 2014). The South African context is different because it is a rapidly developing nation with a vast amount of opportunities and a critical demand for the engineering skill. Significant socio-economic disparity has a huge impact. Most of the rural schools are characterized by poor facilities, inadequate resources and generally high failure rates (Poh and Smythe, 2014). Some poor and rural students study by candlelight, walk long distances to get to school, and often support many dependants (Poh & Smythe, 2014). Consequently, students from these backgrounds, given their poor academic background and inadequate English-language ability, tend to face challenges in their tertiary studies and do not perform as well as expected (Rauchas et al., 2006). On the other hand, (and in the same university classroom), some South African students from various backgrounds attended better performing schools with significantly better learning facilities, well qualified teachers, and higher educational standards. Lastly, the minority attend expensive

and independent private schools or colleges where the quality of education is often extremely high (Mashiloane, 2015).

Better understanding of which aspects of students' backgrounds impact on their success in engineering study is therefore of vital importance. This study seeks to better understand the interacting variables affecting engineering student performance at a South African university and to attempt to predict student success based on information available at enrolment. This will help the university to identify potentially at-risk students and develop more targeted measures to assist them. This study will implement and evaluate the effectiveness of the most commonly used and new machine learning algorithms in predicting student performance.

Data mining can be defined as the process of using a variety of data analysis tools to discover hidden patterns and relationships in data that may be used to make valid predictions. It is the process of extraction of useful information and patterns from a large data set. The selected algorithm or a combination of algorithms are implemented to build a model which searches for patterns of interest in the chosen dataset. The model built on the dataset is thus applied to predict new instances on new data. Machine learning is the field of study that gives computers the ability to learn without being explicitly programmed (Russell, 1995).

As an emerging field of study, educational data mining attempts to identify and expound on the key factors affecting student retention, pass rate, student performance and ultimately, quality of graduates released into the industry and society. South African universities currently use various methods to select and support first year students, but this research seeks to better identify factors associated with students' success and failure, helping students choose the right course of study and predicting the academic performance of a student. Thus, the university will can better allocate student support resources and ultimately improve student retention and graduation rates.

Background

In an analysis of the related studies conducted over a 20-year period, it was observed that some of the commonly used machine learning algorithms include artificial neural networks (ANN), the J48 decision tree (DT), naïve Bayes (NB) classifiers, support vector machines (SVM), linear regression (LR), logistic regression (LG), and the k-nearest neighbour (kNN) algorithm. It was also noted that some of the features that were regarded as useful in the studies of student performance prediction were past academic scores, demographic and socio-economic information.

Research in student performance dates to 1996, when Cripps (1996) predicted student performance using ANN. Cripps (1996) investigated the effectiveness of ANN in predicting degree program completion, earned hours, and grade point average for college students. McLauchlan et al. (1999) researched on student performance with ANN and concluded that the algorithm showed promise as a predictive modelling tool which could be used for assessment or evaluation purposes. In the early 21st century, Hunt (2000) compared LG and the emerging ANN and concluded that logistic regression performed statistically better than the neural network. As machine learning developed, researchers such as Wang and Mitrovic (2002) implemented ANN to a student dataset and obtained an impressive 81% accuracy, with their main attribute being internal assessments. Minaei-Bidgoli and Punch (2003) mined data from an on-line educational system which involved student behaviour and traits including marks and used these features to predict students' final grade.

Nigerian researchers (Oladokun et al., 2008) collected variables from 5 generations of graduates' data and built a model using ANN to predict the likely performance of a candidate

being considered for admission into the university and achieved a prediction accuracy of over 74% showing that ANN can work successfully as a prediction tool. Cortez and Silva (2008) investigated the reason for student failure in mathematics and the Portuguese language by using DT, random forest learning, ANN, and SVM. The results concluded that a good predictive accuracy could be achieved if the first and second school period grades were available.

Ramaswami and Bhaskaran (2009) conducted a study on feature selection techniques in educational data mining using NB algorithm and determined the impact of feature selection on the prediction accuracy of a classifier. The results which they obtained showed that a minimum number of features resulted in an increase in prediction accuracy, increase in performance of an algorithm and reduction of computational time. Kovacic (2010) explored the impact of socio-economic, demographic and environmental factors on the persistent drop-out of students using DT algorithm and obtained a classification accuracy of 60.5%, thereby drawing a conclusion that the most important factors separating successful and unsuccessful students are ethnicity, course program and course block.

García and Mora (2011) presented work done using a NB algorithm to obtain a model for predicting new students' academic performance taking into consideration socio-demographic and academic variables and obtained 60% accuracy. Osmanbegović and Suljić (2012) investigated the impact of socio-economic, demographic variables and entrance test exam on student performance and conducted experiments using the DT, NB, and ANN algorithms to predict the final grade. In this case, the NB algorithm predicted better than the other two, with 76.65% accuracy, though the others also proved good predictors (the ANN predictor scored lowest with 71.2% accuracy).

Singh and Kumar (2013) evaluated the effectiveness of the NB algorithm, the decision table, instance based learning, and ANN in building a classification model for predicting student performance in 2013. In this case, the instance based learning algorithm generated the most efficient and effective model ideal for that dataset.

Freeman et al (2014) obtained accuracy of 65% using a DT algorithm and 69% using kNN. Also in the same year, Ahmed and Elaraby (2014) evaluated the DT algorithm, rule induction, ANN, kNN and NB algorithms for their effectiveness in classification of student performance and obtained a classification accuracy of 83.65% using the NB algorithm.

In a study conducted by Shahiri and Husain (2015), 90% prediction accuracy was obtained using DT algorithm in predicting student performance and the main attributes were internal assessment, student demographic and extra-curricular activities. Also in another 2015 research by Jishan et al (2015), 91% prediction accuracy in student performance using DT algorithm was obtained with cumulative grade point average as the most important attribute for prediction.

Mashiloane (2015), a South African researcher experimented on classification and clustering and implemented a variety of machine learning algorithms to predict student performance in 2015. The study focused primarily on a dataset of 826 instances obtained from Computer science students at a South African university and the investigation obtained poor results of less than 50% performance in prediction from the classification algorithms implemented. Because of the poor performance of the classifiers implemented, it was not possible to convincingly answer the question that student performance in Computer Science could be predicted.

Most recently, Intelligentie and Bredeweg (2016) used internal assessment and extra-curricular activities as the main attributes and implemented a SVM that obtained 80% classification accuracy in student performance.

The literature review highlights the effectiveness and success of machine learning algorithms in predicting student performance. Interestingly, it can also be observed that relatively little student performance prediction research has been done in Africa, particularly in the South African context. It was also observed that five machine learning algorithms namely DT, ANN, SVM, LG and NB were frequently highly successful in student performance prediction in other academic environments; this research aims to evaluate these five machine learning algorithms in a South African context.

Research Question and Aim

The research question to be addressed by this paper is, “Is the use of machine learning algorithms in academic data mining effective in predicting student performance in South African engineering programmes?” This research aims to identify the contributing factors of student success in engineering education in a South African context and implement machine learning algorithms to predict, with the highest degree of accuracy, student performance of a prospective first year engineering student.

Methodology

This paper implements machine learning algorithms in academic data mining to understand and predict student performance. In this research, student performance is modelled as a classification problem. The response variable, motivated by the Universities’ rules and regulations, is based on the number of subjects passed to proceed to second year. The features evaluated in this paper consist of all the engineering student data that was made available to the researches by the University. However, after implementing feature selection methods, only the variables that contribute more to the success or failure of a student are the ones used in model building.

Five machine learning algorithms are identified in the literature for consideration in this study: SVM, ANN, DT, LG and NB. They are selected because of their success in other academic environments. A SVM algorithm is a discriminative technique that implements a separating hyperplane on the data points which maximises the margin between two classes. This method is highly effective for both linear and non-linear data and performs exceptionally well in both binary and classification tasks. ANNs are the computational or mathematical model derived from the biological neural network structure. The multilayer perceptron algorithm is a commonly used implementation of ANN which consists of “a set of sensory elements that make up the input layer, one or more hidden layers of processing elements, and the output layer of the processing elements” (Witten et al., 2016). The DT algorithm is a supervised learning technique which breaks down and subdivides a dataset into smaller partitions of similar nature while incrementally developing a decision tree model. The algorithm is developed through an iterative process of splitting data into discreet groups, where the objective is to maximize the distance between groups at each split. LG is a supervised learning technique which is used to ascertain the probability of an event occurring in a binary format. It describes data and elaborates more on the relationship between a dependent binary variable and one or more independent variables. The NB algorithm is technique which is derived from prior probability, a Bayesian approach that predicts future events based on previous knowledge, experience and the likelihood of occurrence. It is derived from Bayes rule of conditional probability stemming from the assumptions that attributes are conditionally independent and that there are no hidden attributes that can affect the prediction process.

Two software packages were used in conducting this study: Python 3.0 (Van Rossum, 2009) and Weka (Hall et al., 2005). Python is a programming language mainly used in the field of

data science and Weka is a software package developed at the Waikato University in New Zealand for statistical and machine learning.

The next section of the paper discusses how the student data is pre-processed into the correct format for further analysis. Then, feature selection techniques such as correlation analysis identify the most informative variables that attribute to student success. In the following section results are discussed. When evaluating performance of models built by the machine learning algorithms chosen in this study, accuracy refers to the percentage of the correctly classified instances and error is described by the percentage of the incorrectly classified instances.

Data Pre-Processing

The dataset consists of enrolment and performance data for four-year engineering degree students from a South African university. The data underwent a knowledge discovery process involving pre-processing where it was cleaned, outliers were detected and removed and imputing decisions were made on missing values. The data was then transformed into the right format for analysis to be performed. After pre-processing the data, 1366 student records were taken into consideration. The features considered for this study are outlined in detail in Table 1. Note that these features were not necessarily selected based on assumed applicability to student success, but rather on the consistency and perceived accuracy of the available data. For example, socioeconomic indicators in this data set were based on unverified student application responses which were frequently missing. The possible values also reflect the raw data, and in some cases are as presented as reported by the applicants themselves.

Table 1. List of attributes available after pre-processing.

Attribute Name	Possible Values	Coding
Gender	{M-Male, F-Female}	Nominal
Maths	{0-100}	Numeric
Physics	{0-100}	Numeric
English	{0-100}	Numeric
Life (Life Orientation)	{0-100}	Numeric
Ethnicity	{African, Coloured, Indian, White}	Nominal
Home Language	{Afrikaans, Another Language, English, French, Ndebele, Netherlands, Northern Sotho, Other African Language, Portuguese, Southern Sotho, Swati, Tsonga, Tswana, Venda, Xhosa, Zulu}	Nominal
Age	{18-39}	Numeric
School Province	{Eastern Cape, Free State, Gauteng, KwaZulu Natal, Limpopo, Mpumalanga, Northern Cape, Northwest, Western Cape}	Nominal
Number of subjects passed	{0-8}	Numeric

Religion	{Afrikaanse Protestante Kerk, Anglican, Apostolic Faith Mission of Sa, Assembly of God, Christian, Full Gospel Church, Gereformeerde, Hindu, Jehovah's Witness, Jewish church, Lutheran, Methodist, Muslim, Nazarene, Nederduitsch Hervormde, Old Apostolic of Africa, Other, Roman Catholic, Seventh Day Adventist, Zion}	Nominal
Result	{P-Pass, F-Fail}	Nominal

Variable Selection

Variable selection entails selecting the most relevant features necessary for optimally building prediction or classification models for better model performance. Irrelevant features result in low performing classifiers and thus must be excluded. It is necessary for elimination of noisy data and enables us to retain the most beneficial attributes. Furthermore, the prediction accuracy and training time of the model is greatly improved. There are a variety of ways of conducting feature or variable selection, but we focus on correlation analysis and wrapper methods.

Filter methods use statistical analysis to individually check the relationship between each variable and the response variable. A scoring is thus applied indicating whether a feature can be kept or dropped. The most straightforward filter method is classical correlation analysis, which quantifies the dependencies between variables based on the data set. The resulting correlation is a number between -1 to 1; 0 indicates no correlation, while 1 and -1 indicate perfect positive and negative correlation, respectively. If two predictor variables are highly correlated, the prediction algorithm will not benefit from considering both variables. Also, if correlation between a feature and the response variable is 0, then that feature has no impact on the response and can clearly be dropped from the prediction analysis.

	age	math	physics	life	english	passed_sub
age	1.000000	0.209851	-0.241954	-0.135789	-0.143350	-0.138728
math	0.209851	1.000000	0.451382	0.023203	0.033086	0.191373
physics	-0.241954	0.451382	1.000000	0.188109	0.136772	0.265755
life	-0.135789	0.023203	0.188109	1.000000	0.357239	0.080442
english	-0.143350	0.033086	0.136772	0.357239	1.000000	0.034264
passed_sub	-0.138728	0.191373	0.265755	0.080442	0.034264	1.000000

Figure 1. Correlation matrix showing the correlation between variables.

Figure 1 shows a subset of the correlation matrix for only the numeric variables in this study. The response variable, "passed_sub," is the number of subjects passed. Note that physics is the most highly correlated feature to the response, followed by mathematics and age. One can also see that Maths and Physics are unsurprisingly the most correlated of the features. However, a correlation of around 0.472 is not strong enough to make one of the variables redundant, particularly when these two variables are the most correlated with the response. This is how the numeric data interacts with the response variable.

Applying correlation analysis to both the numeric and non-numeric variables in the dataset, correlation between a variable and the response variable can be determined and ranked in Table 2 as follows:

Table 2. Correlation ranking.

Attribute	Correlation
Physics	0.2391
Maths	0.1836
Age	0.1191
Ethnicity	0.0808
Life	0.0773
English	0.052
Religion	0.0408
Gender	0.0387
School province	0.0359
Home language	0.029

Another useful technique for analysing the set of features involves selecting subsets features implementing the prediction algorithms using only the subsets. A straightforward search can then identify which subsets of features yielded the best results, and one can then infer the most significant features from the best performing subsets. Table 3 shows which features were most likely to be included in the best performing feature subsets. Note that this list of significant features is similar (but not identical to) the features identified using correlation analysis.

Table 3. Feature selection using wrapper methods.

Selected Feature	Rank
Maths	1
Physics	2
Ethnicity	3
School province	4
Age	5

Based on the analysis of results from the wrapper methods and correlation analysis, the wrapper method rank is accepted as it is derived from an in-depth analysis of the variables using multiple algorithms to obtain the best combination of feature that explain the problem better.

Experiments and Results

The initial run of experiments conducted evaluate the performance of different classification algorithms in predicting student performance as shown in Table 4. In terms of classification accuracy, the DT algorithm performed best with an accuracy of 65.86%, and all the tested algorithms were better than 60% accurate.

Table 4. Classification performance comparison

Criteria	Algorithm				
	LR	NB	ANN	SVM	DT
Correctly Classified Instances	259	260	247	265	270
Incorrectly Classified Instances	151	150	163	145	140
Prediction Accuracy	63.17%	63.41%	60.24%	64.63%	65.86%

Table 5 shows an additional set of estimation criteria for each algorithm. Of interest is the Kappa statistic, which measures how closely the instances classified by each algorithm matches the ground truth. A Kappa of between 0.21-0.40 is considered fair, thus the algorithm has performed fairly. Again, the DT algorithm is the best performer, but all of algorithms could be categorised as fair classifiers.

Table 5. Estimation comparison of classifiers.

Criteria	Algorithm				
	LR	NB	ANN	SVM	DT
Mean absolute error	0.45	0.4362	0.45	0.3537	0.435
Kappa statistic	0.2606	0.2635	0.2084	0.2897	0.3157
Root mean squared error	0.4753	0.4864	0.5025	0.5947	0.4846
Relative absolute error	90.10%	87.34%	90.08%	70.81%	87.41%
Root relative squared error	95.10%	97.32%	100.53%	118.99%	96.94%

Finally, several standard performance measures are presented in Table 6. Note the precision and recall values, which refer to what fraction of the predicted positive outcomes are correct and what fraction of the true positive outcomes were correctly predicted, respectively. Thus, precision is a measure of the classifier's exactness and recall a measure of the classifiers completeness. The F-measure is the harmonic mean of precision and recall and indicates how well the model balances the two performance measures. In each of these measures the DT algorithm again performs best, with the other algorithms performing similarly.

Table 6. Detailed accuracy by performance measure

Algorithm	TP Rate	FP Rate	Precision	Recall	F- Measure	MCC	ROC Area	PRC Area
DT	0.659	0.343	0.658	0.659	0.658	0.316	0.622	0.623
SVM	0.646	0.358	0.647	0.646	0.645	0.292	0.644	0.594
NB	0.634	0.372	0.637	0.634	0.630	0.269	0.664	0.648
LR	0.632	0.372	0.632	0.632	0.630	0.262	0.677	0.655
ANN	0.602	0.393	0.608	0.602	0.600	0.212	0.655	0.654

Conclusion

In this study, five supervised learning algorithms were evaluated based on their performance to predict success or failure in a binary classification problem of classifying either a pass or fail in first year engineering courses. The DT algorithm proved to be very effective in this study of predicting student performance. This is a significant improvement from the previous study done by Mashiloane (2015) in which less than 50% prediction accuracy was obtained in predicting

student performance at a South African University. The success of decisions trees offer an advantage of simplicity and are easier to understand therefore they can be used in an academic setting to enhance and improve student learning by assisting in the allocation of resources and measuring student progress.

Additionally, correlation analysis and prediction using feature subsets were used to identify which of the student characteristics are significant in predicting student success. The variables observed to be most correlated to success include physics and mathematics, which seems appropriate given the engineering curriculum. Indeed, most South African engineering programmes explicitly consider math and physics scores for enrolment. Interestingly, this study also identified ethnicity and school province as significant when predicting student success. The significance of ethnicity is unsurprising when one considers the enduring effects of the Apartheid system on education in South Africa, and should serve as a clear indicator to universities that transformation requires ongoing and focused attention and effort. On the other hand, the significance of the school province could be a direct result of the differing provincial school systems, or might be an indirect indicator of geographic and logistical considerations such as how far a student must travel and whether they stay with family.

This study has shown that learning algorithms can be of value in predicting student success in engineering. Institutions can use these results to consider how to best utilise student support resources to target at-risk students.

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Showing phenomenography at work: A study of engineering students' conceptions of the Mohr circle

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This paper presents a phenomenographic study on how students typically relate to and experience the topic of the Mohr Circle – an important technique for analysing the structural integrity of engineering materials subjected to stresses. The study was undertaken because the coordinator of a course on the topic found, in line with the literature, that his students generally found the topic difficult to master. The study and its findings are presented in a way intended to demonstrate the phenomenographic methodology and its ability to provide pedagogically useful insights for understanding students' difficulties and for making appropriate modifications to the way the topic is taught.

Introduction

Since its development in the 1970-80's (see, for example, Marton, 1981, Marton and Booth, 1997), phenomenography has evolved into a widely recognized research methodology in higher education. "It offers what may be thought of as a 'stronger' or more rigorous form of qualitative research, with guidance available on how each stage of the research process should be carried out" (Tight, 2016, p.332). Cummings (2016) advocates its use "as a qualitative research method to inform and improve the traditional aerospace engineering discipline" (the title of his paper) as well as other engineering disciplines. This paper presents an example of 'phenomenography at work' and demonstrates its utility as a means of gaining pedagogically useful insights when teaching engineering students. The example is a study on students' conceptions of the Mohr Circle, an important technique for analysing stresses in rigid bodies and mechanical components. The study is useful in its own right as the literature on conceptual difficulties students find with the Mohr Circle is thin. Only two articles on these difficulties were found, one by Karunamoorthy, (2014) and another by Quinlan et al. (2012), and neither investigated the difficulties from a phenomenographic perspective.

The context of the study was a third year course on materials failure analysis that included an introductory module on the Mohr Circle. The attention given to this topic was typically three lecture periods and an afternoon tutorial session (sometimes two). The number of students taking the course varied between 20 and 40. In line with the literature (Karunamoorthy, 2014, Quinlan et al., 2012), the course coordinator had found that his students typically struggle with the topic finding it somewhat abstract and difficult to master. The nature of their confusions and the reasons for their difficulties with the topic were not clear. Accordingly, a study was undertaken to gain a better understanding of the nature of the students' difficulties with the topic so that appropriate modifications could be made to the way it was taught. The methodology selected to address these questions was phenomenography. The paper begins by introducing the topics of the Mohr Circle and phenomenography and then summarizes the study that was undertaken.

The Mohr Circle in Stress Analysis

In the design of structural components in engineering it is vital to understand whether or not each component will be able to withstand the forces and stresses to which it is subjected and not deform or fail. To gain such an understanding requires the analysis of the structural integrity of that component given the properties of the material from which it is made, the geometric design of the component, and the nature of the stresses that it will experience in service. The analysis is commonly facilitated by means of a technique known as the Mohr Circle. To appreciate the nature of the analysis and of the study on the Mohr Circle presented in this paper it is helpful to consider the example of a system of two-dimensional stresses applied to a point in a body as represented generically in Figure 1a.

When the body is subjected to normal stresses σ_x and σ_y and shear stress τ_{xy} in two dimensions as shown in the figure, a pattern of stresses within the body occurs that depends on the relative magnitudes of those applied stresses. The exact nature of this pattern is not immediately obvious; stresses in some directions within the body will be greater than in other directions. If the coordinate axes are rotated conceptually, the stresses relative to the new coordinate system x', y' and z' will change as suggested in Figure 1b. The magnitude of the stresses relative to the new coordinate system, i.e. $\sigma_{x'}$, $\sigma_{y'}$, and $\tau_{x'y'}$, are given by Equations 1 to 3.

$$\sigma_{x'} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta + \tau_{xy} \sin 2\theta \quad (1)$$

$$\sigma_{y'} = \frac{\sigma_x + \sigma_y}{2} - \frac{\sigma_x - \sigma_y}{2} \cos 2\theta - \tau_{xy} \sin 2\theta \quad (2)$$

$$\tau_{x'y'} = \frac{\sigma_y - \sigma_x}{2} \sin 2\theta + \tau_{xy} \cos 2\theta \quad (3)$$

As can be seen from Figure 1b, there will be a particular angle of rotation at which the stresses experienced within the body will be a maximum and a particular angle at which the experienced stresses will be a minimum. The planes associated with those angles of rotation, i.e. the planes in which the maximum and minimum stresses lie, are termed the principle planes. They have very specific directions defined by a specific angle Θ for the maximum stress and $\Theta + 90^\circ$ for the minimum stress. If the maximum stress in the direction Θ exceeds the yield strength of the material that makes up the body, then plastic deformation and possibly failure will occur in the plane defined by Θ . To analyse the structural integrity of a body subjected to these two-dimensional stresses therefore requires a determination of the magnitude and direction of the maximum stress and an evaluation of whether or not it exceeds the yield stress of the material of the body. The stress patterns generally are different at different points in the body so the analysis must be conducted at multiple points.

The maximum stress at a point in a body can be determined by an appropriate manipulation of Equations 1 to 3 once the stresses and their magnitudes at the point have been identified. However, the Mohr Circle provides a quicker and simpler graphical means of obtaining the needed information. The technique is based on the observation that squaring and adding Equations 1 and 3 leads to Equation 4 which is the equation of a circle, the Mohr Circle, having its centre at $(\sigma_{avg}, 0)$ and a radius R as given by Equation 5.

$$\tau_{x'y'}^2 + (\sigma_{x'} - \sigma_{avg})^2 = R^2 \quad (4)$$

$$\sigma_{avg} = \frac{\sigma_x + \sigma_y}{2} \quad \text{and} \quad R^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2 \quad (5)$$

Accordingly, a circle can be drawn with radius R and centre at coordinates $((\sigma_x + \sigma_y)/2, 0)$. As shown in Figure 1c, this circle will pass through points A and B at coordinates (σ_y, τ_{xy}) and $(\sigma_x,$

$-\tau_{xy}$) respectively. Once drawn, the magnitude of the maximum and minimum normal and shear stresses experienced at the point, i.e. σ_1 , σ_2 and $\tau_{\max}$, $\tau_{\min}$ respectively, and the direction Θ of the principle planes can be determined from a plot of the Mohr Circle.

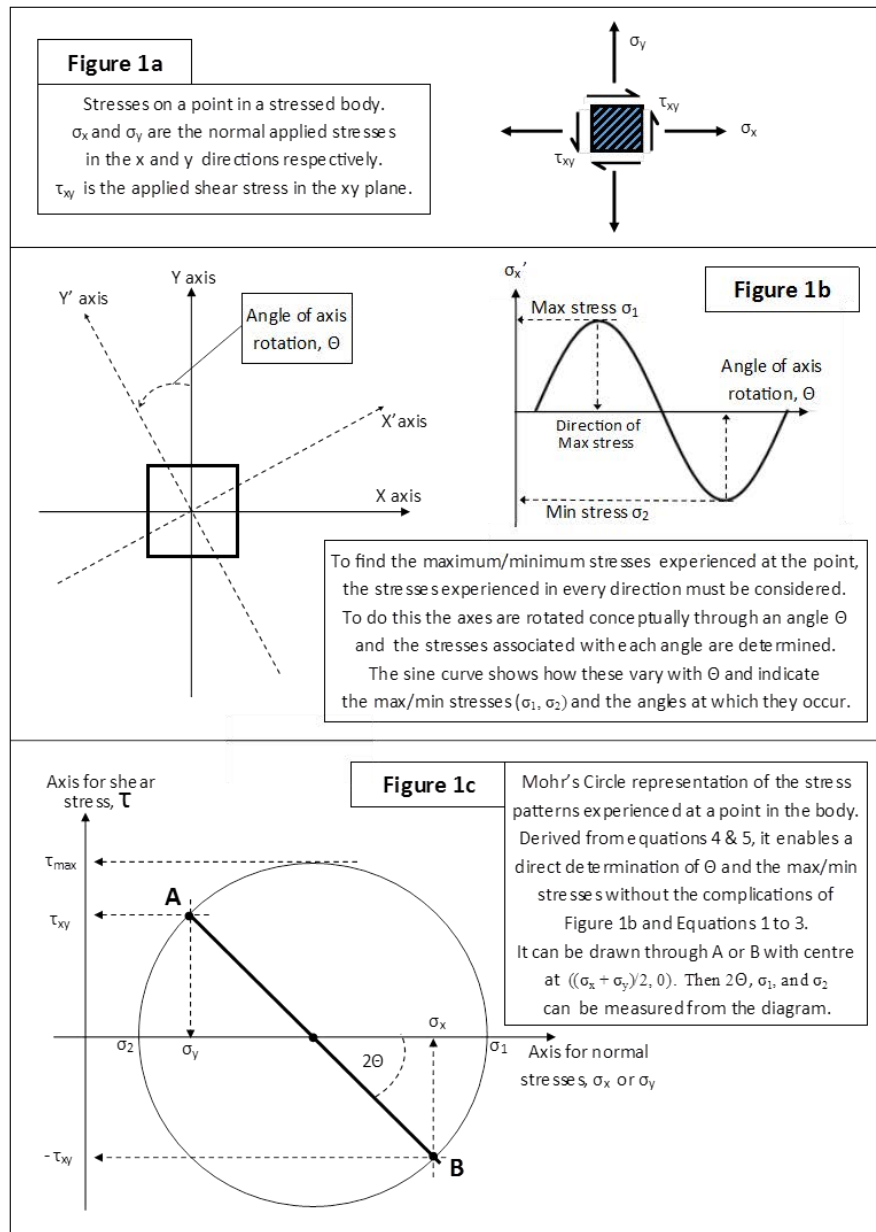


Figure 1: The Mohr Circle representation of 2D stresses at a point in a body

Phenomenography at work

Phenomenography was developed over the period from the 1970's into the 1990's (Marton, 1981, Marton and Saljo, 1976, Marton and Booth, 1997). A recent review concludes that "it still appears to have much to offer to higher education research" (Tight, 2016, p. 319). Its usage within engineering education research is not as extensive as in other fields but it is receiving growing attention (Case and Light, 2011, Magpili and Vasuthanasub, 2012, Dringenberg et al., 2015, Cummings et al., 2016).

Rather than reviewing here the theoretical underpinnings of phenomenography in any detail, the various aspects of the methodology, what it entails, and what it can deliver will be described in the context of ‘phenomenography at work’; that is it will emerge as the example of a phenomenographic investigation into students’ conceptions of the Mohr Circle unfolds.

What phenomenography aims to achieve

Faced with the challenge of trying to understand why students are struggling with a difficult topic like the Mohr Circle, a phenomenographic investigation aims to understand the variation in the ways that the students in a class experience or conceptualize that topic. The premise here is that students respond to situations or to phenomena according to how they experience them (Marton and Booth, 1997). Therefore, in order to gain pedagogically useful insights into how students might learn and respond to a particular topic and how it is taught, it is helpful to gain an understanding of the different ways in which those students conceptualize and experience that topic. To be pedagogically useful, such insight should relate to the students collectively and should focus primarily on the qualitative differences in the students’ experiences/conceptions, otherwise the individual idiosyncrasies of a multitude of students are likely to overwhelm and obscure any insights that might be obtained.

Therefore, the outcome of a phenomenographic investigation – its ‘outcome space’ – is a presentation that is carefully crafted to communicate the qualitatively different ways in which students in the study typically relate to the topic in question. This is illustrated by the graphical representation of the outcome space that emerged from this study that is presented later in the paper.

Setting up a phenomenographic investigation

The research questions guiding a phenomenographic study focus on the relation between students and the phenomenon in question, the Mohr Circle in this case. Being aware that the focus is on this relation, not on the students and not on the phenomenon itself, is crucial. Otherwise, the investigation can slip into a study of students or a study of the phenomenon or topic, neither of which reveal anything specific about how the students might think about or learn that particular topic. The research questions that guided the study were as follows.

- 1) What are the qualitatively different ways in which students taking this course (a) understand the Mohr Circle representation of the stresses in failure analysis, and (b) apply that understanding?
- 2) What pedagogical modifications to the course do the answers to these questions suggest?

What one is seeking to understand is the range of conceptions or experiences that may be or are likely to be present in a body of students. As will be seen, such understanding can give insights into the kind of ‘learning paths’ which students need to follow if they are to master a topic. The pedagogies a teacher uses can then be informed by those insights. Accordingly, the data for the study should consist of information that conveys, implicitly or explicitly, the range of views or experiences to be found in the collective. Maximum variation sampling rather than representative sampling of the student group is therefore indicated (Green, 2005). Typically, this can be achieved by a careful selection of 10 to 15 students. To maximise the variation in this study, consideration was given first to students’ academic ability (as reflected by their marks in a related course), and then to gender and ethnicity. Ten students were selected on this basis and were invited to volunteer for the study. The normal ethical procedures were followed.

Gathering data

To gain insights into how students may relate to a topic requires data that reflects or is born out of their experience or thinking about that topic. Appropriately structured and conducted interviews are the most common way of gathering such data. Typically, the interview protocol is semi-structured (Cohen et al., 2007) in nature in that it allows the interviewer to deviate from the pre-planned questions to pursue any line of thought that seems interesting and relevant.

The protocol that was formulated for the study was based on five sets of questions. The first enquired about how the interviewee related to the topic, and what s/he found interesting, confusing, helpful or important. The second and third sets addressed the issues of what a Mohr circle was, and the students' conceptions about stresses and their relationship to the Mohr Circle. The fourth and fifth sets solicited the interviewee's experience of learning the topic, their experience of the textbook and any suggestions they might have about modifications that would be helpful for learning the topic.

Initially, 2 students, randomly selected from the 10, were interviewed in 'pilot interviews' to test and refine the interview protocol and questions. Only minor changes were found to be necessary and the remaining 8 students were then interviewed using the refined protocol. All interviews were recorded and transcribed.

Analysing the data

The ten interview transcripts constituted, in phenomenographic terminology, a 'pool of meanings' (Marton, 1981) in that together they embodied the full range of 'meanings' (i.e. conceptions and experiences) about the topic that students had described or implicitly expressed during the interviews. A phenomenographic analysis of such data aims to establish whatever variation is evident and is pedagogically relevant in this pool of meanings, and to describe that variation in terms of qualitatively different categories (Marton, 1981, Marton and Booth, 1997, Akerlind, 2005b, Akerlind, 2005a, Collier-Reed et al., 2009).

To do this in the study, each transcript was read carefully to identify specific phrases that conveyed particular ideas, experiences or conceptions and seemed relevant to the research questions. Phrases with similar meanings were coded with a short label to generate an emergent list of codes that embodied the meanings found in the data. Iterative reflection on the relevance of, and interconnections and differences between the codes facilitated an ever deepening awareness of the essence of the variation in the ways students related to the topic. In a highly iterative process, codes were consolidated and redefined to reflect this deepening understanding and to develop a parsimonious set of categories that embodied and described the variation that was evident. Parsimony is important because otherwise the individual idiosyncrasies of a multitude of students are likely to overwhelm and obscure any pedagogically useful insights that might be forthcoming from the study.

The final stages in the analysis were to clarify what was similar and different about each category; to select relevant extracts from the transcripts that provided evidence for those similarities and differences; and to rework the category labels so that they were both as memorable and as descriptively accurate as possible. The resulting set of substantiated and appropriately labelled categories was then examined for structure as discussed shortly.

The outcome space of the study

The phenomenographic analysis identified four qualitatively different conceptions of the Mohr Circle that were evident in the group of students interviewed. In summary, these were that the

Mohr Circle is a topic, a procedure, a tool, and a visualization. Each conception, along with its associated sub-categories and nuances, are presented, explained and justified as follows with the distinguishing labels of each category and subcategory being highlighted in bold italics.

*Category 1: The Mohr Circle is a **Topic** to be studied and learned.* In this conception, the focus is on the educational context of the course; the student's attention is on what is required to pass that course. For example, Student 7 stated that "It's just that part of the course where you just have to get through it, hope it's not in the test. I don't understand it so I can't relate them to my work".

*Category 2: The Mohr Circle is a **Procedure** for analysing stresses.* In this conception, the focus is on how stresses can be analysed by means of the Mohr Circle. At a rudimentary level, it recognizes the Mohr Circle as a procedure for **simplifying** a stress analysis. As Student 8 put it, "[Mohr Circles] are simplifying the way we look at tri-axial systems [...] So I think they are very good in terms of simplification". At a more sophisticated level, there is the recognition that the simplification comes about by **replacing** with a graphical representation the equations that describe the stresses. For example, "The equations do the same thing as the Mohr's Circle, but for me I saw the Mohr's Circle as easier to grasp because [with] the equations you basically put in the values and calculate different intermediate values for the next stage until you get the maximum shear stress. But for the Mohr's Circle it's just a graphical way of doing it whereby you have your axis, you plot, you draw a circle and thereby find your shear stress" [Student 2].

More sophisticated conceptions of the Mohr Circle as a procedure move beyond recognizing these two rudimentary understandings of what the Mohr Circle does in general to what the procedure entails as a means of **analyzing** the stress patterns in a body. As Student 7 put it,

In one example we've done, we were given σ_x and shear stress σ_y [sic] where we have to somehow do a circle from what we're given and then find the average. [...] From then you're going to see the minimum shear stress and maximum shear stress.

At one level, the Mohr Circle was conceived merely as a procedure for determining the maximum and minimum stresses a body experiences. Student 7, for example, went on to say, "All I know is that you draw it [the Mohr Circle] from what we're given and then somewhere here it's the minimum shear [sic] stress and somewhere here is the maximum shear [sic] stress". However, as illustrated by the following quote from Student 2, a more advanced conception is that the maximum/minimum stresses will have a particular orientation.

You can calculate the stresses at different orientations of your element. If you have a certain orientation and you have normal stresses and shear stresses, then if you want to calculate the stresses at a certain angle then you can use Mohr's Circles. [Student 2]

More particularly, the maximum/minimum stresses lie in particular planes, the 'principal planes', which are oriented at a particular angle to the coordinate axes. This more advanced conception was hinted at in only one of the transcripts.

*Category 3: The Mohr Circle is a **Tool** for analysing the structural integrity of a body.* In this conception, the focus is on the purpose of the Mohr Circle procedure. Student 6 put it this way.

[The Mohr Circle] looks more complicated than it should be because it's a tool. [...] After understanding it, I won't say it's easy but it's useable. [...] They [the stresses] are there, they do that, they show what the things are. I see them as a tool, not [so much just] as a description of what's happening.

At its simplest, this conception sees the Mohr Circle as a tool for **modelling** how a body responds to stresses. Student 5, for example, said that, “I think Mohr’s Circle is like a mathematical model for stresses”. A more complete conception of the Mohr Circle as a tool is that is useful for **examining** the stress patterns in a body and, more specifically, examining them at different points in the body. This conception is illustrated by the following extract.

Within an object there are different points and you put stress. Different points experience that stress [differently]. Mohr’s Circle takes that point and it interprets what’s happening there. [Student 6]

This conception, however, does not include the awareness of the purpose of examining stresses at different points in the body, namely that such examination is for **evaluating** the structural integrity of a body subjected to stresses; i.e. “will it stay intact or fail” [Student 3]. This is a more advanced conception in that it appreciates that deformation or failure will occur if the maximum stress experienced anywhere in the body is greater than the yield strength of the material. This is illustrated by the following quote.

You get the maximum stress and you come back and plastic deformation happens. [i.e. if the stress experienced exceeds the yield strength, plastic deformation occurs.] I just understand the responses of a material to those [stresses]. So if you have maximum stress it would plastically deform afterwards and with minimum stress it goes back to its original shape. [i.e. if the stress experienced is greater than the yield strength it would plastically deform and if less it goes back to its original shape when or if the stress is released]. [Student 7]

Still a more advanced conception of the Mohr Circle as a tool involves the awareness that evaluating whether or not a body is likely to fail or deform is critically important when **designing** a mechanical component. Alternatively, when **troubleshooting** the failure of a component, such an evaluation can indicate whether or not a body has failed because of a design fault or because it was over stressed. The following extract illustrates these more sophisticated conceptions of the Mohr Circle as a tool.

I think Mohr’s Circles are more applicable when analyzing a situation – maybe a finite element analysis of things such as pressure vessels, trying to see how much force in terms of shear stresses that component is subjected to, the design limit, or even the initial design whereby you want to determine where you don’t know the operational stresses. So you would be trying to find the maximum theoretical use factor to find the design operational stresses. [Student 1]

*Category 4: The Mohr Circle is a **Visualization**, a graphical visualization of stress patterns in a body.* In this conception the focus is on the kind of visualizations which the Mohr Circle enables. This constitutes a more sophisticated conception of the Mohr Circle in that the conception of the Mohr Circle as a tool with the functionality just described is implicit but that the tool does more – it enables a visualization of the stress patterns that are important when modelling, examining, evaluating, designing and troubleshooting. Student 8 put it this way.

I do have difficulty grasping these systems the way they are, but with the Mohr’s Circle I can really see where the maximum shear is. I can actually see where the X and Y directions are. So I think they [Mohr Circles] are very good in terms of simplification.

Interpreting the outcome space

The outcome space just described has been organized in a particular way to highlight the progression from less to more sophisticated and complete conceptions with the least sophisticated categories and subcategories being presented first. Figure 2 summarizes these progressions. (Note, however, that the first category (the Mohr Circle is a topic to be studied) has been dropped as it is obvious and pedagogically unhelpful.) Two other structural features are conveyed in the figure: (1) the more sophisticated conceptions assume and build on the less sophisticated conceptions; and (2) there is a big picture variation in the conceptions that distinguishes between conceptions of what the Mohr Circle does, how it is used, and the visualizations which it enables.

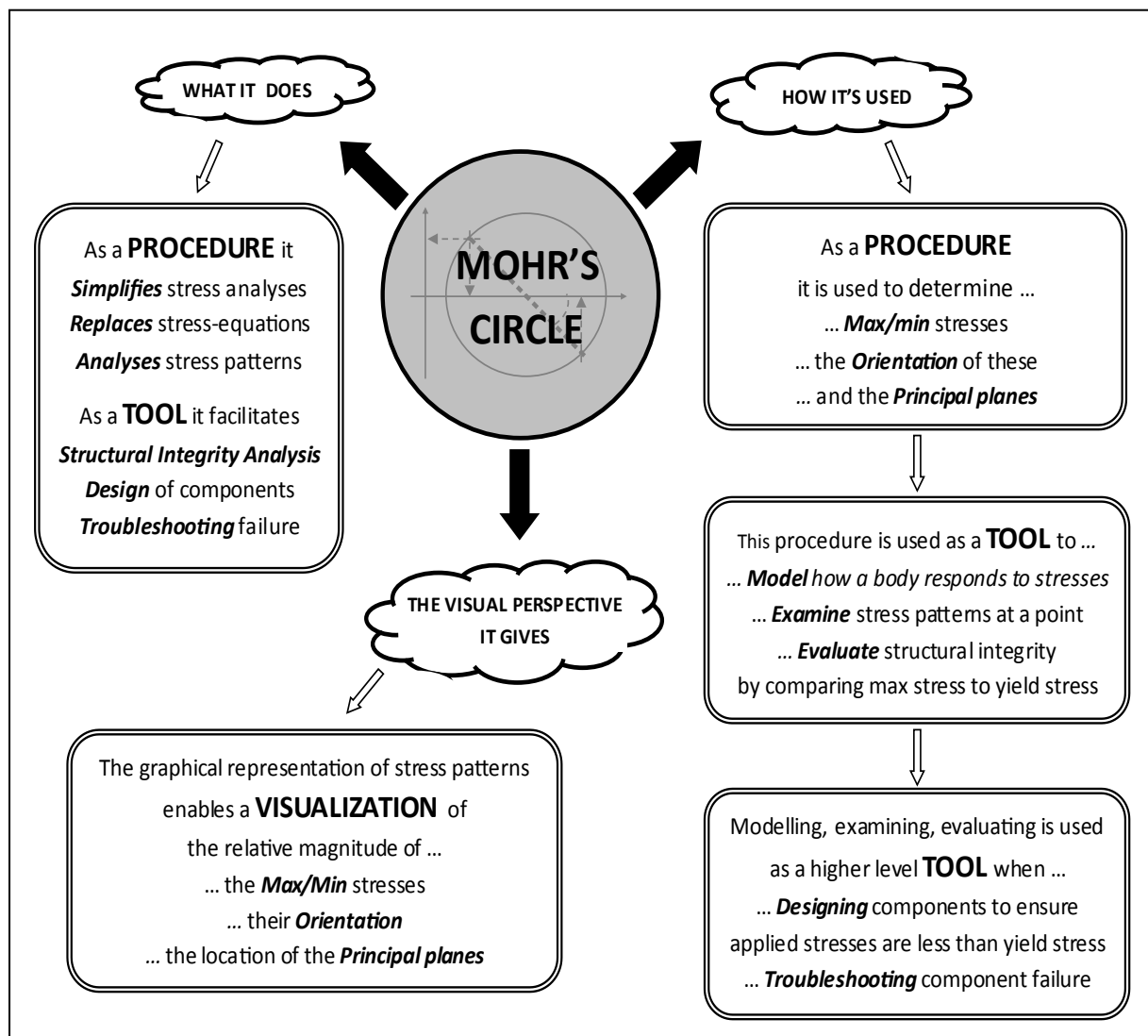


Figure 2: The 'Outcome Space' of the Phenomenographic Investigation into the Variation in Students' Conceptions of the Mohr Circle

The structure evident in the outcome space is as important as the establishment of the qualitative differences in the students' conceptions of the topic, if not more so. The reason is that the hierarchical structure evident among the categories constitutes, in effect, a 'conceptual scaffolding' of the topic that is pedagogically very useful. It is useful because it suggests how

one conception builds on and relates to earlier conceptions in the progression; and it suggests a conceptual ‘learning pathway’ of how a student’s learning typically needs to progress in order to master the topic. What is of particular significance is that the conceptual scaffolding and learning pathway derives from what is evident among the students rather than from a teachers’ intuition, a textbook or anecdotal observations.

Implications of the study

The phenomenographic study has described the variation in the ways students relate to, experience, and conceptualize the topic of the Mohr Circle. It has articulated the findings in terms of a framework, the outcome space, that is structured in two ways: a hierarchy of increasingly sophisticated and complete conceptions of the Mohr Circle and its application which provides a useful conceptual scaffolding of the topic; and a triangulation of three perspectives on that hierarchy. The latter is useful pedagogically in that it suggests three angles a teacher might use in their teaching to enrich the students exposure to the topic. Many educators (for example Felder and Silverman, 1988) have emphasized the beneficial synergies for student learning that can accrue from coming at a topic from multiple perspectives.

The conceptual scaffolding indicated by the study findings is pedagogically useful in a number of ways. In the first place, it is useful for course documentation. The graphical presentation of the outcome space in Figure 2 is memorable and provides a concise overview of the key points in the topic. What is more, it aligns with the ways in which the students typically think about the topic. The outline has obvious utility as a summary reference that can be included in the course outline, can be used in formal input, and can be referred to by students when solving problems and when revising the topic.

The conceptual scaffolding can also be useful for a teacher when troubleshooting student learning of the topic. In effect, it ‘opens up’ a teacher’s awareness of the kind of difficulties students typically experience in learning the topic. For example, there are a number of points in the conceptual progression that has been identified that may function as threshold concepts (Meyer and Land, 2003) in that students will struggle to master more advanced concepts if they have not appropriately grasped key but lesser concepts. Examples of such ‘sticking points’ include the awareness that the Mohr Circle refers to a point in a body and that the analysis should focus on many points to gain a fuller understanding of the structural integrity of a stressed body. The distinction between the Mohr Circle as a procedure and as a tool may constitute another sticking point; students may become satisfied with their mastery of the topic once they have mastered its procedural aspects. In a similar way, they may fail to progress conceptually from *examining* to *evaluating* the stress patterns in a body, failing to gain a robust appreciation that the purpose of using the Mohr Circle is to investigate the structural integrity of a body. The same kind of sticking point may apply with regard to the progression from appreciating the ultimate purpose of the Mohr Circle as a tool when *designing* components or *troubleshooting* their failure.

The conceptual scaffolding indicated by a phenomenographic study can also be useful when designing a course or a modification to the way it is taught. In this regard the learning pathway suggested by the conceptual scaffolding is particularly useful because it suggests how the focus of teaching should progress from the more basic concepts to the more complex and sophisticated. Combined with the other insights forthcoming from the study, it also suggests which points along that pathway require particular emphasis and reinforcement.

Conclusion

The aim of this paper was to present a study that demonstrated ‘phenomenography at work’ in an engineering context and to show how the methodology can provide pedagogically useful insights. Although the focus of the study was the Mohr Circle, it could have been any topic which engineering students struggle with.

The paper has demonstrated what a phenomenographic study involves, what kind of findings it can generate, and how useful these can be pedagogically. It has shown how the methodology is able to open up a teacher’s awareness of the conceptual variations that typically exist among the students they are teaching and how such awareness can be used to design and implement appropriate pedagogical interventions and modifications.

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Flexible curricula: Addressing the transition from engineering science to engineering design

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In 2013 the Council on Higher Education (CHE) presented a proposal to increase the duration of university degrees by a year in response to very poor completion rates. One of the arguments presented for the proposal is the need to intentionally bridge a number of 'transitions', for example the articulation gap between school and university. In engineering degrees one of the transitions identified is the transition from 'engineering sciences' to 'complex problems and design'. However there has been little systematic work on the nature of this transition. The argument that I make in this paper is that at the heart of the transition from engineering science to complex problem solving and design is the introduction of contextual detail. While engineering educators are familiar with progression in conceptual complexity inherent in disciplinary specialisations, we tend to be less mindful of the complexity added by contextual detail, and the changing logic of reasoning that it introduces.

Drawing on concepts developed in Legitimation Code Theory, specifically semantic gravity and semantic density I discuss the insights these concepts provide for understanding the nature of the transition from engineering science to engineering design. I show a change in the logic of the reasoning, from generalisable abstract thinking to reasoning that shifts between the specifics of concrete artefacts and the generalizability of abstract theory. I show how the introduction of contextual detail introduces a new form of complexity, requiring a different way of reasoning. I propose that thinking about engineering design projects in these ways offers insights that open up options for helping students through the transition from engineering science to engineering design more intentionally.

Introduction

The Council for Higher Education (CHE, 2013) has presented a proposal to increase the duration of university degrees by a year. The proposal is presented in response to very poor national completion rates in higher education in South Africa (Scott, Yeld, & Hendry, 2007). For engineering this means increasing the standard program to five years, but with the intention to allow enough flexibility in the program structure to enable completion in four years. One of the arguments presented for this proposal is the need to intentionally bridge a number of 'transitions', for example the articulation gap between school and university. The engineering degree exemplar (CHE, 2013, pp. 166-183) identifies a transition from science to engineering science, and a transition from engineering sciences to complex problems and engineering design among others. However the exemplar does not address details of the nature of these transitions nor how they might be addressed. What changes through the transition, and how might educators respond?

In this paper I discuss some aspects pertaining to the transition from engineering science to engineering design. But engineering design in an engineering curriculum can mean a range of different things. I have taken the view that engineering design projects represent the sorts of problems that come closest to those problems faced in professional practice. It is a view shared by engineering education scholars concerned with preparation for engineering practice, who in the 1990s were arguing for more design in engineering curricula dominated by engineering sciences (Harris, Grogan, Peden, & Whinnery, 1994; Sheppard et al., 1997). More recently design-type problems of the nature I am discussing have become associated with problem based learning (Edström & Kolmos, 2014). I use this conceptualisation of design because it helps to

highlight the differences between complex, open-ended, ill-defined educational projects set up to mimic professional practice (see for example Bucciarelli, 2003; Dym, Agogino, Eris, Frey, & Leifer, 2005; Jonassen, Strobel, & Lee, 2006) and those well-defined, convergent problems typical of engineering textbooks and tutorial questions. It is a far more general sense than may be associated with design in engineering courses. But it forms a useful basis for understanding the transition from 'engineering sciences' to 'complex problems and design'.

Theoretical antecedents

The paper is based on a PhD dissertation (Wolmarans, 2017) that drew on two theoretical traditions. The first deals with professional knowledge and design thinking research (especially Abbott, 1988; Schön, 1983; Simon, 1981) and the second draws on knowledge theorists from sociology of education (for example Bernstein, 2000; Maton, 2014; Muller, 2009; Wheelahan, 2010). The analysis was based on conceptual tools from Legitimation Code Theory (LCT) (Maton, 2014), specifically LCT (Semantics). In this paper I have paraphrased some of the key theoretical ideas, but have referenced the theoretical roots in footnotes for those who might be interested in pursuing this line of research. I have kept the theoretical background very brief because the purpose of the paper is to discuss the findings in a way that is relevant to engineering educators.

The idea of engineering design associated with engineering practice as 'the application of science to solve real world problems' contains what knowledge theorists have identified as two different ways of making sense of the world (Bernstein, 2000)¹. On one hand are the formal rules of specialised disciplinary concepts and relations between concepts (conceptual relations). This knowledge is abstract and aimed at generalisability. On the other hand is familiarity and case precedent (Schön, 1983) needed to make sense of relevant aspects of problem contexts and knowledge of artefacts, what they are and how they work (contextual relations)². This tends to be knowledge of particular situated instances or concrete examples. It is important to note that neither are 'the world' rather that both draw on concepts with which we 'make sense of the world'. The difference lies in the focus, conceptual coherence internal to a disciplinary specialisation, or knowledge external to a discipline, based on 'everyday' understanding and familiarity with things.

Identifying the nature of the transition from science to design:

Drawing on the distinction discussed above, the purpose of engineering science can be described as developing mastery of disciplinary concepts and the acceptable relations between these concepts. Problems presented in textbooks and examinations focus on relatively complex conceptual relations but tend to be stripped of contextual detail. Contexts and artefacts are presented in idealised forms that disguise the variability and uncertainty of the real world. For

¹ See for example Bernstein's (2000) distinctions between vertical and horizontal discourses, internal and external 'languages of description', and 'singulars' and 'regions' each of which attempts to describe in different ways the relation between specialised disciplinary knowledge and its relation to the objects that it describes. Muller (2009), following Bernstein, introduced a distinction between conceptual and contextual coherence as the basis of curriculum logic and developed Bernstein's use of 'grammaticality' in terms of the external language of description to include 'verticality' to describe the internal language of description. Maton's (2014) introduction of semantic gravity and semantic density offers a slightly more nuanced and differentiated way of describing the relation between knowledge and object of knowledge. See also Wheelahan (2010) who draws in critical realism as a way to strengthen the influence of the external world on our understanding of it.

² See also (Abbott, 1988) on three modes of professional reasoning: 'diagnosis' and 'treatment' (I associate with contextual relations) and 'inference' (conceptual relations).

engineering sciences, the complexity lies in the conceptual relations while the contextual relations tend to be simplified; idealised into forms often quite dislocated from reality.

Engineering design is often seen as a counter point in the curriculum, a subject that reintroduces the complexity and uncertainty of the 'real world' (Bucciarelli, 2003). Making sense of the complexity of situated contextual detail (of both context and artefact) involves a process of identifying and simplifying what really matters from the full detail of the situation (Schön, 1983; Simon, 1981) and translating the variability and uncertainty of the contextual detail into theoretical form amenable to predictive analysis (Abbott, 1988). These theoretical analyses then need to be implemented 'back into the world', a process of translating the output of analysis into a physical artefact, or description of an artefact. For engineering design the complexity often lies in making sense of a situated context and artefact, and deciding on what and how to translate these into theoretical terms.

In these terms the curriculum question becomes: *How do we shift students from the certainty of problems stripped of contextual detail as in textbook problems, to the uncertainty introduced by complex situated contexts and artefacts where students are required to do the simplification and idealisation themselves?*

For example, how does one go from:

"... a plane surface (1,6m x 2,5m) is submerged in water at a 30° angle. Determine the magnitude of the force acting on one side and the position of its centre of pressure"

to:

"Design a new slipway for the relocation of the yacht club to the SW corner of the harbour"?

The two examples are selected to illustrate the difference between 'typical' engineering science problems and engineering design problems. Both examples represent extreme positions, chosen to highlight significant features. They should not be considered definitive examples, there are engineering science problems that are less idealised, less generalised. For example the submerged plate may represent a sluice gate loaded only on one side. The question may ask the student to determine the depth of water that would force the gate open (fluids examples are adapted from Douglas, Gasiorek, & Swaffield, 1985). Similarly the design problem might be more or less constrained by changing the level of idealisation and specificity. This formulation of the problem emerged from the broader design problem that required a redesign of the Cape Town harbour to introduce a new passenger liner berth, part of a potential solution required the relocation of the yacht club.

In the first example students were provided an idealised and simplified 'artefact' stripped of interaction with its context except for a generic but well defined fluid. The solution is the magnitude, position and direction of an idealised force. The problem is abstract, contextually simplified and generic but analytically relatively complex, integrating multiple mathematical and physical principles. The solution remains abstract and symbolic.

In the second example students are confronted with the contextual detail of a specific context and type of artefact. Before they can progress to any analysis they need to simplify and idealise the problem themselves.

What is a slipway, what is its purpose? Where should we put the slipway? What matters about the new location, are there important spatial or founding considerations? What happens underneath it? How do I model it: does buoyancy matter; what is the density of seawater, and does it even matter; what about tidal changes; wave action; oops and the vehicle loading in service, how on earth do I approximate that?

Students have to make sense of the artefact and context before they can think about what and how to analyse anything. They have to translate their understanding of the specifics into more generalised theoretical terms, extract and abstract from the particulars of the concrete case. From the specifics they have to identify relevant theory that might help them to make design decisions. And from theoretical insights they might identify new contextual questions. Because of the uncertainty of the specific scenario, they can probably get away with a far simpler battery of analyses, drawing on codes of practice. But first they have to identify which analyses, which codes. And once the analyses are completed they will need to consider the numeric answers in relation to the specifics of the scenario. The solution does not end with an abstract symbolic number, but needs to be translated back into the world, both qualitatively to inform design decisions and more quantitatively in the form of detailed technical drawings and documents. Where engineering sciences tend to remain in idealised, abstracted, contextually simplified form, engineering design introduces specific, contextually complex detail both before and after the analysis.

Characterising design projects: contextual complexity and specificity

LCT (Semantics) was useful for analysing the features discussed in the examples above, and provides a basis for considering how to sequence projects to bridge the transition from engineering science to engineering design. The discussion is premised on the position that a key component of the transition from engineering science to engineering design is the reintroduction of the specificity and complexity of contextual detail. For this discussion I use the 'problems' presented above as examples, the difference between determining the precise point load on a submerged plane and designing a slipway - the *submerged plane problem* and the *slipway design problem*.

The specificity of context and artefact:

The basis of relative specificity lies formally in the concept of semantic gravity (Blackie, 2014; Georgiou, Maton, & Sharma, 2014; Maton, 2009), the extent to which meaning depends on its context. In the *submerged plane problem* (Figure 1 illustrates shifts in specificity) both the context (a fluid) and the artefact (a plane) are generalised and idealised. Understanding what they are and how they work does not rely on making sense of the specifics. The fluid has no distinguishing contextual features; rather it can be defined by formal and familiar theoretical properties. Likewise the plane can be any plane, assumed to be perfectly flat, infinitely thin, and perfectly rectangular. There is no concern over material choice - it is neither given nor required. There is no consideration of contributions from other possible loads - the interaction between context and artefact is a neatly defined generic interaction. The problem is presented already abstracted from any specific scenario and presented in theoretical terms transferable across contexts and applicable to multiple artefacts.

In the *slipway design problem* (shown in Figure 2) the context is a particular context and the artefact while not referring to a specific slipway, does refer to a type of object, far more specific than the generic plane. Before any analysis can begin one needs to make sense of the context and artefact on their own terms. The reasoning begins in making sense of the specific: its function and potential location in the harbour, local ground conditions and surrounding infrastructure, the types of vehicles and boats involved. One cannot apply generic theoretical models directly to specific scenarios. First the context and artefact need to be simplified to what really matters and abstracted to a far more generic formulation, amenable to analysis. What is required is a shift from the specifics of the contextual detail to the generality of theoretical descriptions. But it is not a unidirectional form of reasoning, theoretical insights also contribute to identifying significant contextual features and organising them in relation to each other. The

completion of the design would require the translation of generalisable analysis to the specifics of the slipway, now a more specific artefact than the type referred to in the brief.

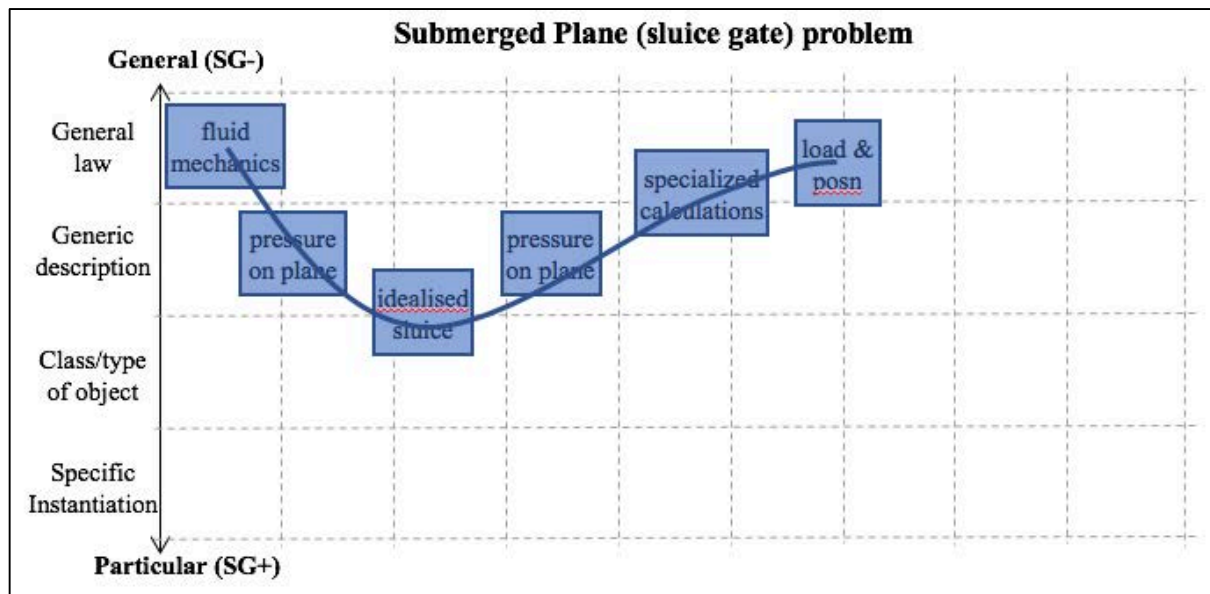


Figure 1. Example of specificity in a 'typical' engineering science problem.

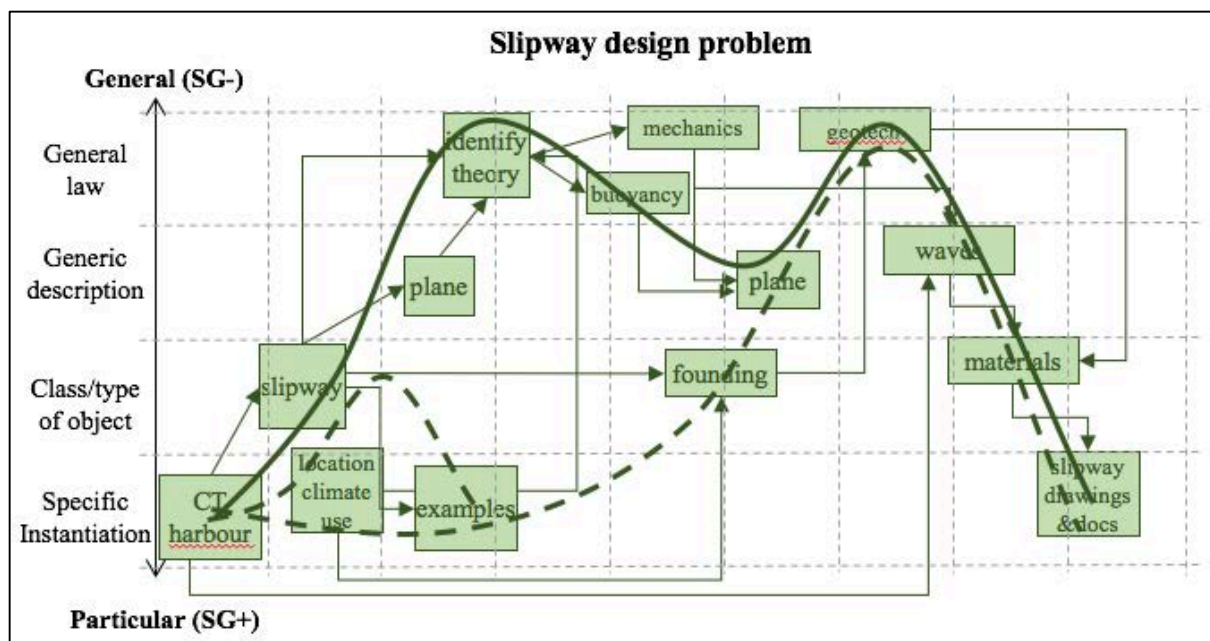


Figure 2. Example of specificity in a 'typical' complex engineering design problem.

A comparison of the two figures shows 3 significant differences in the nature of reasoning required. Firstly, the logic of the submerge plane problem (even when elaborated to an idealised sluice gate problem) is located in general laws (in this case associated with fluid mechanics). The problem is constructed to test understanding of the concepts using a generic idealised artefact, while the logic of the slipway design project begins with a specific context and artefact type and ends with a specific drawing of the artefact. It is a logic of general $\rightarrow$ specific $\rightarrow$ general compared to a logic of specific $\rightarrow$ general $\rightarrow$ specific. Secondly, the slipway design problem spans a far wider range between specific and general than the submerged plane problem, which remains far more general throughout the problem. And thirdly, the design

problem includes multiple waves from specific to general and back. I argue that it is the detail inherent in specific context with real external referents that generates multiple threads of reasoning which are absent in most typical engineering science problems which are intended to test the mastery of specific conceptual relations, usually in separate problems.

The complexity of the problem:

Associated with the different logics of the shifts between specific and general is a shift in the source of complexity in the problem. In the slipway design problem the complexity originated in the contextual detail, followed by shifts to conceptual detail depending on the relevant disciplinary insights recruited. By contrast most contextual complexity has been stripped from the submerged plane problem, the complexity is located in the conceptual relations.

Formally the definition of complexity lies in the definition of 'semantic density' from LCT (Semantics). Semantic density refers to the relative condensation of meaning into symbols and practices (Maton, 2014). But informally I have used Herbert Simon's design rather pragmatic definition of complexity:

... Roughly, by a complex system I mean one made up of a large number of parts that interact in a nonsimple way. In such systems the whole is more than the sum of its parts, not in an ultimate, metaphysical sense but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. (Simon, 1981, p. 195)

When a context or artefact is categorised as *contextually complex*, I mean that there are a large number of physical elements that need to be identified and understood, and their interrelationships considered. The more that students have to make sense of simultaneously embedded interactions themselves the more complex the contextual reasoning. The more that the brief does the work of identifying and separating out what is significant, and sequentially defining the parts and their interactions, the simpler the contextual reasoning. From this perspective the submerged plane problem is contextually very simple. As posed the complexity of the interaction between real artefacts and real contexts has been simplified, requiring very little consideration. On the other hand the slipway design starts out as contextually very complex. The process of abstraction includes a process of simplifying the contextual detail.

When a problem is categorised as *conceptually complex*, I mean that multiple concepts (and/or disciplines) are implicitly embedded in the required reasoning. As the problem brief identifies relevant disciplinary traditions, identifies specific concepts, or procedures, it progressively does the work of simplifying the conceptual relations. The submerged plane problem integrates mathematical integration, pressure depth relations, and moment calculations. However, it is probably located in a fluids course, which cues the significant mathematical and scientific relations, simplifying the analysis. It retains interdependent relations between concepts, but significant concepts tend to be implied by the course. On the other hand the conceptual analysis of the slipway can only begin once the various significant contextual aspects of the slipway design problem have been identified and translated into theoretical terms. The relevant conceptual relations tend to be emergent from the contextual details, although disciplinary insights are significant in making sense of the problem too. In some ways because relevant theoretical relations need to be identified before any analysis can begin, the conceptual relations may be more complex than those located within disciplinary courses requiring more comprehensive mastery of a discipline.

Thinking about progression: the dual threads of conceptual and contextual complexity

Many design lecturers do consider design projects as some sort of representation of professional practice, with design briefs intended to mimic professional practice. However

design projects in an academic context are not the same as those in practice and cannot be. Although inspired by professional practice, they are always modified in order to fit into the academic context. They are dislocated from the field of practice and 'recontextualised' into academic projects intended for academic purposes. It is this process of recontextualisation (Bernstein, 2000) that provides the opportunity to design intentional trajectories that transition smoothly (or more smoothly) from engineering science to engineering design. But the challenge of developing an intentional and progressive trajectory is that we need to know what progresses and how it might progress. In this paper I have suggested that the introduction of specific artefacts and specific contexts leads to an introduction of contextual complexity that needs to be addressed before students can engage with conceptual reasoning, and that because relevant conceptual reasoning is emergent for the specifics of the projects, the contextual complexity adds to conceptual complexity.

Most engineering educators are quite familiar with trajectories of learning disciplinary knowledge - they intuitively pay attention to increasing conceptual complexity, new concepts build on prior concepts as networks of legitimate relations between concepts grow in magnitude and complexity. Textbooks have well-established sequences of knowledge. Progression through a discipline involves the progressive building of conceptually coherent frameworks. But I think that there is far more uncertainty in what progression means in design. When engineering is conceptualised as 'the application of science', and design projects as 'preparation for practice', there is a tendency to assume that if students have enough mastery of theoretical concepts (conceptual relations) then it is a simple thing to 'just apply' them to real world problems. And there is the potential to focus on generic skills in design as preparation for practice. Both contribute to a blindness to knowledge in design, both the power of theoretical knowledge and the complexity of working with it relation to contextually complex problems.

But progressively building in contextual specificity and associated detail is a challenge of trade-offs. Complex contextual detail introduced too early, before students have adequate mastery of conceptual specialisations is likely to trap them in common-sense understandings separate from the power of generalisable knowledge. Problems constructed with simplified contexts and idealised artefacts downplay the importance (and difficulty) of learning to simplify and idealise things in the world oneself. What I offer in this paper is one way to describe what differentiates engineering science (idealised contexts that focus on mastery of complex conceptual relations) from engineering design (the introduction of specifics, with associated contextual detail). The 'transition' is defined by a change in the logic of the reasoning as a result of contextual specificity with associated complexity.

Conclusions:

That there is a difference between engineering science and engineering design is recognised within the engineering exemplar presented in the proposal for a flexible curriculum (CHE, 2013), even if it is identified intuitively. But the proposal does not engage with the nature of this difference, nor what form a more intentional transition might take. Bucciarelli (2003) does describe some of the differences, and makes suggestions about how engineering science problems might be able to introduce some of the complexity inherent in more 'realistic' problems using an example in mechanics. But he does not provide a precise way to describe these differences. Dong, Maton, and Carvalho (2015), using semantic gravity from LCT, do describe design as spanning a wide range of semantic gravity, from particular case based knowledge to more general design principles. But they leave implicit that contextual detail is

associated with stronger semantic gravity while conceptual detail is associated with stronger semantic density.

I have argued that shifting from engineering sciences to engineering design requires the reintroduction of the complexity of conceptual detail (of context and artefact). While it is critical that students develop mastery over complex conceptual relations within disciplinary specialisations, it is not sufficient. I am suggesting that engineering judgment lies in learning to simplify complex contextual details and translate them into the generalisable abstract terms located in disciplinary knowledge and amenable to predictive analysis. In additions solutions require translation of symbolic answers into implications for and decisions about the world. Engineering curriculum designers need to take into account the complexity that contextual detail brings to a problem, with a view to intentionally developing the skills to interpret the world and to describe it theoretically. But most engineering curricula focus on development of building complex conceptual mastery, seemingly leaving contextual complexity to chance. When suddenly confronted with the complexity of the world students are often left to rely on what they brought with them before they started the degree program. Or in practice, if they never learn to translate contextually specific problems into more generalisable theoretical forms amenable to analysis, they are potentially left to rely *solely* on precedent with little recourse to the insight that theoretical knowledge brings to bear on a problem.

When contexts and artefacts are always presented in idealised and simplified theoretical terms, many students faced with contextual complexity for the first time are likely to lack the skills to translate the problem into theoretical form amenable to predictive analysis. When solutions to engineering science problems are always convergent and exact, many students will have no appreciation of the importance of considering different solution options or solution processes. When solutions always end in a numerical answer, many students will remain unfamiliar with making sense of that number in relation to the world. The transition from engineering science to complex problems inherent in engineering design is a very intimidating step if there has been no plan to incrementally introduce the complexity, uncertainty and judgement needed to make sense of contextually situated problems. We need to help students to get used to identifying significant elements of the context and artefact and discarding others; to deal with the variability and uncertainty of the real and translate it into more fixed and certain quantities amenable to predictive analysis; to consider their analysis in relation to the complex and uncertain world from which it was abstracted; and to translate the theoretical outputs into a form that can be recontextualised back into the world.

My argument is that the 'transition' from engineering science to engineering design is not a trivial one. Design introduces a new form of reasoning based on a different structure of knowledge. Even if made explicit and introduced intentionally, many students will probably need more time to become used to this additional way of reasoning, hence the association with the need for a 'flexible' curriculum, or at least an extended curriculum if content is not reduced elsewhere. However I am inclined to suggest that it is not a flexible curriculum that we need to address the transition from engineering science to complex problems and engineering design, but rather an explicit recognition of what it means to recruit engineering science in the design of contextually situated problems and solutions. This is more about a renewed focus on knowledge in context, with a commensurate reduction in focus on the solely conceptual knowledge. The alternative is to extend the degree to allow space to develop the skills to read, abstract and simplify real contexts and real problems with their associated intrinsic complexity. Although the flexible curriculum proposal does recognise the existence of a transition, I'm not convinced that flexibility is enough to bridge the transition.

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Post intervention reflection on guided discovery learning in a process engineering course

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This paper reflects on the experience of designing and implementing an innovative guided discovery learning approach in a 'catch-up' course on the topic of minerals processing in a second year chemical engineering programme in 2015. The approach deviates from conventional discovery learning approaches in a number of ways but most particularly in the design of the tasks students are set and in the extent of guidance and support provided for the students. Feedback from the students and observations from the implementer of the approach suggest not only that the approach was successful in facilitating effective learning but also in overcoming the major shortcomings of conventional discovery learning methods.

Introduction

An innovative 'guided discovery' mode of teaching was designed and implemented for a second year chemical engineering course in 2015. The context of the implementation of this approach was a spring school that was offered in response to major problems with the module on mineral processing in the Process Engineering II course stemming from being presented by a new lecturing team. Some aspects of the topic had been over-emphasized, some under-emphasized, and, most significantly, insufficient attention had been given to the conceptual difficulties behind the calculation procedures in the topic. Students had performed badly in the test and had complained about the module in general. An intensive but short catch-up course was organized for the students over two days (i.e. 14 contact hours) during the mid-semester break. I, as a retired academic very familiar with the topic, was called in at short notice to design and deliver the catch-up course. The mandate given was to cover the full set of expected learning outcomes and to assume the students had little or no grasp of the topic. Approximately 130 students attended the course.

The design of the course was informed by a combination of the experience gained in the more than ten years of having taught the module; different teaching approaches that had been tried over that period; observation of the efficacy or not of those approaches; a background in higher education theory, research and practice; and familiarity with relevant literature. The design, which will be described in detail shortly, was based on constructivist learning theory but deviated from constructivist norms with respect to the role of the teacher and how student learning was 'guided'. In essence, it combined principles of discovery learning with strong mediation of learning in what I have termed 'guided discovery learning'. In order to explain and justify this approach and to provide a framework for the reflection and discussion later in the paper, a brief overview of constructivist principles is necessary. Thereafter, the design and implementation of the catch-up course will be described and feedback from the students who attended will be discussed. The paper concludes with a reflection on the efficacy of the approach used and a discussion on the issue of guidance in constructivist pedagogies.

Constructivist Learning Theory and Practice: A Brief Overview

The key tenet of constructivist learning theory is that students construct their own knowledge from what they experience and from working with and reflecting on that experience. As Felder

and Brent put it, “We learn most of what we know by connecting new information to relevant cognitive structures in our long-term memories ... and by trying things, getting corrective feedback and learning from our mistakes, and trying again” (Felder and Brent, 2016, Section 12.2). Therefore, according to this constructivist principle, teaching and learning environments should be organized for ‘active learning’ that “involves students in doing things and thinking about the things they are doing” (Bonwell and Eison, 1991, p. 2). This contrasts with the ‘passive learning’ that is associated with the ‘direct instruction’ that is typical of traditional lecture-dominated education approaches where students listen to the ‘sage on the stage’ as s/he delivers information in an attempt to ‘transfer knowledge’ to a mostly passive audience.

Although traditional engineering education does employ some active learning elements in the form of homework assignments, projects, laboratory work, and tutorials (Prince, 2004), ‘active learning’ is not typically pursued during lecture periods. However, a variety of active learning methods for the classroom are available and several researchers have summarized those that are particularly appropriate for engineering education (Prince, 2004, Prince and Felder, 2007, Felder and Brent, 2016, Froyd, 2007). Among these are discovery-oriented learning approaches.

At their core, discovery-oriented learning approaches shift students’ learning attention from the teacher to a well-defined task. The intention is that engagement with the task will lead students to ‘learn by discovery’, i.e. as they engage and struggle with the task and the concepts and skills which completion of the task require, students will self-construct the requisite knowledge.

There have been two broad movements in education theory and practice that adopt this ‘learning by doing’ approach: the ‘discovery learning’ movement and what I will call the ‘problem-based learning movement’. ‘Discovery learning’ (Shulman and Keisler, 1966) is the earlier of the two and was popularized by Bruner (1961) who emphasized that concepts discovered personally are more likely to be remembered than if they are ‘taught’ directly. The problem-based learning movement consists of a cluster of variants including problem-based learning itself (Barrows, 1996); project-based learning (Blumenfeld et al., 1991); case-based learning (Mallik and Aston, 2003); inquiry-based learning (Maab and Artigue, 2013); and self-directed learning (Guglielmino, 2008).

A characteristic of discovery-oriented learning approaches that is particularly relevant to this paper is the issue of guidance. The discovery learning approach, in its purest form, advocates minimal guidance from teachers in order to maximize the learning benefits anticipated from discovering things for oneself. Minimal guidance is also a strong feature of most approaches in the problem-based learning movement. There are a number of qualifications and criticisms of both movements on this issue as will be discussed later in the paper.

Design and Implementation of the Catch-Up Course

The intended learning outcomes of the course consisted of mastering relevant knowledge and specific calculation skills. Students needed to develop elementary knowledge about mineral processing equipment and how it was organized in mineral processing circuits. Because students had already been introduced to these topics, the attention given to them needed to be only at the level of revision. The calculation skills they needed to develop had to do with standard procedures undertaken in order to understand or predict the performance of those mineral processing circuits. It became apparent that this aspect of the topic, which, in my experience, students find to be conceptually difficult, had been inadequately addressed and important aspects had not been addressed at all. The accuracy of this perception was confirmed

by a brief survey of students that was conducted at the start of the spring school. In this respect, therefore, the course functioned truly as a catch-up course and not as a revision course.

Accordingly, the course focused primarily on the key calculation procedures in the topic and their conceptual underpinnings. The concepts and associated calculations were divided into four groupings to align with the time available, i.e. two morning and two afternoon sessions. The general structure of the course was then completed by associating with each grouping the relevant mineral processing equipment and circuit arrangements.

The pedagogical design of the course had four pillars: a mixture of activities; a form of discovery learning; strong guidance and support of student learning; and attention to student diversity especially with regard to the pace at which they worked through the course material.

The mix of activities was intended to provide variety, to regularly switch attention between different perspectives on a topic, and to maintain student interest and focus. The mix included short lectures, videos on items of mineral processing equipment, structured exercises, tutorial problems, and, as discussed shortly under student guidance, both planned and unplanned feedback to the students.

The ‘discovery learning’ component of the pedagogical design consisted of students working through structured, multi-step exercises and tutorial problems on their own and/or with peers. (The design of these exercises is discussed later in the paper.) The context for these exercises and the tutorial problems along with an overview of the relevant knowledge was provided prior to the exercises by the short lectures and videos. However, the extent of these overviews was relatively limited as it was anticipated that students would ‘discover’ and construct for themselves the relevant knowledge as they worked through the structured exercises. The tutorial problems were provided to augment what was learned in the structured exercises; to provide extra problems typical of the level to be expected in tests and exams; and to provide extra material so that quicker learners had meaningful work they could do once they have completed the structured exercises.

The guided aspect of the pedagogical design was built into the structure of the course and of the exercises, and was augmented by extensive interactions with and feedback to the students. As students worked through the exercises, the teacher and teaching assistants circulated through the class and interacted multiple times with every student and student grouping. Many times the interactions went no further than simply asking whether a student was okay and how far they had progressed. Otherwise, engagement with students was only in response to questions or requests for assistance. The strategy here was to respond only to students’ felt needs so that the guidance that was provided was tailored to their own discovery processes.

During the interactions, the lecturer and teaching assistants gained important insights into students’ progress and the kind of difficulties they were experiencing. As such, the teacher ‘discovered’ important information about the students’ learning which then augmented the feedback given to them. This feedback was provided both individually and corporately, and was intended to be an important aspect of the guidance provided to students. Corporate feedback was both planned and spontaneous in nature. Planned feedback was given periodically at appropriate points during the structured exercise sessions, typically in the form of reviewing and commenting on the solutions of the exercise problems up to that point. Spontaneous feedback along with additional input was given when it became apparent from the interactions with students that there was a difficulty that many shared and that required collective attention.

The fourth pillar of the pedagogical design was catering for student diversity. This was achieved firstly by means of the system of interacting with students individually and multiple

times during each exercise set. Secondly, it was achieved by providing extra problems and questions over and above those given in the structured exercises. These were marked as being “optional, if you have the time”. The quicker students therefore always had plenty of work they could do and all students would have additional work they could undertake after the course had been completed.

To conclude this description of the course design, a number of implementational issues are worth mentioning. The first was that about 150 students were expected to attend the course, and accordingly a large venue was required. The second was that the combination of lectures and guided exercises required the venue to be equipped with good multi-media resources and also to allow easy access to every student. This is an unusual combination for a teaching venue at university. The requirement was met by selecting an appropriately equipped lecture theatre that had a seating capacity much greater than the expected number of students. Access to students was then enabled by seating students only in alternative rows so that the teaching assistants could move up and down the empty rows.

Student feedback on the course

At the end of the course, students were asked to evaluate the course by indicating their general experience of it, and by commenting on the learning environment, on the teaching approach used, on how much they had learned, and on any other aspect of their experience. Of the 130 students who attended 72% (i.e. 93 students) completed evaluation forms. The comments were overwhelmingly positive about the course and its effectiveness in helping students towards mastery of the topic. The very few comments that were negative in nature had to do with the intensity of the course (6 students reported getting quite tired), its structure (more breaks, and a three day format with shorter hours were suggested), and the venue (one student said it was uncomfortable while several reported the reverse). Students’ comments on implementational issues – the venue, the sound system, the pace and level of the course, its organization and clarity of presentation, and the teacher’s ability – are not discussed here beyond stating that they were positive in nature and indicated that these issues had been attended to satisfactorily and so had not undermined the effectiveness of the pedagogies used.

With regard to comments relevant to the pedagogical design of the course, the following quotes from the evaluation forms are noteworthy. “I think it was really beneficial to allow us to engage in class activities so that we can know what we really do not understand. It is also beneficial to relate the theory we are lectured with real life situations and how we apply and use what we learned to industrial calculations.” Several students commented on the balance between the different types of activity. Two reported that “the teaching approach was on point because it was a combination of tuts, examples and a lecture ... all in one”, “doing many examples accompanied by explanations and visual aids”. Another commented that “it was very nice. It was more like an interactive tutorial, there is a learning session, then time for you to apply yourself and there is time to ask questions”. Several students remarked that the format gave them time to apply themselves, “time to think”, and “time to ask questions without worrying about time being an issue”.

Many students reported specifically that they found the learning environment to be “better than normal classrooms because it was not a one-way traffic. We were able to discuss with friends and that helped us to be free and open to learning”. One student put it this way, “It [the teaching environment] didn’t feel like a lecture where one has to behave in a certain way, but it was relaxed, since one could just ask his/her peers questions if one was stuck and also there was the lecturer and tutors to help”. The observations that the interactive environment was conducive to feeling “free and open to learning” and that one did not have to “behave in a certain way”

are noteworthy. In this regard, one observation was particularly telling – “[you] could focus on [the] task at hand, as everyone in the class was also focused and no distractions” (underlining by the student). This speaks volumes about the limitations of the lecture format in keeping students focused and engaged and the very high level of engagement that was created and maintained by the interactive, problem-focused format used in the course.

The benefits of being able to interact with peers and the availability of support and individual attention from the teacher and his assistants was noted in various ways by most of the students. “The working environment was easy and allowed for interaction with lecturers, tutors and peers. It made it easier to learn”. “We could get individual attention when we were having a difficulty and were allowed to work together with our peers to understand how they approached the problem”. “And [you] really have a chance to experience how other people view things and how they approach questions”. “We got a chance to express our thinking and therefore get judgement on that as part of guiding to think on our own”. “We could talk among ourselves while doing the exercises and explain it to each other”. “The lecturer and tutors were kind enough to explain to me explicitly until I personally said I comprehend the material”.

In terms of the impact on student learning, most students reported significant gains in their understanding and mastery of the topic. One student put it this way.

At first, I was confused about what [the] particulates concept is about. I did not have a clear understanding of how to draw the graphs and even do the calculations. But now I understand and am happy with what I have grasped from these classes.

Particularly gratifying were a number of reports that students not only gained the desired knowledge but also enjoyed doing so. “I gained a deeper understanding on the subject and most importantly enjoyed it”. “I enjoyed the lessons and fully understood virtually everything that was taught in class”.

Reflections

It is unfortunate that the circumstances of the spring school did not allow a formal assessment of student learning of the topic to be undertaken. Accordingly, an evaluation of the efficacy of the pedagogy used and the students’ responses to it must rest on the course evaluations, the feedback obtained from the students, and on observations made during the implementation of the course.

From the perspective of the designer and implementer of the pedagogical design, a number of features of the catch-up course and how students responded to it stand out. The first was the very high level of student engagement that was attained and the extent to which this was sustained for up to 7 hours each day. As the one student reported, everyone in the class was focused and engaged, and there were no distractions. This level of engagement may have been partly attributable to the fact that most of the students were worried about their lack of mastery of the topic. However, my observations and some of the written feedback from the students suggest that this was far from the main driving factor. Students appeared to be relaxed and to be enjoying the learning experience and stated as much in their course evaluations.

A second feature that stands out is the multiple efficacies of the kind of interactive learning environment that existed during the course. Virtually all students commented on this in their course evaluations. They were free to work at their own pace collaboratively or individually in whatever way suited them. What is more, the availability of immediate expert help meant that the kind of conflicts between students over concepts, opinions or procedures that can bedevil and waste time in collaborative learning environments could be quickly addressed and settled and turned into helpful learning opportunities for those involved. It was also apparent

that the interactive learning environment was motivational for the students. One student stated this directly: “[the] interactive [environment] created more interest in the subject”.

A third feature that stood out was the educational efficiency of the pedagogical design. The first aspect of this has already been discussed – students were maximally engaged in their learning and were not distracted. All students, even the quickest learners, had plenty of work to keep them meaningfully engaged all the time. The availability of immediate expert help and guidance meant that the learning benefits of struggling with new concepts and cognitive conflicts could be maximized in that help was available when it became apparent to the students that the struggle was becoming unproductive and frustrating.

The design was also efficient with respect to teacher resourcing. Only two teachers were present throughout the catch-up school. We found that most of the time this was adequate to provide the kind of student support and guidance intended for the 130 students because all were deeply engaged with their work in an essentially self-directed manner. Additional teaching assistants – up to three – were available some of the time, but even without this, engagement with the students was generally relaxed and not particularly taxing.

A further conclusion with regard to the efficiency of the pedagogical design is that it aided the teachers in their role as mediators of the students’ learning. Because they were continually monitoring students’ progress and engaging with them, particular difficulties students were encountering quickly became obvious. On some occasions, these difficulties derived from shortcomings in the way the material had been presented to the students or stemmed from the designer’s misunderstanding of the nature of the conceptual difficulty students had with an aspect of the topic. The interactive format of the pedagogical design and the way in which ‘lecturettes’ were mixed in with student activity allowed the teacher to seamlessly interrupt student activity to address and deal with any such pedagogical shortcomings that had been ‘discovered’. In effect, the teacher, like the students, was learning by ‘discovery’.

Before discussing the more technical aspects of the pedagogical design, it is appropriate to consider its negative features. They are few and are logistical in nature. The venue for ‘guided discovery’ must cater for both multi-media lectures and interactive tutorial-type work that requires easy access to every student. This is an unusual requirement in today’s universities. Either lecturing facilities in tutorial venues need to be installed or upgraded, or creativity must be exercised in adapting standard lecture theatres to facilitate access to students. The second logistical problem has to do with timetabling; the standard structure of single or double hour-long periods is a problem. The ‘guided discovery’ format requires ideally that sessions be at least three hours long. Shorter periods undermine the effectiveness of the design in that the amount of time that can be devoted to formal input and feedback to the class is constrained and there is less time for student engagement in the structured exercises. The latter point is not be dismissed lightly because it takes time for students to get into those exercises, to wrestle with the issues that come up, to discover any difficulties they might have, to receive help and guidance, and then to move onto the next aspect of the exercise. The learning benefits of this process grow with the length of the engagement.

Discussion

Discovery-oriented learning, whether in its original manifestation or in the later problem-based movement, has at its heart a particular task that is given to students. The design of the task and of the circumstances in which that task is to be accomplished is what distinguishes the variants of the approach. However, according to Kirschner et al. (2006), the variants have two features in common. First, the task provides an opportunity for students to self-construct the requisite knowledge and is specified by appropriate goals and relevant information. Second, the task

specifications provide minimal guidance on what to do and how to do it because “learning is idiosyncratic and so a common instructional format or strategies are ineffective” (p. 78). There is general agreement with the premises behind the first of these features but not with the second; the advocacy of minimal guidance is contested. Recent literature (for example Mayar, 2004, Alfieri et al., 2011, Kirschner et al., 2006), which includes extensive meta-analyses, reports that unguided or minimally guided discovery-oriented approaches have not lived up to expectations and appear to be less effective for student learning than more traditional, more ‘guided’ modes of instruction.

The uneven but generally negative evidence about the efficacy of minimally guided discovery-oriented approaches is supported by compelling arguments. In the first place, minimally guided or unguided tasks lack structure and this can be a problem for students (Mayar, 2004). They must not only self-construct the requisite knowledge but must also get their heads around the context, and structure the task in a way that facilitates appropriate self-construction of knowledge. As Alfieri et al. (2011) point out, there is no guarantee that all students will succeed in this and, even if they do, many will spend considerable amounts of time in doing so; the use of learning time is inefficient (Alfieri et al., 2011). The reason for this, and the most compelling argument against minimal guidance, is cognitive overload (Kirschner et al., 2006). As Kirschner et al. point out; the early advocates of minimal guidance did not have the benefit of the insights of modern neuroscience that has revealed the role of working memory in the construction of knowledge in long-term memory as well as the limited capacity of working memory. They therefore argue as follows.

Inquiry-based instruction requires the learner to search a problem space for problem-relevant information. All problem-based searching makes heavy demands on working memory. Furthermore, that working memory load does not contribute to the accumulation of knowledge in long-term memory because while working memory is being used to search for problem solutions, it is not available and cannot be used to learn. Indeed, it is possible to search for extended periods of time with quite minimal alterations to long-term memory. (Kirschner et al., 2006, p. 77)

The conclusion from this is that discovery-oriented learning methods should be optimally, not minimally, guided so that student engagement is maximally focused on learning and minimally focused on structuring and making sense of the task and its requirements. Marzano (2011) shares this conclusion and advocates ‘enhanced discovery learning’ that provides more extensive and appropriate guidance to students than is typical of most discovery-oriented learning approaches.

The guided discovery approach described in this paper is similar in many ways to Marzano’s enhanced discovery approach but differs in two important respects. First, it advocates not just appropriate guidance but strong guidance along with strong student support. Second, it has at its heart not a task as such but a very specific kind of task, namely a highly structured, multi-step exercise. In this respect, it diverges from most discovery-oriented approaches. The extent of the strong guidance and of the structuring of the exercise is such that it would perhaps be more accurate to describe the technique as ‘guided construction of knowledge’ rather than ‘guided discovery’. To illustrate this it will be helpful to describe in more detail the nature of the structured exercises employed in the catch-up course.

Each of the four structured exercises provided in the course were based on a careful articulation of the conceptual, procedural and contextual underpinnings of the calculation methods the students needed to master. (This articulation is much the same as that which underpins a properly structured lesson plan in traditional lecturing.) Thereafter, a realistic context was selected or designed that had the capability of illustrating all of those underpinnings. The

exercise was then developed as a series of examples and/or questions each of which illustrated, interrogated or applied one or more aspects of the calculation method and together covered all aspects. These examples were ordered in a logical and coherent manner from the more elementary to the more complex. The lecturette that preceded the exercise was then developed to provide a sufficient introduction or overview of the method's underpinnings, and the tutorial problems that followed the exercises were selected to augment and reinforce what students were expected to learn from the exercises.

The strategy behind the design of the structured exercises was that students would 'discover' essentially on their own, but assisted by appropriate guidance, support and reinforcement, each of the key conceptual, procedural and contextual aspects of the calculation method in focus. The other elements of the guided discovery technique – the mix of activities, informational input and feedback etc. – functioned to prepare, support, guide and augment the discovery learning that the structured exercises were intended to facilitate.

Conclusion

The paper has presented, explained and illustrated a guided discovery learning approach. The few negative aspects of the approach that have been identified relate to logistical rather than pedagogical issues. Both the feedback from the students who experienced an implementation of the approach and the reflections of the implementer have shown that it has a number of distinct advantages. The approach appears to be very effective in facilitating student learning of a topic they historically found difficult to master. It provides a learning environment that leads students to engage intensely with a topic in a largely self-discovery mode of learning that they find interesting and enjoyable. It enables the teacher to engage effectively with students in ways that enable him or her to not only provide appropriate and timely guidance to individuals but also to 'discover' and immediately address conceptual and practical difficulties the class as a whole may be experiencing. The methodology is not complex or very prescriptive and is a mix of components that are each relatively familiar to academic staff not versed in active learning techniques. As such, staff should not have much difficulty in implementing the approach themselves.

My conclusion from implementing this pedagogy and from student feedback is that if students are actually learning and consciously aware that they are increasing in mastery of a topic and its associated skills and practices; are working in a self-directed manner at a pace that suits them; are able to interact with peers in whatever way suits them; are enjoying the learning process; are aware that expert support and guidance is immediately available; and are confident in the teacher's ability and the organization of the course; then not only will effective learning take place but the students' capacity to stay engaged and focused for long periods will surprise them and their teachers.

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Understanding characteristics of leavers to sustain a diverse engineering talent pool in the United States: A case study

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Extended Abstract

In the United States (U.S.), Hispanics and Blacks participate in engineering education well below their representation in the population. This underrepresentation represents a critical underutilization of talent—especially as fewer U.S. citizens pursue engineering careers. Increasingly in the U.S., scholarly attention has shifted to redressing attrition in undergraduate engineering education as a viable mechanism to enhance a larger and more ethnically diverse talent pool. Attrition in undergraduate engineering education is a concern that spans across ethnic groups (Slaughter, Tao and Pearson, 2015). According to the American Society of Engineering Education (ASEE 2012), the undergraduate graduation rates are 59.7% for Whites, 44.4% for Hispanics, and 38.3%, for Blacks. Zarske et al. (2012) argue that for the U.S. to maintain its technological capability, the engineering profession will have to draw much more heavily on groups currently underrepresented in the field. To enhance and increase diversity in the engineering workforce, innovative ways must be implemented to cultivate a diverse, well-trained and globally competitive talent pool (ASEE 2014).

This exploratory study seeks to contribute to the engineering education literature on attrition by using a case study approach to examine institutional factors that may provide insight on ethnic variations in attrition (“leavers”) from the engineering pathway of a large engineering college in the U.S., Georgia Institute of Technology (Georgia Tech). For the purpose of this study, “leavers” are defined as students who did not graduate with a baccalaureate degree in engineering from Georgia Tech at specific points in time (e.g., four, five, and six years) since first enrolment. Data were derived from various student information systems for first-time freshmen for Fall cohorts 1999-2009. The study sample includes 11 cohorts and a total of 26,993 students. Data were analyzed using logistic regression.

Findings indicate that living on campus and earning high grades in “gateway” courses (calculus and physics) are positively correlated with graduating with a baccalaureate degree in engineering. Advancing our understanding of factors that contribute to ethnic variations in student attrition in undergraduate engineering education is especially important in multicultural or multiracial societies with legacies of inequality. In a global and knowledge-based economy, it is imperative for countries to draw on the talents of all citizens.

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A control systems approach to improving final year engineering students' conceptual and contextual grasp of dynamic systems

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Introduction

Well reported difficulties in engineering education throughput and retention (Fisher 2011), as well as complaints of graduate inability to 'apply knowledge' or demonstrate the necessary technical competence have led to a range of initiatives to both understand the difficulties as well as improve engineering education. The 21st century sees increasing complexity in the nature of engineering work. The UNESCO (2010) definition highlights the relationship between Science, Technology, Nature and Society. These complexities have implications for engineering educators, particularly those working with technologies and systems characterised by dynamic and exponential development, specifically control technologies. Educators have a responsibility to respond effectively to a changing technological landscape if we are to improve our graduate performance. This paper presents a curriculum review and implementation process - drawing on theoretically-informed tools from the sociology of education - designed to improve students' conceptual and contextual grasp in a process engineering qualification.

Context

The module under investigation is Process Control, presented to final-year Chemical Engineering students at a traditional university in the Western Cape, South Africa. The overall aim is to teach students how to design control systems and evaluate their performance, for single and multiple input-output systems. Such a curriculum is dependent on students' grasp of modelling and optimization concepts which have been covered in preceding modules. A major challenge is the integration and application of these concepts in a system design project.

The module has evolved over five years, and consists of traditional lectures, interactive computer-lab sessions, tutorials focussing on worked examples, and a practical laboratory session. Assessment consists of semester work (a practical report and five assignments), and two summative assessments: a mid-semester two-hour test and an end-semester three-hour test, both taken in a computer lab. From past experience, observed student difficulties include the understanding of the physical/concrete meaning of dynamic system models; the interplay between the physical system, its schematic representation, the algorithmic representation and approximated mathematical form; and insufficient skill in the use of programming languages for simulating control systems. For the lecturer, difficulties include balancing quantity versus depth; design and timing of a plantwide control design assignment; efficient use of lecturer and student assistant time; and constraints on availability of resources, such as the preferred programming language not being available to students for working at home and limited seating available in computer labs. In order to better understand and address these challenges, a project was undertaken to analyse the curriculum from a theoretically-informed perspective and adopt a new approach to the major project for the module.

Theoretical framework

Legitimation Code Theory (LCT) (Maton 2013) has emerged as a significant set of theoretically-informed tools to analysis and understand knowledge and practices. LCT Semantics has been used in a number of engineering studies (Blackie 2014; Wolff & Lockett 2013; Wolmarans 2016) and is concerned with ways of making meaning that connect abstract ideas to concrete applications so as to enable effective and ‘cumulative’ learning - learning that enables students to connect and extend concepts. Weak semantic gravity refers to a concept that transcends a particular context, and strong semantic gravity means something is dependent on a particular context. Semantic gravity (SG) offers an ideal tool to analyse levels of abstraction in engineering theory/practice. There are significant differences between the formulaic expression of a particular concept and its schematic representation or practical application. These multiple layers can be seen as representing a ‘semantic range’. A curriculum needs to embody a semantic range in such a way as to enable cumulative learning.

Methodology & Findings

The first phase of the research project involved a breakdown of the sequential curriculum, with detailed examples of different levels of abstraction. The analysis - using a specifically designed *semantics* translation device – demonstrates the semantic range of the course as a whole, and the focus for the different teaching and learning activities.

Table 1. Process control study *semantics* translation device

Level descriptors	Semantics continuum	Levels of Abstraction	Process Control examples of SG levels	Previous course structure		Revised structure
				Lectures Wk 1 - 10	Project Wk 11 - 13	Lectures & Project Week 1 - 13
Theoretical Abstract	Weak SG (Context Independent)	L1	Conservation of mass & energy principles; Control principles: measure and manipulate			
		L2	Mathematical expressions of process system (conservation of mass & energy) and control principles			
		L3	Block diagram schematic of process and control systems			
Practical Concrete	Strong SG (Context Dependent)	L4	Simulation of process and control systems			
		L5	Physical process and control systems			

A control systems approach to the analysis – where the student learning experience *system* is a mirror of *the system* they are trying to learn - led to a revised curriculum delivery structure, with theory and practice scaffolded through the major project. Data were gathered from pre-assignment questionnaires, assessments, student interviews and feedback. Results suggest:

- Students struggle with the translation of L3 to L4 abstraction: successful programmatic implementation of control system representations.
- A small group of students show better performance in L4 than L3 (successful simulation without successful control system representation). Interviews confirm that they rely on pattern recognition of previous examples, rather than conceptual understanding.
- The design project starts with L4 (simulation) as entry point, and students move up and down levels of abstraction based on assessment requirements. Feedback suggests that repeated experience and practice with the simulation (L4) have helped with the physical interpretation (L5), as well as the underlying concepts (L1 to L3). This suggests that the careful design of an entry point into the hierarchy of abstraction is vital.

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Hardwired: Facilitating engineering studies

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This paper explores the possibility that students are hardwired in the way they learn. Every year many students enrol for engineering studies and year after year too many students fail dismally in their studies. With two decades of tertiary level teaching experience this left the author with more questions than answers. How is it that with lecturers having years of experience students were still failing? Have the lecturers lost the plot or are they missing something essential? How does one assimilate new knowledge and acquire new skills? How to adopt new or change current teaching methods to facilitate learning better? The answer to these questions is proposed as the ability of a person to master new knowledge or skills in a restricted period of time. In an endeavour to understand the time model of the human brain to master and assimilate new information a study was conducted to determine some of the parameters that could possibly have an influence on the timing model. Exploring some seminal works resulted in the development of mathematical models that was implemented and the progress of students monitored. The results obtained during the study supports the proposition that students are hardwired in the way they learn.

The first insight is the concept of comparative judgment introduced by E.H. Weber (1834) and further explored and expanded by G.T. Fechner (1860) and L.L. Thurstone (1927a,b). S.S. Stevens (1957) further explored their work in 1957. The main theory states that there is a minimum perceived threshold when noticing or reacting to a stimulus. This has a twofold application: The first application is on developing measurement scales transforming ordinal scale data into rational scale data when measuring student performance other than a mere "pass" mark; The second application deals with the depth of detail that students are able to deal with when confronted with new material.

The second insight is revisiting the way new knowledge or skills are introduced. The Guttman (1947a,b) scale is constructed in such a manner as to accept that each new measure on the scale presupposes all the measures below it i.e. if one can add 5 digit numbers, one can also add 1 and 2 digit numbers. The application of this pertains to the order in which material or skills are to be presented to students. This is presented for the sake of completeness as it is the backbone of the Rope-Weaver's Principles, a set of guidelines for lecturers, curriculum developers and even students to assist in understanding the processes of learning.

The final piece in the puzzle was the works of Dreyfus (1980), Kruger and Dunning (1999), Burch (1970) and others on the way humans learn as opposed to animals or machines. A thorough understanding of the knowledge and skill acquiring process pertains to the timing and exposure period to the new materials or skills, i.e. one simply does not know that which one does not know. This has secondary application related to the method of delivery.

From the mathematical foundation found in the works discussed above a failure model was developed and data collected of student progress using the implemented model in the field of software development. The mathematical model and data not shown here due to the length

restriction of the extended abstract. The following principles for the Rope-Weaver's Model were derived from the failure model and data collected.

The First principle assumes that each new level of mastery encompasses all the ones that it relies on. This is in line with the Guttman scale as discussed above. In this model the simple-rule based or novice levels lie in the centre and the more advance maxim or expert levels on the outer levels. This can be paralleled to the weaving of a rope. Each layer building on the ones below to build the strength of the overall rope.

The Second principle is to postpone the introduction of a new topic until all students or "most" at least have entered into the Intermediate level of mastery of the current topic. The rationale behind this is born from the work of Johnson-Laird et al (1980). If the step between the new topic and the mastered topics is too great, the challenge to recognize, understand or master the fundamental knowledge or skills is masked by the impulse stimulus generated by the introduction of the material itself. It is a neurological issue that also manifests in other situations e.g. the so called "blank" experienced by students during tests from the resulting overload by the stimulus that even masks all the "easy" material that is mastered.

The Third principle is to break down the work to be mastered during a course into small enough steps. The rationale is to support shorter intervals between the introduction of new materials or skills. Furthermore closely related topics are presented in short succession so as to keep the apparent gap between topics introduced as small as possible. Some of these sub-topics are not interdependent and may be reordered as proposed in the Fourth principle.

Fourth principle is the "parallel" or "staggered" introduction of non-dependent materials or skills. The rationale here is as a prior topic's mastery is being matured a new unrelated topic may be introduced. It was found during the study that unrelated topics may be introduced in parallel without any negative effects on the other. The mastery of these unrelated topics can now mature at the same time.

The Fifth and final principle is the process of facilitating the transcendence from ignorance to intermediate level. During the initial phase the novice needs to be couched as the novice operates optimally using a set-of-rules based learning. This means that the rules need to be drilled until they become mastered to the point of second nature. The second phase, transcending from novice to intermediate level, is concerned with the introduction of maxims. The boundaries of the rules need to be enlightened or exposed. As the students progress in this phase they will enter into the state of self motivation. They will start to explore on their own. This is the transcendence into the expert level. This is our goal.

These principles are similar to rope's structure. The different strands or fibres, fundamental concepts, are spun together into threads. The strands and fibres are the basic building blocks that constitutes a topic. Some are dependent and others are independent. They are all just loose ideas until spun together into a thread or topic. Different threads are woven into yarns. Yarns constitute the broader study themes. The yarns are finally woven into the final rope structure. The rope structure is akin to subjects or fields of study.

A study based on the implementation of the principles discussed above revealed a "toe" or plateau near the infancy of the learning curve. A new equation is introduced accounting for the various sections that the curve is divided into:

$$\Pr(x) = \alpha(1 - e^{-\beta x}) + (1 - \alpha)(1 - e^{-\eta(e^{\gamma x} - 1)}) \text{ with } 0 < \alpha, \beta, \gamma, \eta < 1$$

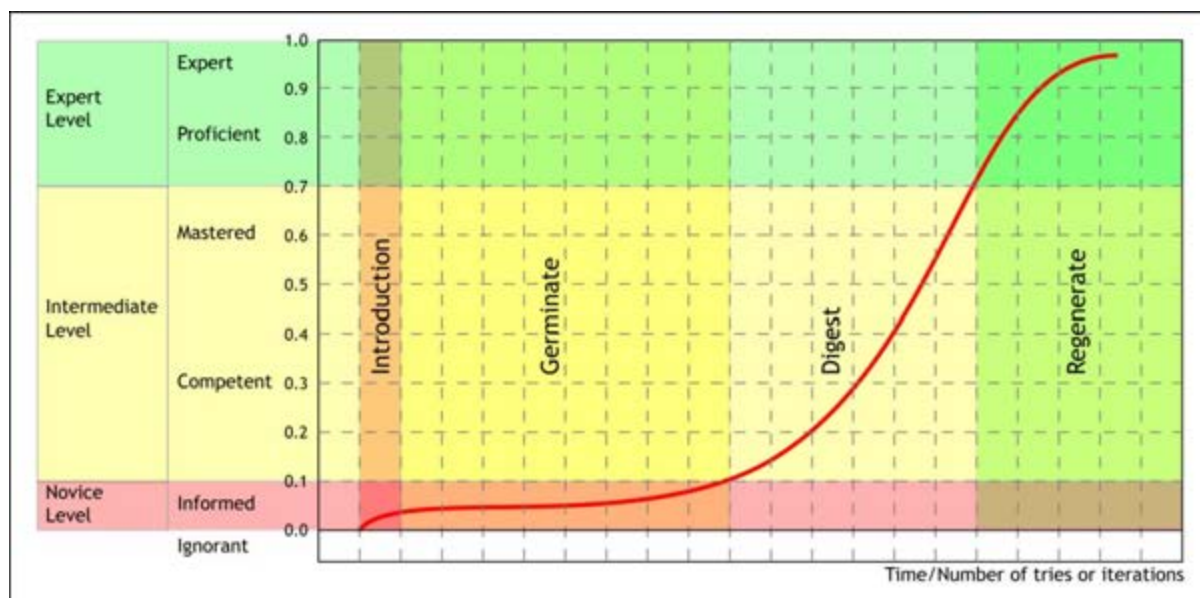


Figure 1. Annotated learning curve.

In conclusion the implemented Rope-Weaver's model not only improved the pass rate but also resulted in the improved knowledge and skills of the students in a course on software development as well as their attitude towards study in general. The Rope-Weaver's model was used in the development of the curriculum of the B.Eng.Tech. degree.

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Investigating trends in the South African output of graduate engineers

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Since at least the early 1990s concerns have been raised about whether South Africa is producing sufficient engineering graduates to fill the roles in industry that are assumed to be required to facilitate economic growth (see, for example, Du Toit & Roodt, 2009; Lawless, 2005). Preliminary evidence, however, suggests that South Africa has in fact doubled its output of four-year bachelors engineers over the last decade or so. At the same time, the national school system has changed to a different final exam, the NSC in 2008. This it appears has increased the number of eligible candidates for engineering studies.

This talk will present up to date data both on the production of engineering graduates as well as the size of the pool of eligible students (based on admission requirements), tracking data from the early 2000s into the present, and thus allowing for a comparison of trends since the introduction of the new National Senior Certificate. The analysis, using published throughput data, offers a rough modelling of the current state of the system by which engineering graduates are produced in South Africa. This analysis focuses on the four year bachelor's qualification where the data allow for fairly tight estimates of this sort, but recognises that similar work should be conducted in future on the engineering qualifications offered by the universities of technology.

This study finds that actually a significantly large proportion of eligible students do in fact enter engineering studies, in line with the findings by Sjoberg and Schreiner (2015) showing the interest of young people towards STEM careers in developing countries. The findings will also be discussed in the context of labour market trends and possible future patterns for employment.

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An analysis of engineering graduate destinations using LinkedIn

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The issue of what graduates do after they leave university, often captured under the topic of ‘graduate destinations’ is a matter of increasing interest and concern in society, especially in contexts of expanded participation in higher education, concern over availability of suitable jobs, and broader societal interests on the purposes of higher education (see, for example, Brown, Lauder, & Ashton, 2010). This is no less so for professional degrees like engineering, where the issue of employment after graduation might seem more straightforward. Surveys of graduate destinations typically suffer from relatively low response rates (Cape Higher Education Consortium, 2013) and therefore this study sought to develop a new methodology for tracking graduate destinations using LinkedIn. Research in this area with engineering graduates has also been limited, and thus this study, focusing on chemical engineering graduates from the University of Cape Town, brings new insights to a debate often characterised by untested assumptions. Following the graduating cohorts from 2003 to 2012 it was shown that about a fifth go on to postgraduate studies. Of those that proceed to the workplace, the vast majority go into traditional graduate chemical engineering jobs in operations, mostly in the petrochemical and mining sectors in this South African context. The study also sought to determine the potential impact of the 2008 recession on these graduate destinations but the results are inconclusive in that regard.

The significant contribution of the present study therefore is in demonstrating the potential value of a relatively straightforward method for tracking graduate destinations, by accessing the data that graduates increasingly make available publicly on a platform such as LinkedIn. This study therefore does not require consent of those involved (data is only reported anonymously) nor does it require responses to a survey, which are notoriously challenging for institutions aiming to track graduates. We have shown that the vast majority of recently graduating classes in this programme do in fact put their information out on LinkedIn, and a relatively straightforward qualitative coding method allowed us to convert this to quantifiable data. We have worked on the assumption that complete LinkedIn profiles (we discarded any that were incomplete) are sufficiently accurate for this research.

The methodology is therefore promising for further work across other disciplines and in other national contexts. It also carries the potential for investigating employment trajectories after the first job, and will allow for some disaggregation across social categories like race and gender that have been of concern in the engineering profession.

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Constructive alignment in an introduction to engineering course: Walking the talk

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Many students continue to enter mechanical engineering degree programmes having had little or no exposure to artefacts, systems, or processes typically associated with developing a tactile understanding of what the discipline entails. Furthermore, the transition from a school to university environment remains a difficult one for students – particularly those from under-resourced schooling and less privileged social backgrounds. Our experience suggests that students more than ever need focussed interventions to help ensure that they are successful in their undergraduate studies. Introductory courses in engineering have been found to play an increasingly important role in this regard. These courses provide opportunities for interventions to engage with more than engineering sciences to address aspects such as, 1) developing the ability to communicate effectively as a critical requirement for both success in their studies as well as when they begin their careers as engineers, and 2) to recognise is that society has been shifting increasingly towards the recognition that all activities should focus on the sustainability of the world in which we live, and 3) developing an ethical approach to engineering as a core competency. Consequently, mechanical engineering students must understand the impact of the engineering activity in a global, economic, environmental, and societal context., Thus, a traditional approach adopted by introductory engineering courses of focussing almost exclusively on engineering science is no longer appropriate.

In developing the introduction in engineering course, the three lecturers of the course (the authors of this paper) focussed on carefully integrating this broad range of critical knowledge, skills, values, and attitudes so that the students would experience the course as a coherent, integrated whole. However, after having run the course for two years, it was apparent that the students were not experiencing the course in the integrated way we had envisaged. A review of the literature suggested that it was not enough to simply ensure that the content of the course itself was coherent and well-integrated, but that the course objectives, the activities in the course, as well as the assessment should also be very clearly aligned.

This paper describes what it means to effectively align a course in this way by drawing on the notion of constructive alignment as developed by Biggs (2014).

Constructive alignment acknowledges that learning is a process of constructivism, in that individuals make sense of or construe meaning from the learning events that they are given the opportunity to interact with. Here, the learning outcomes, learning activities in the class, as well as the assessment are all designed to directly relate to one another.

Constructive alignment is a design for teaching in which what it is intended students should learn, and how they should express their learning, is clearly stated before teaching takes place. Teaching is then designed to engage students in learning activities that optimise their chances of achieving those outcomes, and assessment tasks are designed to enable clear judgments as to how well those outcomes have been attained. (Biggs, 2014, p. 5-6).

Our course provides first year students with a broad introduction to the discourse of mechanical engineering in a contemporary world through a variety of activities culminating in a group

design competition. Throughout the course, students engage with classical mechanical engineering concepts, participate in experiential activities, and locate what they are learning using case studies. Drawing on this understanding of what the course was about, the resultant objectives are as follows; note the verbs that begin each objective statement:

The objectives of the course are to:

- Highlight the role of mathematics and science in engineering;
- Develop academic literacies in reading, writing, and oral presentations;
- Develop groupwork skills;
- Provide hands-on experience in engineering activities and projects;
- Emphasize the impact of the engineering activity;
- Provide an awareness of professional ethics; and
- Appreciate the multiple experiences and perspectives on the way we frame problems and negotiate solutions to them.

The underpinning philosophy of constructive alignment is that learning objectives, course activities, as well as assessment must align. Drawing on the course outcomes, the learning objectives for the course were collaboratively developed by the authors and a language expert with a background in science education and academic literacies.

We drew on the work of Anderson and Krathwohl (2001) who had reworked Blooms taxonomy in the context of cognitive process and knowledge dimensions (see Figure 1). The cognitive process dimension of this reworked taxonomy is represented by a continuum of increasing cognitive complexity, i.e. ranging from thinking skills such as “remembering” or “recall” that are considered less cognitively complex to those such as “evaluating” and “creating” that are considered more cognitively complex.



Figure 1. Blooms Taxonomy (derived from Anderson and Krathwol, 2001)

The knowledge dimension classifies four types of knowledge ranging from concrete to abstract forms. These four types of knowledge are *factual*, *conceptual*, *procedural* and *metacognitive* (knowledge of one's own cognition or approach to learning).

The learning outcomes that emerged are as follows. Note that the learning objectives are written as statements, after Anderson and Krathwohl (2001), that incorporate the intended cognitive process (as a verb) and the knowledge (as the object) that the students are expected to interpret in a particular way (see Figure 1).

To be successful in this course, students will be able to:

1. Understand the interrelationships between the natural and pure sciences and engineering;
2. Identify, evaluate and acknowledge appropriate sources of information;
3. Understand and analyse text;
4. Create coherent written reports and oral presentations in the framing and solution of engineering problems;
5. Begin to safely apply the techniques, skills, engineering tools and procedures necessary for contemporary and future engineering practice;
6. Evaluate own and others' contribution to the execution of course activities in a group;
7. Understand and critically evaluate the impact of the engineering activity in an economic, environmental and societal context – both locally and globally; and
8. Understand and apply the professional code of ethics to evaluate aspects of engineering practice.

The learning activities designed to align with the learning objectives described above take the form of lectures, tutorials, interactive group work, independent learning and practical work. Both facilitated class based activities and independent non-contact activities are included.

The primary forms of assessment for the course are two class tests, the final exam, two team reports and practical reports, although there are also formative assessment activities such as a reflection exercise. Table 1 indicates the alignment of different assignment tasks with course objectives. The learning objectives shown in the table as 1 through 8 refer to the list above.

Multiple sources of data were drawn upon to illustrate the theory-in-action; these include student reports, focus group interviews, lecture and tutorial material, and reflective diaries of academic staff. In this paper, the ethics module presented in the course is used as a case study for illustrating and retrospectively reflecting on the extent to which the theory is applied by practitioners. The objectives of this module were determined during the planning phase, and were communicated to the students at the start of each lecture. Teaching and learning activities focusing directly on ethics were conducted in three lectures and a tutorial session. In addition, regular meetings took place between the lecturers on the course to support the core teaching and learning activities. These included module planning, material preparation and tutor training. The preliminary findings indicate that while the constructive alignment framework is used to design a coherent experience for the student, more can be done to provide a tighter link between the desired objectives, planned activities and eventual outcomes. Interventions could focus on clearer communication of objectives and desired outcomes, improved assessment, and better articulation between material in this module and the rest of the course.

Table 1. Planned alignment of assessment with course objectives.

	Assessment											
Learning outcomes	Class test 1	Class test 2	Class Test 3	Team Project Village energy	Team Project Design steam car	Reflection exercise	Practical work (Afternoon sessions)					Exam
							1	2	3	4	5	√
1	√	√	√									
2				√	√		√					
3					√		√					
4				√	√							
5							√	√	√	√	√	√
6				√	√	√						
7				√			√					
8	√											√

Given the diverse experiences of student participants in the class, some course objectives are met from experiences gained prior to participating on the course. Nevertheless, it is crucial that learning experiences are designed and implemented in a manner that provides the student with the best possible opportunity of meeting the desired outcomes. This is especially important given the diversity of students' backgrounds, and the overarching aims of the course.

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Enriching engineering student experiences of final year projects through gamification and authentic learning

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Background

For students registered for the BEng: Electrical and Electronic Engineering degree, UJ requires the student to complete a full academic year project in their final year to show that they can integrate the knowledge they have gained throughout their studies. The current process requires the creation of suitable project outlines by study leaders which are then manually assigned by the course coordinator. Previously this process has been problematic with the main points of contention raised through interaction with the department and students being: (i) A lack of input taken from students on project allocation, (ii) A lack of transparency of the process used to assign projects, and (iii) A less than optimal final assignment due to the manual process used. Using as inspiration work done at UCT (O'Donovan, Gain, & Marais, 2013) a gamified approach to addressing the problem was proposed.

Research Design and Methodology

As the goal of the study is both to validate further the use of gamified academic interventions in the engineering education context, as well as to create an applicable artefact for solving the problem, a design research, and more specifically developmental research (Akker, Plomp, & Nieveen, 2013) approach is followed as shown in Figure 1.

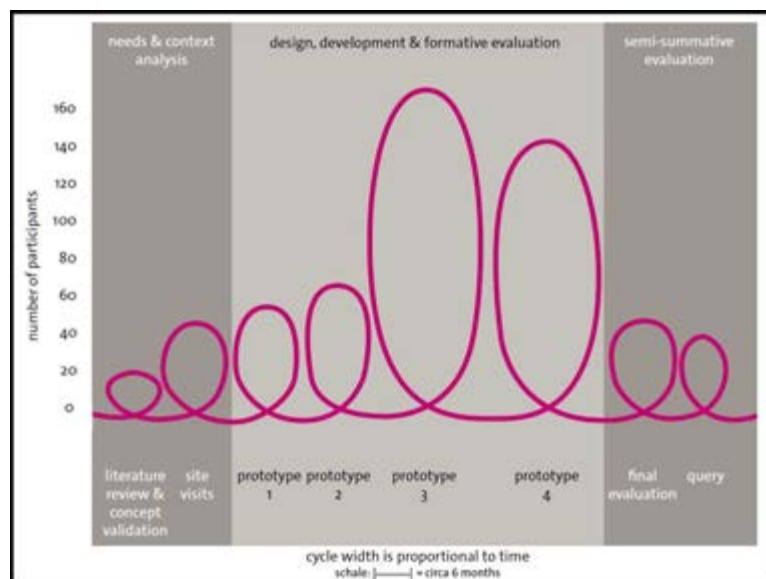


Figure 1: Phases of a developmental research study from (McKenney & Akker, 2005)

The initial phase of the work involved a literature review, needs analysis, as well as a number of workshops with stakeholders to map out the course of the development.

Prototype Design and Development

The design principle of the system can be conceptualised as follows: Entering into their fourth year of studies, the engineering student is still in a mindset of being a **student**. When they are assigned their first project, the **student** now takes on the cloak of a **journeyman**. This is the first time they are expected to take on the guise of an engineer and apply their knowledge holistically. Once they have completed their **journeyman** phase, the student takes their penultimate step (before graduation) to fulfilling all of the requirements of a **candidate** engineer. These roles may not be universally applicable, but were deemed relevant within the context of this study.

The first prototype design was done in 2016 using a web based portal hosting a location based game and field trailed during the 2016 project presentation day. Feedback was obtained via interviews with study leaders and students as well as via an anonymous online questionnaire. Following this field trial, the decision was taken to expand the project for the 2017 academic year to include an authentic learning approach based game and to expand on the challenges that could be undertaken by the student. The same web based portal was used as the platform the system would be run on, and the second prototype was expanded from the previous design to now comprise of the following elements:

The Tender game: An authentic learning based game where students initially fill the role of an external party submitting a tender to solve one of the engineering problems presented in the projects list. In the second stage they take on the role of a tender committee member to use their engineering knowledge to select the best tender presented to solve each of the engineering problems. (Implemented in 2017).

Challenge based skills tests: Following on from the concepts put forth by (McGonigal, 2015) a challenge based section was added where students could test their skills in a number of the study areas' projects. Their success in these challenges could increase the strength of their tenders being evaluated in the tender selection stage. (Implemented in 2017)

Location based game: The location based game uses QR codes and the university campus as the game world. Players move between project presentations and "check in" at goals (presentations) by scanning and interacting with presenters. The game is competitive and at the end of the day the players are awarded with prizes. (As developed and first implemented in 2016).

Games are presented to students as shown in Figure 2:

Course Structure and deadlines						
Setup	Project selection		work	mock seminar	work	project day
	Tendering	Tender Voting				
Study Area Challenges	Tender Game			Location Based Game		Location Based Game
COURSE OPENS 09 FEB 2017	TENDERS CLOSE 24 FEB 2017	PROJECT ALLOCATION 09 MAR 2017		PRESENTATION DAY MAY 2017 (estimated)		PRESENTATION DAY NOV 2017 (estimated)
Student Phase			Journeyman Phase			Candidate Phase

Figure 2: Course Structure, roles and game presentations

Votes collected during the tender game were used to determine the preference of projects for

students as input into the Gayle-Shapely algorithm to help determine optimal project allocation.

The feedback from the class of 2016 (and study leaders) was very positive and after updating the portal by incorporating lessons learned from the 2016 academic year, the 2017 class of students were given the opportunity to register and partake in the process from February 2017 (participation is voluntary). So far, the 2017 class has had an adoption rate of 100% on the side of the study leaders (all projects were captured and assigned to study leaders well before the due dates as well), and within 3 days of the portal being made available, 90 of the 99 students had already registered to participate.

The third prototype development is in progress and field trial results will be published in a subsequent paper. This project is being undertaken as part of the doctoral studies of Mr. J.J. Greeff.

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Learning in practice: Developing ethical judgement in engineering students through facilitating student reflection on work experience

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Ethical judgement involves the ability to make an informed decision based on value choices in a situation that is complex. It is more than being a practical or strategic or professional decision and critically involves juggling the interests of different stakeholders. Within the profession of engineering, the Engineering Council of South Africa's (ECSA) Code of Conduct provides the formal parameters for ethical conduct (ECSA 2017). On one level, the Code prescribes conduct that requires compliance rather than understanding. At another level, the code requires the application of judgment and discretion in order to uphold the key objectives. The balancing of these two aspects is central to developing a professional and ethical identity.

Framing the challenge of ethical judgement within the engineering student's experience is key to engaging the student as a fellow co-practitioner of ethics within the community of engineers. This allows the student to view themselves as a significant co-contributor to the integrity of the profession rather than a consumer or recipient of externally constituted values. This perspective sees the students' experience within the university as vitally connected to the practice of the profession within industry where learning is enhanced through engagement.

The interface of the university and the wider society is where engaged scholarship takes place: developing understanding of what it is to be a professional through reflective critical engagement with the professional environment. The University of Cape Town's Strategic Plan (2016-2020) defines engaged scholarship as the "utilisation of an academic's scholarly and/or professional expertise, with an **intentional public purpose or benefit** (which) demonstrates engagement with *external (non-academic) constituencies*" (emphasis per original). Engaged scholarship results in the generation of new knowledge, the integration of knowledge, the application of knowledge and the effective dissemination of that knowledge (UCT Strategic Plan 2016 footnote 1 pg 1).

Within the engineering curriculum for student engineers, developing ethical judgement falls under Exit Level Outcome 10, Engineering Professionalism (ECSA 2012). After registration as an engineer, Outcomes 8, 9 and 10 of the Competency Standard for Registration as a Professional Engineer (ECSA 2014, Group D) require an engineer to act ethically, exercise judgement and take responsibility. Developing opportunities to connect undergraduate competences to professional work experience can be seen as of key importance in developing professional judgement.

Work experience can be seen to be a key intersection of the university with industry. Scholarly and critical engagement with work experience can thus be anticipated to generate new knowledge and to provide opportunities for disseminating knowledge through the relationships established and built up with the host companies.

A key concern of employers is that graduate students are not sufficiently prepared for the world of work. Work experience provides this bridge. At present, the number of hours are stipulated by the university, without any formal requirement to measure what the student has gained from this process (Jawitz 2005:134).

This paper explores opportunities for engineering students to develop ethical judgement from critical reflection on ethical issues arising within professional work experience. In particular, it examines possibilities for ethical reflection and action that emerge where fourth year electrical and chemical engineering students at the University of Cape Town were required to reflect on their work experience and to identify and critically engage with an issue they experienced relating to a conflict of interest. The students assess their choice of action against the requirements of the Engineering Council of South Africa's (ECSA) Code of Conduct and reflect on possible alternatives. The students' work is profiled to show how they engage with the challenges of the work place and the requirements of a professional engineer as regards decision-making and action.

The ECSA Code of Conduct requires engineers to act in a way that reflects positively on the engineering profession (ECSA 2017:3(5)a) and avoids real or possible conflicts of interest (see ECSA 2017:3(2)f). Real or potential conflict of interest is a practical issue, with both direct and indirect consequences in the wider business environment, that engineers need to consider when making decisions or deciding on a course of action (Companies Act 2009: section 75-77). Conflicts of interest inevitably present themselves to qualified professional engineers in their day to day practice and need to be anticipated so that appropriate decisions and action can be taken.

The results of this investigation show that the curriculum for prospective engineers needs to anticipate and provide a space for students to develop:

- skills to recognise potential conflicts of interest
- confidence in their ability to identify alternative options
- willingness to subject personal action to scrutiny and the
- desire or inclination to choose to act ethically.

For the student learning what it is to be an ethical professional, work experience can be of key importance to the development of ethical reasoning skills and ethical judgement as it provides the opportunity to apply a range of skills within the professional environment. This paper seeks to propose concrete ways in which learning opportunities can be extended.

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Crib sheets: Can we learn from them?

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Introduction

Our students are failing. It is important to understand why students fail and how their ability to learn and gain a deeper understanding of key concepts can be improved.

Students are often given the option to bring their own crib sheet into formal assessments such as exams and tests. Students can become quite industrious at compiling these sheets, using small writing and including volumes of material such as theory and worked examples.

While there is debate amongst academics whether or not the crib sheet is a good tool to promote learning, we are interested in understanding what can be learnt from the information that students put on these sheets.

Assessment frequently defines what students perceive as their curriculum (Ramsden, 1979). Formal assessment, in particular, sends very powerful messages to students about what is being valued within their learning context, resulting in what is called ‘the backwash effect’ (Biggs and Tang, 2011). Sambell and McDowell (1998) refer to this phenomenon as the *hidden curriculum*.

Literature review

There remains much debate regarding whether or not the use and construction of student-constructed crib sheets results in improved student performance. Studies on the topic include surveys, interviews, focus groups and analysis of crib sheets to understand the effect of crib sheets on assessment results, retention of information and anxiety levels. Some studies have noticed differences in the way that students construct crib sheets and have tried to link these differences to student performance. Erbe (2007) measured crib sheets by the volume of information that they contain. De Raadt (2012) developed a method of coding crib sheets in a computing course. The coding considered layout and content (including the use of coding examples, abstract representations and sample answers). It was found that students who included coding examples and sample answers performed worse and those who included abstract representations performed better. Visco et al. (2007) conducted a small sample of qualitative interviews on an engineering course but did not find a relationship between the ‘quality’ of a crib sheet and student performance.

The link between the nature of crib sheets and the learning practices of students is particularly interesting and potentially very revealing to a teacher. Various ways of characterising these learning practices have been developed (for example, Woollacott, 2014). Different ways in which students approach learning have been identified – the distinction between deep and surface approaches (Marton and Saljo, 1984), and between deep procedural and surface procedural approaches (Case & Marshall, 2004). However, no research has been

undertaken that looks specifically at detailed coding of the content of crib sheets in relation to indicators of students' learning practices.

The study

The study being undertaken is a work in progress. Its objective is to develop a framework to analyse the content of crib sheets used by engineering students and relate this content to indicators of students' learning practices and/or approaches. The context of the study is the School of Mechanical, Industrial and Aeronautical Engineering at Wits.

The framework that is being developed considers crib sheet content and the way it is presented, for example: mind maps, tables, diagrams, worked examples, formulas, interpretations, key points and notes copied verbatim from course material. An evaluation of the extent to which students are believed to have gained a deep understanding of course concepts is included.

The framework is being developed from an analysis of two sets of crib sheets. One set is from a third year final examination in Operations Management (n=27) which requires a high degree of application of concepts from students. The second set is from a second year test in Thermodynamics (n=262), a course requiring a deep understanding of key concepts although the level of application required from students is more procedural in nature. The approaches used is expected to differ for these courses, as a result of course design and because third year students have more experience than second years in determining what is 'expected' in assessments. Planned future work includes a student survey and interviews to obtain more in depth insight.

Preliminary results indicate a variety of content and structure in crib sheets. The nature of the content can give an indication of student engagement with course material. The structure and volume of content are seen as much less important than the information that students choose to place on their crib sheet. Understanding can be inferred by the mindfulness used in the creation of the sheet (including selected information over all information). This could indicate a deeper approach to learning.

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Codebreakers: Designing and developing a game for telecommunication engineering students

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Background

This paper contains the details of the design and development of a game for the module Telecommunications for fourth year Electrical and Electronic Engineering students at the University of Johannesburg. The goal of the game is to assist students in preparing for tests in a fun way. The main advantage of the game is that questions are generated randomly and students can thus play a number of times with different questions each time. Students also get immediate feedback.

During teaching evaluations, some students felt that more example questions and answers would be beneficial, however giving additional assignments only add to their already full schedules. Giving more worked out example questions results in most students studying the memorandum, without attempting the questions first on their own. A method was thus deemed necessary to give students additional exercises, without adding too much additional stress while providing immediate feedback without supplying memorandums.

The use of serious games has been successfully used in various study areas in the South African context. A serious game developed to teach students statistics was designed in (Leendertz, Lizanne, & Martin, 2015). A game was also successfully used as part of a game design course in (O'Donovan, Gain, & Marais, 2013).

Design and development

The module Telecommunications is a good candidate for testing the idea of using a serious game in Electrical Engineering, since the syllabus lends itself well to incorporation into a game. The content of the module focuses on encoding and decoding algorithms, which includes amongst others Markov modelling, Shannon-Fano coding, Huffman coding and Hamming coding.

An online computer game has been developed using a developmental research approach (Akker, Plomp, & Nieveen, 2013) and (Richey & Klein, 2005). Students solve puzzles and challenges to advance in the game. The quests and challenges are based on the theory covered in the module. Student participation and interactions are logged to determine the success of the game.

The game is specifically designed for the fourth-year Telecommunications module and addresses the following requirements:

- Free movement. The challenges or quests in each section correspond to a specific part of the work and it is possible to only target a specific section of the work before a test via the game.

- The challenges and quests are different in each section to keep the game interesting.
- The game should be optional. Students will have the option to either do an assignment or play the game.
- The challenges and quests should be randomised so that students can repeatedly play the game to improve their skills.
- Students' efforts are tracked. Personal score boards and overall leader boards are used to motivate students.

The game, named Codebreakers, starts with the student walking through a castle and then being trapped in a prison cell. The villain, Dr. H, Master of Codes, informs them that they need to travel the world and break all the codes before they will be set free. In the prison cell, you have three doors, leading to three different game areas:

1. The Markov Maze is the first game area. Students need to find their way through a maze and diffuse bombs blocking the road. The bombs are diffused if you can correctly calculate the probability of occurrence of a specific message based on the given Markov Model.

2. The second door leads to two different sections, each testing a different source coding scheme. The first path leads to the Fano Forest. Students need to navigate through the forest by following the direction boards. However, the direction boards are in binary and the instructions are given in symbols. Students need to convert the symbols to binary codewords to determine the correct path to follow.

The second path leads to the Huffman Holes. Students need to determine the correct answer to a specific question and jump in the correct hole.

3. Lastly, students enter the Hamming Hills. Students are trapped in a cell in the hills and need to flip switches to on and off positions, based on the Hamming encoding scheme. A correct combination of on/off switches will open a door and you can proceed to the next area.

The game areas are quite different and will enable us to test which type of environment is more successful. An example of game areas from the game is given in Figure 1.

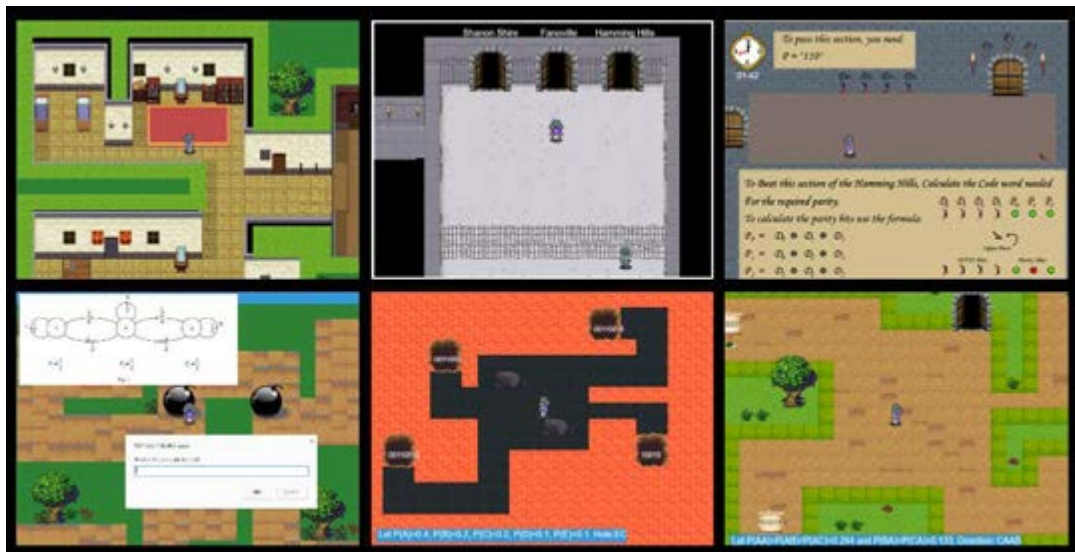


Figure 1. Different game areas

The game is funded by the University of Johannesburg's Teaching and Innovation fund, although most people involved volunteered to be part of the project without payment. The team consisted of two undergraduate students, two postgraduate students, a graphic design student, the lecturer and a volunteer from industry. The game will be played for the first time during the first semester of 2017. An initial poll showed that the majority of the students enrolled in the 2017 course will be interested in playing the game.

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About an online lecture set up using Microsoft presentation software and text to speech application

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Online lecturing has been under consideration for quite a few years (Bourne et al, 2005), and could make education more efficient given the financial constraints of the South African Higher Education context. The Massachusetts Institute for Technology is well-known for providing recorded lectures online (e.g. Lauffenburger, 2006). Many lecturers may not be comfortable being recorded. In addition, once the video is recorded, it will be difficult to include more or remove material (e.g. spoken words) while still ending up with a seamless product. This work strives to overcome such issues by using TTS (text to speech). Feedback from students is obtained, e.g. as in previous studies for conventional video recorded lectures (e.g. see McKellar & Maharg, 2005), in order to assess how students would respond to lectures being online with TTS instead of face-to-face.

Using text to speech software and include it in a video is not new (e.g. Salvor, 2016). He suggests that audio files can be created by a text to speech application, and included in a video using VLC media player software.

In this work, the text to be converted to speech was typed in the notes section of a PowerPoint slide. This is to keep a record of the text attached to the slide. The SAPI5 TTSAApp (which can be downloaded for free) was then used to convert this text to an audio file, which was then inserted in the PowerPoint slide. The audio button (loudspeaker) was moved to an appropriate position, for example next to the section of the slide that the audio refers to. The audio was set up to start automatically at the appropriate position in the animation pane timeline. Microsoft Anna (Windows 7) audio was used for the first half of the lecture, and the upgraded Microsoft David (Windows 10) was used for the rest. The animations in the timeline, which were expanded to simulate what would happen during a lecture, were set up to start after the previous animations from the moment the slide was activated. It took the author about 5 days to set this up, trying also to include everything that would normally be said in a lecture. The 30MB 22 slide PowerPoint presentation was then saved as a 220MB MP4 video file, which was uploaded to YouTube, see Huberts, 2017. The two-hour lecture ended up being about half an hour of video. On reflection, the reduced time could be explained by the time available to set up text to convey information clearly and concisely.

Text accompanying the presentation can be modified, either by the author or by other collaborating lecturers, audio files can be changed and re-inserted to replace the old audio on the PowerPoint presentation. Slides can be added or removed, and the video can be re-created in an updated form. The video can be used in following years, and help bringing new lecturers up to speed. The PowerPoint presentation was also made available to students, allowing them to read the text converted to audio in the notes section, or click on the loudspeaker button close to sections of the slide they wanted more information on, thereby triggering the corresponding audio file.

The video lecture concerning heat and mass transfer was presented to 45 out of 62 fourth year BTech students in a normal lecture hall (they were requested to bring their laptops or pads) in the presence of a tutor. After viewing the online lecture, students were asked to score the video online as “10” if it was as good (or as bad) as a normal lecture, or “20” if it was twice as good. Scores between 3 and 20 were awarded by 49 student respondents (some not watching the video in the hall), with an average of 11.6, indicating that the online lecture was judged to be slightly better than a normal lecture on average.

45 students responded to a request to supply online feedback about the video. The biggest aspect raised was the beneficial replaying of the video. Quite a few felt that the lecture was as good as, or better than, a normal lecture. A few students struggled with the sound quality, although one of the students said that David sounded much better than Anna. Other matters raised were that the video could be (re)played anywhere, that there was no opportunity for questions, and that the personal touch of a lecturer was missed. Some interaction with the lecturer seems to be advisable to alleviate some of the concerns raised.

In a test on the online lecture matter, students fared much the same in a question which was repeated from an earlier year. Also, 22% recalled information conveyed during audio and accompanying animation on one of the slides. The author imagines this percentage would have been lower if the students just heard it once in a lecture.

It seems to be possible to substitute a heat and mass transfer lecture at the author’s university with an online lecture without prejudicing students on average. On reflection, the author recommends that a whole course be presented online, with student performance compared to previous years with normal lectures, to support this conclusion. In the author’s opinion, online lectures could be continuously improved, free up time for research or extra teaching, and open up opportunities for collaboration.

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A micro analysis comparing outcomes between extended and core curriculum students in subjects across an engineering faculty

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This study situates its research focus in the South African Higher Education context as outlined in the DHET's New Directions report on the flexible curriculum (Shay, et al. (2016), as part of the debate about the flexible curriculum and its intended impact on the retention and throughput of students. While our research is ongoing, to date our study attempts to answer one main question:

How are the extended students performing against the mainstream (core) students, not only at the funded extended first year but also at the higher, core curriculum levels?

We analysed the final results of all the subjects offered at the diploma level of all departments which offered an extended curriculum programme, in the engineering faculty of CPUT for the 2015 academic year. The data of six engineering departments is captured for analysis as a result. This is the subject of this study.

We made use of statistical methods (especially the Chi Square Test) to interrogate the data captured on our institutional system, and broke it down into mainstream and extended at every subject level. The results show that in some cases, statistically, the differences in performance between the two groups could be attributed to chance, but in others these differences were significant. It is the latter group which suggest that further research is needed at that micro level.

We also found that the results per subject from both the core and extended programme either performed equally well at the epistemic level or failed equally badly, highlighting Case's (2011) observations that one needs to look at more than the curriculum to explain the common threads and anomalies.

We indicate the purpose of ongoing research in which participants whom the data refer to are selectively engaged to conduct in-course research as part of a collective effort to interrogate the results and make further predictions.

Introduction

In the recently released report on the Extended Curriculum Programmes, commissioned by DHET and spearheaded by Shay, the aims of their study were given as follows:

understanding the strengths, limitations and overall effectiveness of the current extended (EXT) curriculum programmes, and what reform is required to strengthen the contribution of these programmes to systemic reform (Shay, S., Wolff, K., & Clarence-Fincham, J. (2016, p. 2).

This study situates its research focus in the South African Higher Education context as outlined in the DHET's New Directions report on the flexible curriculum (Shay, et al. (2016), as part of the debate about the flexible curriculum and its intended impact on the retention and throughput of students. In particular, given that the success rates of all students at tertiary level is low (HESA, 2011) While our research is ongoing, to date our study attempts to answer one main question:

How are the extended students performing against the mainstream (core) students, not

only at the funded extended first year but also at the higher, core curriculum levels?

Our study uses quantitative methods, so done in order to prepare the ground for further qualitative based research into the questions raised in the debates on extended and flexible curricula. By focussing on whole subjects across the two streams, extended and core, we add to this list of Shay, et al. We do raise questions about the effectiveness or otherwise of courses beyond the foundation year in which extended and core students face off, thereby posing yet further questions, about the curriculum, pedagogy and so on.

Methodology

In this study we analysed the final results of all the subjects offered at the diploma level of all departments which offered an extended curriculum programme, in the engineering faculty of CPUT for the 2015 academic year. The data of six engineering departments is captured for analysis as a result. The use of such data fall into the category of 'routine data', that is, data which is captured systemically and are easily available, they capture large numbers of candidates and they can be used cyclically as they contain rich sources of information. But as Powell, Davies and Thomson (2003) indicate, their use is also potentially fraught with pitfalls.

We used a quantitative research methodology and the null hypothesis is: the differences between mainstream and extended students are purely by chance (there are no significant differences between the two groups).

We used the Chi-Square test to test if there were significant differences in the counts of students who passed and who failed between ecp and core groups. This method can be used when the data are counts – and specifically counts of binary data – and the data can be displayed in a nxn table.

Results

Although we have a large data set and results for every subject, for the purposes of illustration we indicate here how the data analysis was interpreted. The chi-squared value calculated from the data (i.e. 0.4285 in the subject Chemical Engineering Technology 2 offered in Chemical Engineering) is compared with a value in the chi-square distribution which has the same number of degrees of freedom. Most of our data is in 2X2 tables, and some in 3x2 tables. The degrees of freedom relates directly to the size of the table.

Formula: Degrees of Freedom = (nr rows – 1) x (nr columns -1). For a 2X2 table the degrees of freedom is 1. When tracing 0.4285 on the chi-square distribution – we find the p-value of 0.5127. This value is non-significant since it is greater than 0.05. This means that the differences in the number of people who passed (140 out of 162 for ND vs 37 vs 41 for ecp; or 86.4% for ND vs 90.2% for ecp – see Table 1) is purely due to chance.

But in the case of the subject Chemical Plant 3 Equipment offered in Chemical Engineering the p-value is equal to 0.0181 (see Table 2). Here the differences in the number who passed is not due to chance but can be due to other factors (the core students had a 7.5% pass and the ecp had 61.2 % pass). What those factors could be is the focus of ongoing research.

Implications and further research

Further research at the level of the subject, would need to interrogate that within one subject, such as Chemical Engineering Technology 2, for example, the number of students who fail, irrespective of their status as mainstream or Ext students, may point more to the difficulty of the course, the lack of preparedness of the students (most of them if the results were bad), the influence of external events, or a whole range of known and unknown factors. These kinds of

examples, of which we illustrate a few, to give a more comprehensive picture, widen the challenges of seeking solutions to retention and throughput at tertiary level. As Jenni Case highlights,

it is acknowledged that enabling epistemic access and progression is not simply a matter of curriculum structure or more specifically only about more time. It is profoundly about particular ways of teaching that promote particular ways of learning (Case, 2011, p. 13).

Our research supports these assertions that overarching solution seeking necessarily risks not seeing the detail that is evident at the micro level. While the two are not in contest, our data shows that the micro level has as much and as differently important information which is needed to build better responses to the educational crises.

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Service-learning in engineering education: Developing group collaboration

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Background

The Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria includes a compulsory module, Community-based Project (JCP), for all its undergraduate students. This is the only compulsory service outreach programme for these students during their undergraduate degree programmes and accounts for eight credits that constitute 80 notional hours. This module gives students the opportunity to function in groups.

Groupwork as a core element of the module

In a previous study, alumni of the JCP module reflected on the soft skills they had gained from the module and indicated that groupwork (74.0%) and time management (70.2%) were the most critical skills acquired.

Research

The aim of our research is to identify key aspects that contribute to the proper functioning of teams. The study used a survey to investigate the roles the students played in their groups and the impact of these roles on the group, how decisions were made in the group and to what extent expertise and teamwork skills were utilised in the group.

Students have specific roles in the team, such as team leader, spokesperson, administrator, treasurer, motivator or quality control. Of the students surveyed, 68% indicated that they preferred to work in a group; 78% stated that, if given a choice, they would rather work in a group; and 87% indicated that the group rather than the lecturer prescribed what they needed to do in the project.

Even though the students do not always have the experience needed for the particular project undertaken, most of them (80%) were of the opinion that their teams possessed a variety of skills and that the team members' skills complemented each other. The outcomes of the study indicated that most students prefer to be in self-selected groups and that the project should be aligned with their expertise.

Decolonising engineering education in sub-Saharan Africa: Some perspectives

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Background and Rationale

Engineering Education (EE) is the combined imparting and acquiring of knowledge, skills, competencies and attitudes to create physical systems that address specific Man's problems using available resources. It transcends the commonly understood boundaries of Higher Education by encompassing artisan, post-graduation engineering pupillage and lifelong learning experiences. In sub-Sahara Africa, it is reportedly beset with many problems (Akisanya & Omatayo 2013, Mohammedbai, 2015). In this paper, focus is on the 'colonial' curriculum problem within the university part of EE because 2016 South African striking students cited it as one of the issues they needed resolved (Hodes, 2017). Many scholars who have attempted to discuss decolonisation have mainly come from the Humanities (e.g. Heleta (2016), Mgqwashu (2016), Prinsloo (2016), etc.). A scientist (Crowe, 2016), has referred to those calling for decolonising science as "reprehensible". Brodie (2016) suggests reassuring students of their capability to do Maths but does not detail how this decolonises the subject.

This paper presents different insights on tackling the problem. It describes efforts of engineers-cum-educators to interrogate decolonisation. Practicing engineers work with what is available to solve a problem on hand rather than wait for more resources or details if the wait could lead to aggravating the problem. As engineering educators, the imperative was to demonstrate to learners, one of the expectations of the profession they were studying to enter: prompt, well considered action. Thus, students' understanding of 'decolonisation' of EE and how to achieve it were to be sought by the study first. After analysis, the results would have to be used to improve teaching and learning.

Methodology

To understand decolonisation of EE and contextualise possible student views, literature on pre-colonial, colonial and post-independence education systems in SSA especially as related to engineering was studied first. Next, the research followed a mixed methodology. In the exploratory phase on student views, qualitative methods were employed to establish themes that drove their 'decolonisation' demand. Quantitative analysis helped estimate the relative strengths of the emergent themes. In one of the authors' classes, the purpose of the research was explained as intended to improve the lecturer's teaching during the semester. The students were requested to volunteer information on what they understood by 'decolonised EE' and how they felt the lecturer could contribute to its achievement. It was explained that they would not be interviewed: they would simply come to the lecturer's office and say what was on their minds in regard to the two issues. Only that, their voices would be recorded for later analysis of the responses. After the first twenty five volunteers, others were asked to come with two colleagues each, from different classes or engineering departments for the recordings. An additional 42 students (14 and 28) responded to this second call. The resulting qualitative data was transcribed and manually coded. Generally, each student talked for

between 5 and 10 minutes. A metaphysical analysis of the results was done based on the earlier literature review and on the authors' past experiences as engineering students, practitioners and academics in various countries across the region.

Results

Demographic makeup of the two groups of volunteers is shown in Figure 1.

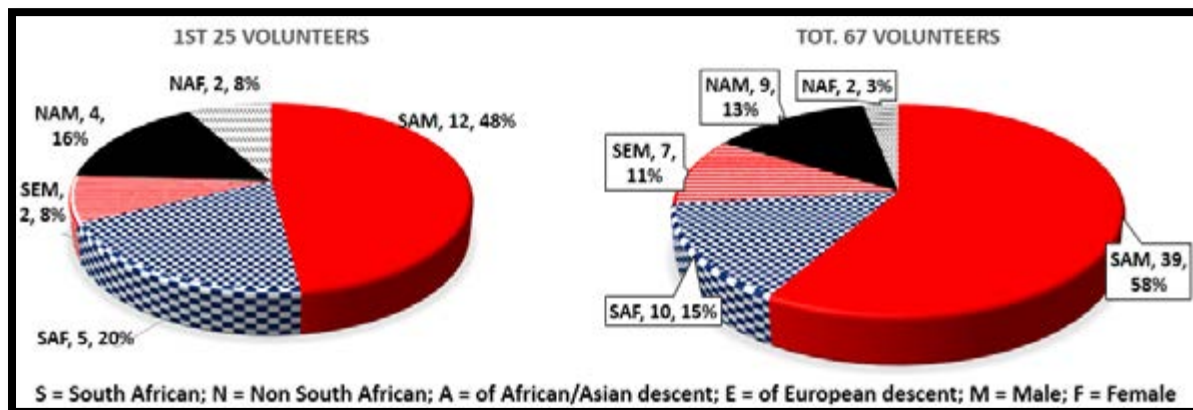


Figure 1. Volunteer composition.

Four themes, based on meanings of most frequent words/phrases in the undirected volunteers' voice recordings emerged. They were: Engineering Curriculum and Africans; Race relations; Facilities and Teaching Methods; and Language. It was also found that the initial 25 volunteer sample was adequate to reveal the themes because the additional 42 did not introduce others, and the relative frequencies of the themes remained almost unchanged as shown in Figures 2 and 3. This seemed to confirm Patton's recommendation of use of small samples for in-depth qualitative studies (Patton, 2015).

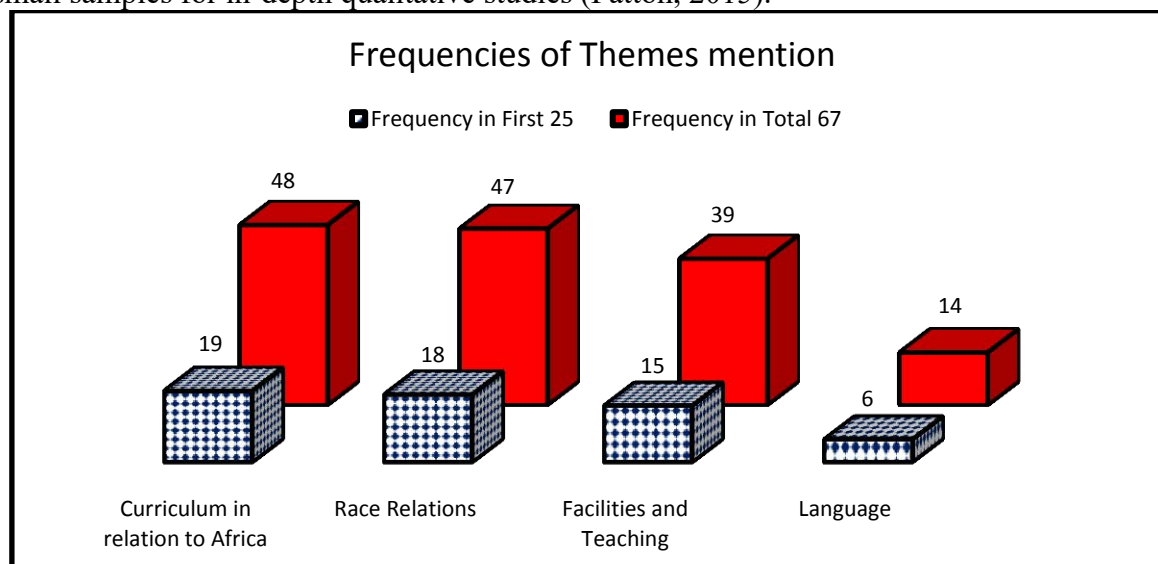


Figure 2. Frequencies of themes.

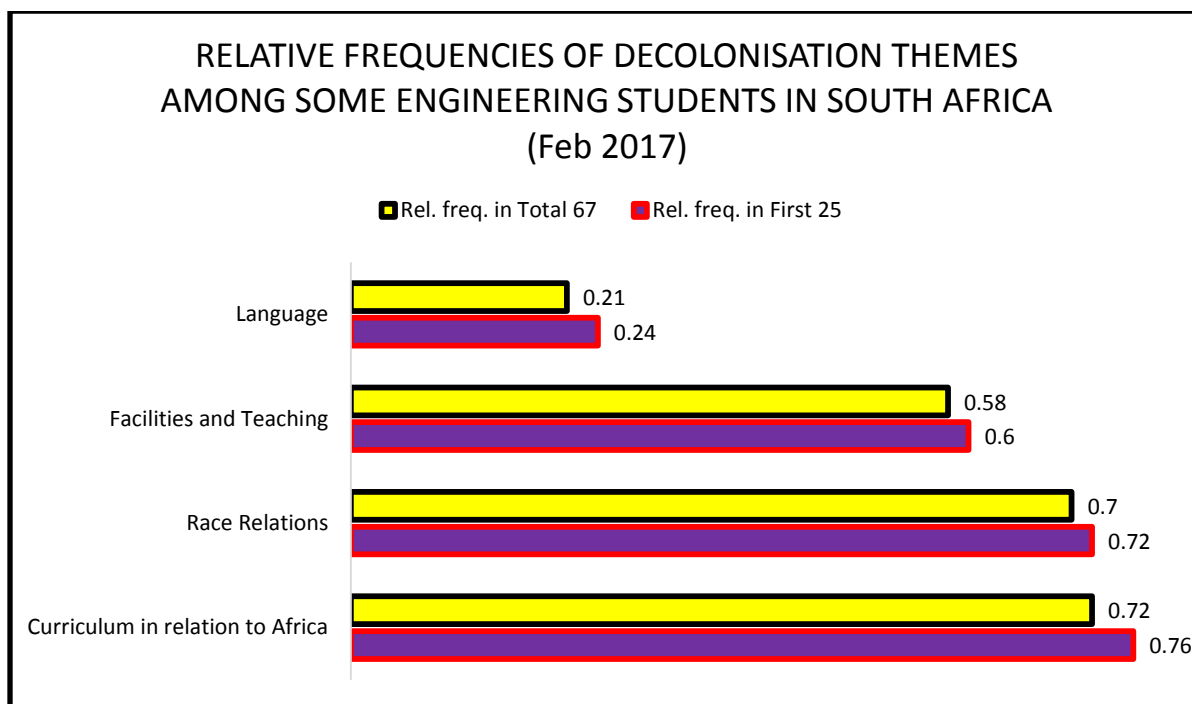


Figure 3. Relative frequencies.

The metaphysical analysis revealed that the continuum of history enabled precolonial and colonial systems to co-exist in a post-independence era and that it shaped the students' views. Of note however, was the observation that volunteering students of European descent were generally silent on issues of race and language.

Conclusions and Recommendations

- Decolonising Engineering Education means a sum total of teaching, learning, training and assessing that produces a group of motivated, knowledgeable and skilled professionals able to understand, own up and address the region's problems and challenges using new and/or established engineering methods.
- In South Africa, an Engineering Education decolonisation process needs to address: Curriculum, Race relations, Teaching methods and Language of instruction.

It is suggested that:

- Engineering lecturers should include teaching of research and innovation results of African engineering scholars in their deliveries. Also, they should increase emphasis on the art portion of engineering in the curriculum.
- English should be the common medium of instruction all way from lower primary to university in South Africa to ease understanding at university level.
- Teaching of engineering should be more practical oriented, with plenty of project and workshop practice. Project work should be of grouped form, ensuring mix-up of cultures and nationalities to further strengthen cohesion.

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Spread sheets in mechanical engineering design: Getting students to learn and to do the ‘real stuff’

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Background and rationale of the research

Mechanical Engineering Design (MED) is the basis of existence of all mechanical systems that are used in today’s economies. From conceptualising a jigger-extracting pin used on feet of the poorest in Africa, to inter-stellar travel braking from 20% the speed of light envisaged by Heller and Hippke (2017) at Max Planck institute, Germany, MED professionals search, plan and convert initially ‘useless’ materials to all kinds of machines and equipment serving Man. Engineering education introduces this subject to students after they have covered basic engineering science courses like Mechanics, introductory Thermo-Fluids and Materials Science and Processes (Savage, 2007). The bulk of that work is mathematical in nature and typical exercises therein are on analysis of ready-made systems having singular ‘correct’ mathematical solutions.

MED – as taught in many institutions and even as delivered in standard undergraduate textbooks like Budynas and Nisbett (2015), Mott (2015), Sharma and Argarwal (2012) etc., tends to continue this analytical treatment with very limited reference to synthesis, creativity, innovation, and to the exclusion of optimisation constrained by non-scientific factors like materials availability, economics, marketability, etc. Yet in the real world, most engineering design problems initially present themselves as requiring interpretation of non-scientific needs first, and then creating or synthesising viable engineering solutions to them. Three major effects arise out of the kind of teaching. First, students are denied opportunity to develop lateral thinking skills on design problems because the interpretation is done for them. Secondly, they are misled to think that engineering is simply about manipulation of mathematical equations and on which they spend a disproportionate amount of time to get often impractical solutions (Kanyarusoke, 2011, Ngonda, 2017). Most importantly, they reach the field lacking self-confidence to use engineering design approaches in addressing society’s problems (Akisanya and Omatayo, 2013). For the university in question, a fourth effect had been the decision by more than half the students not to do the 2nd module because of computational and multi-subject integrative complexity. This paper describes an approach meant to address these problems.

Methodology

A different approach of teaching MED has been tried at one South African university of Technology since 2014. After a qualitative survey of machine elements, their purposes, features and limitations, the approach looks at typical society/industry problems and relates them to different assemblies of elements in a synthesis way of solving the problems. This is followed by quantitative treatment of the elements in assemblies as constrained by established ‘good engineering practice’ principles (GEPs), customer and general economy-imposed factors. The computational work for each element is intense, multi-iterative, related to others in the assembly and hence, realistic. Because of the intensity and iterations, computer use is mandatory. Excel spread sheets are used because of their simplicity,

availability, interactivity and ability to display the governing equations and GEPs to guide students in iterations. Figure 1 shows part of a typical sheet identifying some of these features.

The screenshot shows a spreadsheet for spur gear design. It is divided into sections: Part B (Trial variables) and Part C (Geometrical design). Annotations in green boxes highlight specific features:

- Typical information from customer:** Points to input fields for 'Number of years of service required x ' (6.25), '\$ hour Shifts per day x_{shift} ' (2), and 'Width, w (mm)' (60).
- Advice by spreadsheet that everything above is okay:** Points to the 'CONTINUE' status after checking choices for good engineering practice.
- Equations to guide student on what is happening in spreadsheet:** Points to the 'Estimate gear ratio, $r_{\text{est}} = N_p/N_g$ ' and 'Compute gear teeth, $z_g = r_{\text{est}}z_p$ ' calculations.
- Shaded cells – that is where student action is required:** Points to shaded input cells for 'Select pinion number of teeth, z_p ' (19) and 'Select pressure angle ϕ (use standard 20°)' (20).
- Unshaded numerical value is calculation result:** Points to the calculated value for $C = 3.5627 + 3.9914/(1-B)$, which is 5.038513.

Other visible text includes 'Check your choices for good engineering practice: Is $8m < w < 16m$?' and 'Check your choices for good engineering practice: Is $r < 6$?'.

Figure 1. Screenshot of part of spur gear design spreadsheet.

The student is thus relieved of number crunching. S/he is required to focus on the creative part of the design: namely – select and assemble elements to generate different feasible solutions for the problem. Then use different optimisation criteria to identify corresponding most viable solutions. The new MED course ends with competitive team work design and manufacture of functional machines, addressing specific problems in society. Figure 2 shows one such machine.



Figure 2. A 2-speed fluids mixer with its counter rotating drive mechanism.

Results

With the course running over two semesters, some students get exposure to this approach only once because of failures and of necessity for the concerned lecturer to handle a whole cohort across both semesters. At the end of the course, all in class are surveyed in a 1-5 Linkert scale for achievement of ten objectives - 6 of which are unique to the approach while the other 4 are for the 'traditional' one as well. They are also surveyed for their wish to continue with Design courses at higher study levels as a way of gauging interest aroused in MED. Figures 3 and 4 show such results for the 2015 class.

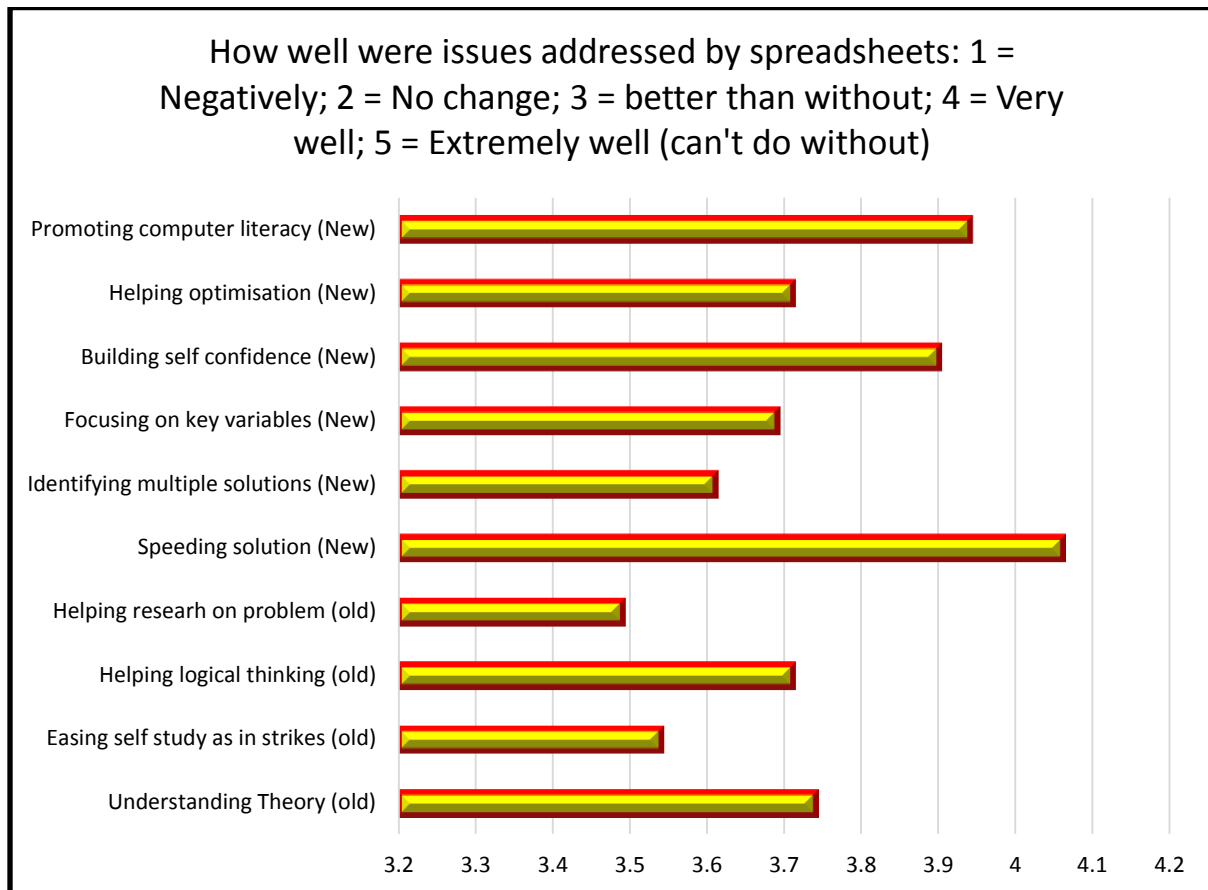


Figure 3. 2015 Student feedback on 10 issues (Averages for 110 students).

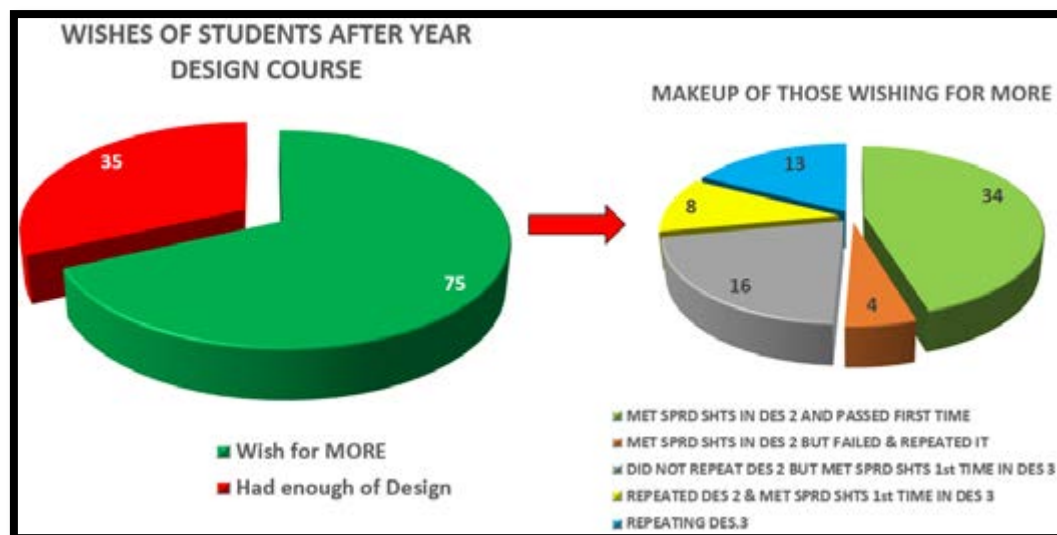


Figure 4. 2015 Student feedback on wish to continue with further MED.

Conclusion

This study revealed that Spread sheets can be used effectively to enable students to learn the subject matter quicker; produce numerical error-free computations; creatively focus on problem variables that matter; optimise design solutions and build self-confidence through building of working machinery because of the time released by speeded up computations. It also revealed an increased interest in MED since previously less than 50% ever wanted to do even the second module. Spread sheets are therefore strongly recommended in MED teaching.

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The role of theory in engineering education research

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Context

This is a review paper that examines the role of theory in the global endeavour of engineering education research. Although *engineering education* may be broadly understood to refer to any formal training in engineering, from technical training at secondary school level to post-tertiary training within the context of an apprenticeship, the focus here is engineering education within the context of tertiary institutions. Traditionally, engineering education has been practitioner-focused, driven by well-meaning educators keen to improve their teaching practice and share their ideas with others. Wankat et al. (2002), in describing the emergence of the scholarship of teaching and learning in engineering education suggest that while '[e]ngineering education has had a rich tradition of educational innovation ... until the 1980s assessment of innovation was typically of the "We tried it and liked it and so did the students" variety.' However, the call for 'systematic, evidence-based research' (Jesiek et al. 2011, p. 79) in the USA since about the 1980s has brought into focus the importance of theory and its role in engineering education research.

Before addressing the issue of the role of theory, it is important to understand the geographical unevenness of the endeavour of engineering education across the globe. A brief survey of activity indicates that the USA is by far the largest centre, having a vigorous organisation, the American Society of Engineering Education (ASEE), which publishes the *Journal of Engineering Education (JEE)*, widely considered to be the top journal in the field. In terms of output, sheer number of participants involved and funding (mainly through the National Science Foundation) the USA far exceeds other regions involved in engineering education research. The Northern and Central European region is the next largest centre, having an organisation (SEFI) and a dedicated journal (the *European Journal of Engineering Education – EJEE*). Other parts of the world engaged in engineering education include Australasia which boasts an organisation and a conference, with pockets of activity elsewhere including in Africa (with South Africa as a focal point) as well as in Asia and South America.

As noted above, there was a noticeable shift in the field in the USA in about the 1980s towards more rigorous research, the promotion of theory as well as an openness to qualitative research methods. This call has been taken up to various extents within the USA and in other parts of the world. In the late 1990s the SEFI community began to explore the synergies between research and engineering education (Seitzer, 2000) and about a decade later, at the annual SEFI conference in 2008, a working group for EER was established. This demonstrated a shift in the field towards more research-based approaches within engineering education in Europe. It also resulted in a special issue in the *EJEE* entitled 'Educational research impacting engineering education' (Baillie and Bernhard, 2009). The articles in this special issue were considered by the editors to be 'thoroughly anchored in the emerging field of EER' (p. 293) and generally employed qualitative methodologies. This trend is gradually spreading to other parts of the world as engineering education becomes more globally connected (Borrego and Bernhard, 2011).

The intention of examining the role of theory in engineering education, and how this has changed over time, will hopefully provide another perspective on engineering education within South Africa in the context of a changing higher education landscape.

Purpose

This paper attempts to understand how the role of theory in engineering education research, as a global research endeavour, is shifting over time.

Approach

This paper takes a broad view of theory and includes the notion of ‘paradigm’, ‘methodology’, ‘model’, or ‘conjecture’ within the broad umbrella of conceptual devices that serve the role of theory. At this stage it is helpful to propose a working definition: a ‘theory is a statement of concepts and their interrelationships that shows how and/or why a phenomenon occurs’ (Corley and Gioia, 2011, p. 12).

In order to analyse the sorts of theories that are used in engineering education, as well as how they are used, this paper draws on the work of Robert Merton (1968). Merton was concerned with theory-building in the field of sociology and described three levels of theory: so-called ‘grand’ theory, middle range theory and ‘micro-theory’. For Merton, grand theories were too distant and abstract to be able to provide important contextual insights into social behaviour which might arise from empirical study. While they could provide descriptive accounts at an elevated level, such as for society as a whole, he did not believe this was of much use. For this reason he preferred to work with middle range theory to bridge the gap between the abstract level of grand theory and context-laden propositions that emerge from empirical study at the level of what might be called ‘micro-theory’.

What Merton called ‘micro-theory’, Prediger et al. (2015), in the field of maths education identified as humble, pragmatic theories: ‘humble in the sense of being concerned with topic-specific learning processes, and pragmatic in that they effectively inform prospective design’ (p. 879). For Prediger et al. (2015) design research also operates at a level between humble and ‘grand’ theory but in the case of the learning sciences, grand theories include those of Piaget, Vygotsky and Dewey and their intellectual heirs.

Since the USA is the largest centre of activity, the scope of analysis of this paper is limited to the flagship journal of the American Society of Engineering Education, the *Journal of Engineering Education*. Drawing on the work of Kandlbinder (2013) who argues for the use of citation indices to analyse the field higher education studies, this paper narrows the search of the literature by examining the ten most cited papers in each year. 1988 was chosen as the start year because the most cited paper within the entire engineering education literature was published in this year (Felder and Silverman, 1988). At this time, the JEE was simply *Engineering Education*.

At the time of writing, five years’ worth of the papers from the JEE had been analysed but the intention is to analyse the years up until 2012. Due to unavailability of the hard copy journals in the early years, the years 1991–1992 were not examined. The analysis therefore includes 1988–1990 and 1993–1994, 50 papers in all.

Results

As Wankat (1999, 2004) found in his analyses of papers published in the *JEE*, the proportion of papers *explicitly* referring to theory was low at 18% (nine papers). A good example of such

a paper was the Felder and Silverman (1988) article already mentioned. This paper can be thought of as introducing learning (and teaching) styles to the engineering education community which is probably one of the reasons that it has been so widely cited. Another reason is probably that the paper draws on principles derived from educational psychology, enabled by Silverman's expertise, but made relevant or pertinent to the field of engineering education by Felder, at the time already a well-known figure in the engineering education community.

Of these nine papers, only one includes empirical data which 'put the theory to work' in a way that is consistent with Merton's notion of theory-building. This was published by Felder with some other associates (Felder et al., 1993) and was entitled 'A longitudinal study of engineering student performance and retention: I. Success and failure in the introductory course'. This paper analysed student profiles in terms of their scores on the Myers-Briggs Type Indicator and the Learning and Study Strategies Inventory and developed a model – actually more like a set of factors – to assist in the prediction of student performance.

Although the remainder of the papers did not explicitly refer to theory, a further 26% (13 papers) contained some form of empirical investigation and concluded with proposition of some sort, however small, regarding a relationship between concepts attempting to explain how/why a phenomenon occurs. For this reason they were categorised as engaging with or humble theory. For example, Barber et al. (1989) used survey questionnaire data to explore why students pursue graduate engineering degrees. They came up with a series of factors including financial reasons, overloaded curricula and family encouragement to pursue PhD studies. Another example is Brickell et al. (1994) who tested five different methods for assigning students to group design projects. They found that groups that are heterogeneous with respect to GPA but homogeneous with respect to curriculum interest appear to perform better.

Together, this means that 44% of the papers surveyed over five years of the *JEE* engaged with theory in some way. The other 56% of the 50 papers analysed did not appear to engage with theory at all and were typically descriptions of curricula interventions or opinion pieces.

Conclusion

This preliminary study has analysed what theories are used and how they are used in the *JEE*, arguably the most prestigious journal in the field of engineering education research. Drawing on the work of Merton (1968) and Prediger et al. (2015) it was found that 18% of the papers explicitly referred to theory, with only one paper bringing the theory in contact with empirical data or engaging in some form of theory building. A larger number of papers used theory in some way, some at the micro-level, so-called humble theory, which typically entailed putting forward some sort of proposition embedded in the context of disciplinary knowledge. Overall, more than half the papers, 56%, in the period analysed did not use theory at all.

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Aligning mathematics taught in the intermediate phase, with afterschool enrichment programs, to respond to a changing Engineering Education landscape

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Introduction

The NWU's SETH (Science, Engineering, Technology and Health) Academy was conceptualized in 2011 as one of a number ways to address the shortage of suitable engineering applicants. The SETH Academy is a grade 8 to 12 program which aims to provide excellent teaching, which is done in the mornings at a school, and bespoke interventions which aims to develop skills, habits, behaviour and attitudes that are prerequisites for success at university and the workplace. These interventions are packaged as a curriculum that is offered at the NWU in the afternoons in the form of project- and problem-based sessions. The afternoon classes include lectures, practical sessions, tutorials, and visits to industry and are offered by university staff, experts from industry, and teachers. The skills and attitudes had been distilled from outcomes as captured in the ECSA outcomes documents, and from interviews with industry.

In the USA, similar schools followed from the 2011 Elementary and Secondary Education Act (ESEA) waiver, and are based on the following paradigm: "Focus schools use achievement gap analysis data to develop a plan to include specific research-based interventions to address achievement gaps... These targeted interventions should be consistent with best practices for narrowing achievement gaps between identified subgroups and align to federal turnaround principles" as found on the South Carolina Department of Education website.

Many of these principles correspond to the aims of the SETH Academy and include: strong leadership, excellent and motivated teachers, improved instruction methods and technologies, exposing both teacher and learner to real-life experiences, implementing strategies to recruit and retain staff, redesigning the school time (day, week, or year), strengthening the school's instructional program, using data to inform instruction, addressing non-academic factors, and engaging families and communities.

Interestingly, the results from some of the USA focus school initiatives are mixed, (Judson, E, 2014). In other words, the impact is minimal. There are also many other initiatives in South Africa aimed at improving the quality of mathematics education, also with varying success.

A reality of the SETH Academy is that although all the learners are homogeneous in their potential to excel in mathematics, the learners come from diverse backgrounds, cultures, geographic areas, and quality of tuition. These realities must be considered when designing

South African specific solutions. However, the SETH Academy is in a unique situation where it has access to the expertise and resources of the university, and specifically the Faculty of Engineering, the Faculty of Educational Sciences, and the Faculty of Natural Sciences to plan and implement interventions.

Research goals and questions

This leads to two questions: How effective are the SETH Academy interventions, and which strategies and processes should be adopted that will lead to effective interventions addressing South African realities?

Based on these broad questions, this proposed study will focus on how to achieve the domain-specific outcomes as captured in the Mathematics CAPS document, and how to develop the set of skills and attitudes as distilled from the ECSA outcomes and industry interviews, using age-appropriate interventions, and taking technology and new teaching approaches into account.

The attitudes, anxiety, habits, behaviour and milieu of the learners are important requisites for success as Erasmus, P (2014) found that active engagement with learners on the cognitive, and affective facets is needed as part of a strategy to improve mathematical functioning, but that this information must be made available to the educator through inter alia screening tests. A virtuous cycle of Metacognitive skills lead to improved Emotional intelligence, leads to improved Study orientation in mathematics, leads to improved Resilience, which then again leads to improved Metacognitive skills (Erasmus, P. 2014).

The SETH Academy therefore uses a standardized test instrument, the SOM (Study orientation Mathematics test) in order to identify the educational needs of each learner, and to design bespoke interventions. The test assesses the following areas:

- Study attitude (SA): Learners' "mathematical world view" about the self, the nature of Mathematics and the nature of learning Mathematics.
- Mathematics anxiety (MA): Panic, emotional disturbance, emotional liability, and self-doubt
- Study habits (SH): Time management, staying focused and consistence in study habits.
- Problem-solving behaviour (PSB): Cognitive and meta-cognitive learning strategies.
- Study milieu (SM): Non-stimulating environments, restrictive circumstances and physical problems
- Study orientation Mathematics (SOM): Summary of the above and a measure of a learner's study orientation.

The SETH programme is now in its 5th year and specific interventions to challenge learners in mathematics had been implemented. It was found that the worksheets did not address affective issues, and shortcomings in knowledge and understanding. However the data of the last few years are available to help inform this study.

Method of approach

The study is currently in the proposal stage, and will only focus on learners in the

intermediate phase (grade 8 and 9). The results of the study will lead into a later study that will include the grade 10 to 12 group. The current proposal is to use the action research methodology for this study.

The reason for the focus is that the Grade 8 and 9 group experience high levels of stress because they struggle to adapt in the new school environment, they come from different backgrounds, and they must address gaps in their knowledge and skill set, whilst expected to develop high-level cognitive skills and mastering new mathematics.

The main goals of this study are as follow:

1. Design and implement a curriculum for the afternoon programme that will address the shortfalls in the cognitive and affective skillset needed for high-level mathematics functioning in a SETH context.
2. Use efficient instruments to track learner progress in terms of cognitive and affective progress.
3. Design and implement remedial interventions to address gaps in their knowledge and understanding.
4. Design and implement interventions to situate mathematics in a SETH context, and to guide learners into “deep learning” (Atherton J S, 2013)
5. Measure the impact of the interventions, redesign and implement the improvements.

Relations between quantities and algebraic expressions together with special and geometric reasoning are two of the nine key ideas in mathematics internationally (Watson, Jones, & Pratt, 2013). These ideas are also part of the five “Big Ideas” stipulated in the CAPS document, which has specific relevance to engineering studies. Askew, (2013) states that “...while there is some evidence of implicit attention to Big Ideas in the Curriculum, without more explicit attention to these, teachers and, consequently, learners are not likely to develop understanding of Big Ideas and how they connect aspects of mathematics together.”

Therefore the “Big Ideas” will be incorporated in problems to develop the understanding of these concepts in context-specific scenarios. Learners will work co-operatively and on their own depending on the planned outcome.

Technology is used selectively in the SETH academy and (TPCK) Technological Pedagogical Content Knowledge, (Mishra & Koehler, 2006) provide a useful theoretical framework on how to integrate technology at multiple levels: theoretical, pedagogical, and methodological.

The afternoon sessions take place on a weekly basis, and a number of facilitators are available during the sessions to assist the educator. The facilitators also help in accessing the progress of the learners.

Conclusion

Meaningful learning takes place when a learner can connect several points of information into one large network of ideas. It is also the ability to do mathematics in the classroom that closely models doing mathematics in the real world. (Sullivan, P. 2011). This process is supported by metacognition, resilience and emotional intelligence. This study will focus on

the aspects that relate to the alignment of the specific aims as set out in the CAPS document and the skills, attitudes, habits and behaviour as defined in the ECSA outcomes document.

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African engineering student's perspectives of using Blackboard and Socrative to prepare for practical work in a laboratory

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Introduction

Learning Management Systems (LMS) have been in existence in the classroom for decades. LMS are primarily used for online or blended learning (Resch, 2010). This is facilitated by placing relevant course material online, tracking and storing student performance and most importantly, establishing a communication between students and instructors. Blackboard, a type of LMS, is used at the Central University of Technology (CUT) ("Central University of Technology," n.d.) where this research is done. Blackboard has traditionally been used by academics at CUT to provide students with course instructions and to alert them of tests and examinations.

Prior to this study, students were given practical workbooks. It was mandatory that students complete the practical workbooks before attending their weekly laboratory session. The workbook contained a preparatory section that was aimed at testing how well students were able to fuse theory and practice. It was observed that practical preparations done by students in these workbooks often led to mass plagiarism and elevated preparatory marks.

This paper proposes a solution by initially uploading preparatory material to Blackboard, a week prior to the practical work required in the laboratory. The tracking function in Blackboard enables the lecturer to monitor how many students access the preparatory material. Socrative, a free, cloud-based, android, iOS and Windows based student response system is then used for setting up an assessment test based on the preparatory material. Setting up a test on Socrative is similar to that on Blackboard but the advantage of setting up a test on Socrative as opposed to one on Blackboard is simplicity.

The importance of practical work in undergraduate engineering courses (Feisel & Rosa, 2005) has been stressed. There have also been studies that show that students enjoy (Swart, 2010)(Swart, 2014) their practical work. However, the perception of African students regarding this new approach to assist them in preparing for their practical work is lacking in the research. This gives rise to some of the following research questions: What are the perceptions of first year African engineering students with regard to preparing for laboratory work using Blackboard and Socrative? Does a correlation exist between the practical marks obtained by the students and their accessing of study material on Blackboard?

Research Methodology

An exploratory case study is employed along with descriptive statistics of the quantitative data. According to Yin (2009), an exploratory case study is appropriate for preliminary inquiries and is ideal for analysing what is common and different across cases that share some key criteria. Descriptive statistics are used as the results are interpreted with regard to first year undergraduate engineering students enrolled at CUT. Quantitative analysis is important as it brings a methodical approach to the decision-making process, given that qualitative factors

such as “gut feel” may make decisions biased and less than rational(Reddy, W, Higgins, D,Wakefield, 2014). The target population was restricted to undergraduate engineering students enrolled for Digital Systems I during second semester of 2015 and first semester of 2016. The sample size was 150 students spread over the two semesters. An electronic response system was used in a classroom environment at the end of each semester to obtain student perceptions on specific questions relating to the laboratory preparation work done using Blackboard and Socrative. Closed-ended questions, featuring Likert scales, were used based on previous research which focused on student perceptions of practical work done in a laboratory(Swart, 2014)(Swart, 2012).

Results

Results indicate that more than 65% of students found Socrative to be user friendly, while more than 75% of these students perceived the questions asked on Socrative to be challenging. 60% of students felt that using Socrative helped them to understand theory concepts better. Results also showed that 76% of students were now accessing their study material from Blackboard on a regular basis. Another key result obtained by comparing the average preparatory marks of students before and after the implementation of this approach revealed a 10% decrease in the overall marks.

Conclusions

The purpose of this paper was to present student perceptions on the use of Blackboard and Socrative in preparing for practical work. Results indicate that students mostly welcomed the new approach, with a good percentage of students indicating that the questions asked on Socrative were challenging and relevant to the work done in their theoretical class. Another important conclusion was that students were now encouraged to use Blackboard as a preparatory tool rather than just as a communication portal between student and lecturer. The 10% decrease in average practical mark prior to and after implementing this approach could possibly be the result of a decrease in plagiarism, as students cannot now simply copy from fellow students before entering the laboratory for their practical work. A recommendation from this study is to encourage academics to implement a similar approach in order to better assist students to prepare well for practical work in a laboratory.

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An evaluation of the challenges and benefits of e-assessment implementation in developing countries: a case study from the University of Pretoria

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Most of South Africa's universities are currently under great pressure to increase their intake of students, although the average incoming student does not have an adequate mathematical background to understand the concepts presented to him at first year level. Therefore, the failure rate for first year students is unacceptably high. One of the challenging subjects presented to all first year engineering students at the University of Pretoria (UP) is a statics course, in which students are introduced to two-dimensional and three-dimensional equilibrium problems.

The large groups of inadequately prepared first year students make it very difficult to provide education of a sufficient standard and the subsequent subjects are also impacted. However, it was believed that this problem could be addressed, at least to an extent, by providing students with opportunities to better their understanding of the fundamental concepts presented in first year level subjects. To this end, an e-assessment system was implemented as an intervention to aid in the continuous assessment of these large student groups (more than 2000 students are enrolled for the course during an academic year) using formative tests for a pilot study in 2016.

The NUMBAS e-assessment solution, developed by Newcastle University in the UK, was utilised to replace cumbersome and resource intensive weekly written tests with an online assessment that could be accessed through UP's internet portal. Each week, the students had a limited time to complete an online test. A bank of questions with random variables were set up per study unit and each student given only one of those tests, thus giving each student a unique test question, comprised of a number of steps. Once submitted, the tests were graded automatically and the students received basic feedback including all correct answers and a short description of the theory, with reference to their text book and online resources. The students were given the flexibility to work from home or on campus, alone or in groups. Group work was encouraged for the formative tests as this would encourage students to work through problems together and subsequently spend more time on various aspects of the subject. Even if students worked together, they still had to complete a separate test for each student in the group.

One of the reasons why the NUMBAS system was utilised, was because the NUMBAS system allows the setup of questions using random variables that are unique to each student, but that would remain the same for that student throughout the test. The system also has adaptive marking capability, which could be used to test if students used the correct method, even if they made a mistake in one of the early steps of a question. The system was available as open-source software and was compatible with UP's existing infrastructure. One of the major benefits of online assessment was that students could access the tests from any device with internet connectivity, including smartphones. This meant that most students could access the tests from off-campus during the disruptions of 2016.

A pilot study was undertaken in the first semester of 2016 with 450 students who had to repeat the course. The pilot study was deemed a success and the question bank was expanded and rolled out to approximately 1700 students who took the course in the second semester. The effectiveness of the intervention was assessed using electronic surveys and focus groups after the second semester of 2016 to gauge user experience and to identify challenges and problems with the implementation of the intervention.

The results were analysed and it was found that more than 70% of students felt that they benefited from the formative e-assessment tests, as shown in Figure 1. The results showed some interesting trends in user experience that will help to improve the intervention in subsequent semesters. One of the major trends in student response indicated a need for additional tests that focus on summative assessment of more complex problems, rather than only formative assessment of the fundamental concepts. This was seen as an indicator of initial success of the system and pointed to positive user experience of the e-assessment system.

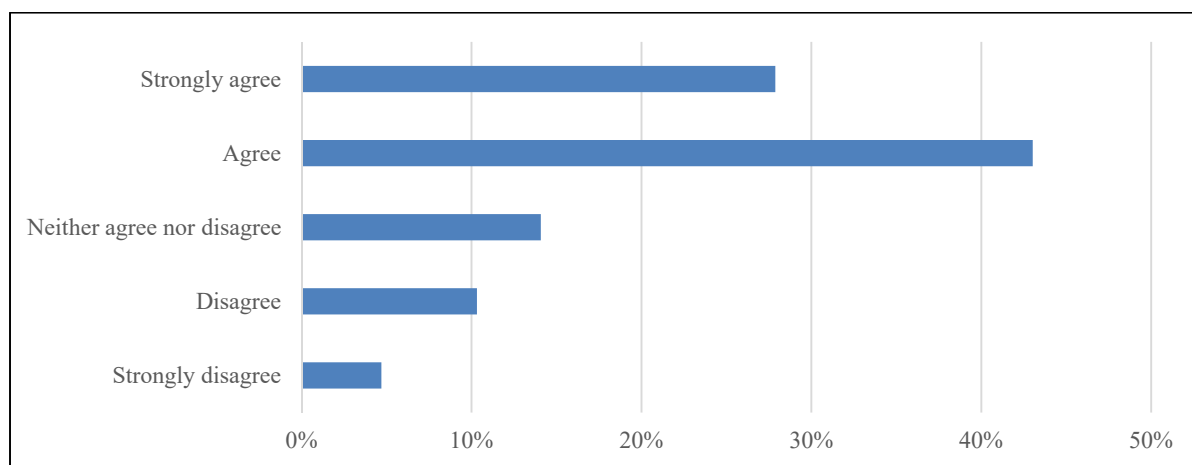


Figure 1. Student response when asked if they benefited from e-assessment

A trend that showed cause for concern was that 9% of students indicated that they struggled to access the tests, as shown in Figure 2. Most of the students who struggled with access, complained about a lack of computer access or internet activity, but some students also indicated problems with software aspects of the tests. Mitigating measures were identified and implemented for these challenges.

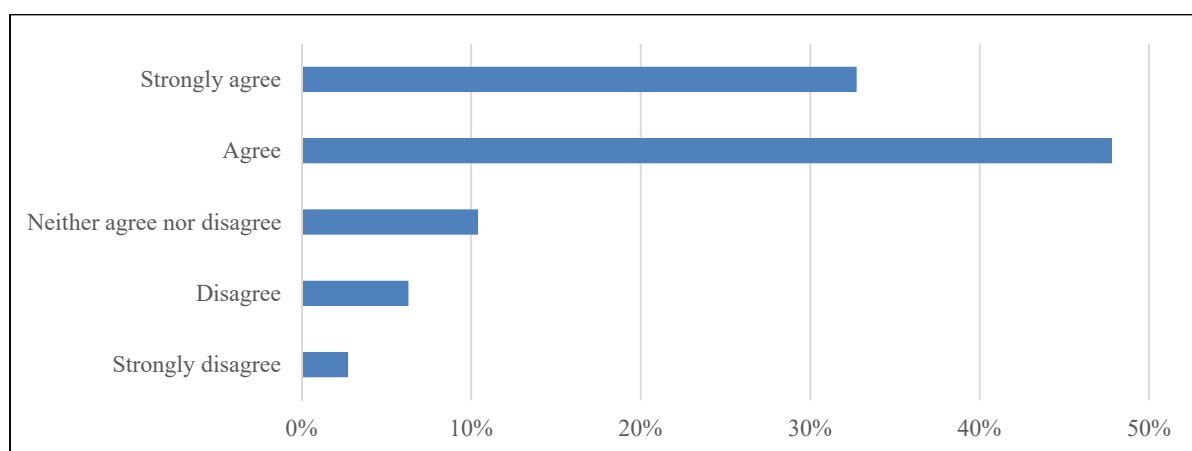


Figure 2. Student response when asked if they could easily access and complete the e-assessment tests

Even though some of the proposed mitigating measures are still under development, e-assessment has already proven to be an effective method of providing formative assessment of a basic engineering subject, specifically in large classes. The system provides assessment opportunities even when students do not have access to campus, which should prove to be particularly beneficial if a similar situation to the disruptions at academic institutions in 2016 develops again in future.

The purpose of this paper is to discuss some of the benefits of using e-assessment for formative assessment in engineering courses. It will also discuss some of the challenges with the implementation of e-assessment for engineering courses in South Africa, using the adoption of the NUMBAS e-assessment software for first year statics at the University of Pretoria as a case study. Furthermore, this paper will discuss mitigating measures that have been adopted with varying degrees of success for many of these challenges.

Managing large number of students in a mechanical engineering laboratory: A lecturing assistant's perspectives

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Introduction

A 2005 report by the U.S. Department of Education stated that the intake of university and college students will continue to increase (Carpenter, 2006). The revolution of democracy and equality in South Africa have shown an increase in the intake of students in higher institutions of learning. The increase is anticipated to increase from about 950 000 in 2012 to 1 600 000 by 2030 (DHET, 2014:30). This high intake of students has led to overcrowded classroom as the infrastructure and number of facilitators have not been developed at the same rate (DoE, 1997).

Higher education engineering requires students to obtain both theoretical and practical instruction. Theoretical lecturing occurs when the theory of the subject is explained in a classroom, while practical lecturing occurs when the theory is demonstrated, using apparatus, in suitably equipped laboratories. However, the current layout of some engineering laboratories poses challenges in accommodating large number of students. The purpose of this paper is to present the perspectives of a lecturer assistant who was tasked with managing large number of students in a mechanical engineering laboratory.

Lecturer assistants at the Central University of Technology are appointed to facilitate practical laboratory work, to receive practical assignments and assess them. Lecturer assistants work collaboratively with the lecturer of the module so as to ensure that the practical instruction is aligned with the theoretical instruction.

The paper will firstly cover literature relating to the management of large classes. The study context is next given followed by the perspectives of the lecturing assistant.

Managing large classes

It's naturally for human beings to push the limits within many endeavours, which is also experienced through the management of large classes where students are encouraged to be hardworking. The variety in experience and learning skills from different students may be used within team work approaches to enable learning in large classes without depending on the lecturer (Le Phuoc Ky, 2002). However, there are factors that affect the management of large classrooms, which include assessment, providing academic feedback, course management and the funding of educational resources (Kerr, 2011). Large classes also tend to have an impact on the academic performance of students, as the lecturer does not have enough time to attend to the issues of each student (Cuseo, 2007). Instead of students doing a project on their own, they may do a group project where member conflicts, cheating and inconsistent skill development may arise (Tomcho and Foels, 2012 & Cyrs, 1994).

Different methods have been proposed on how to facilitate different courses with high number of students, including the use of technology. A large number of students affords the opportunity to use different types of technology like power point presentation, playing of video related content and the use of electronic responsive systems (called Clickers) for feedback. Clickers help non-interactive students also to participate in the large classroom. Social media can be used to continue the discussions outside the classroom. Learning management systems, such as Blackboard, can be used by professors to post notes, tests, assignments, and assignment reports

(Hanoverresearch, 2010). The use of pre-recorded video or audio lectures can be done to prepare the students for the work to be done in the classroom and to pass important messages (Kerr, 2011)

Study context

The mechanical engineering undergraduate programme is a three year course with two years of theory and one-year of industrial practice. To complete the course, some 26 modules need to be completed over four semesters of roughly 14 weeks each. Many of the modules require theoretical instruction in a classroom and practical instruction in a laboratory. The number of students who enrolled for the first semester of 2016 were 190, and, according to the curriculum, they had to complete three practical assignments over a period of 14-weeks. The focus of this study is on the module termed, Strength of Materials II. The module is given in the second semester of the course for mechanical engineering and the background that is required is for students to have Mechanics 1. Strength of materials is one of the major modules that is presented across three semesters, which each subsequent level building on previous knowledge.

The methodology or procedures are provided for each laboratory experiment in a laboratory guide that is provided to all students at the beginning of a semester. Students are divided according to groups and assigned to different time slots. The lecturer and lecturer assistant explains the procedure of the experiments and demonstrate the practical before the students can do it on their own in their groups. The first practical covers tensile testing, the second shear force and the third bending moment.

The practical instruction forms a major part of the student's course mark, where the average result for student practical marks must be above 50% for a student to be able to write the examination. For each practical, students are given seven days (week) to submit an individual report after the laboratory work has been completed. The report is written with the same standard elaborated in the laboratory guide, which also contains the marking rubric. The students write the report according to the results found from each group during the practical instruction.

Lecturer assistant perspectives

The purpose of this paper is to present the perspectives of a lecturer assistant who was tasked with managing large number of students in a mechanical engineering laboratory. The CUT blackboard is the platform of communication between the student and the lectures. The black board can be accessed by students who have registered a certain subject in the beginning of the semesters the subject materials are uploaded on the blackboard the materials include the laboratory guides ,study guides ,videos ,report cover page. The blackboard is accessible from the mobile phones, computer and student libraries within the campus. The reason for placing the video is to.

Clear written laboratory guides

The laboratory guide are uploaded on the blackboard at the beginning of a semester with safety rules and different section of the experiment to be performed. The aim of the practical is clearly stated with the apparatus to be used for a particular experiment. The procedure of performing the practical is listed step by steps with the table used to write down the results during the session. The perspective of a lecturer assistant is that the clear study guides helps the student to know what to do during the practical which helps in the session to manage time in a large class

of student in the laboratory. The Figure 1 below shows the sample of the layout of the experiments.

EXPERIMENT 3 BENDING MOMENT

1. Aim

To show that the bending moment at any section of the beam is equal to the algebraic sum of the moments of the forces to one side of the section.

2. Apparatus



3. Procedure

Setup the apparatus as shown in the above diagram. Take reading F_1 on spring balance after the beam has been set horizontal. Measure the positions of the supports, the weights and the section. Place different known mass on the hangers and adjust the beam horizontal again. Take reading F_2 on the spring balance. Repeat the experiment by placing masses at different positions.

4. Theory

When a simply supported beam is subjected, to a load a bending moment will be setup in the beam. This bending moment is equal to the algebraic sum of the moments to one side of the section.

5. Results

Experimental value of the bending moment at X-X = $(F_2 - F_1) d$.

d = the distance from the spring balance to the centreline of the beam.

	Distance	Reading 1 on spring balance	Reading 2 on spring balance	$(F_2 - F_1) d$ Bending moment
1.	d	$F_1 =$	$F_2 =$	
2.	d	$F_3 =$	$F_4 =$	
3.	d	$F_5 =$	$F_6 =$	

6. Assignment

- Complete the above result table.
- Draw for each experiment the force diagram, calculate the reactions at the supports, draw the bending moment diagram and complete the table below.

	Reaction at LH support	Reaction at RH support	BENDING MOMENT	
			On LH	On RH
1.				
2.				
3.				

Figure 1: laboratory guide

Video presentations

The experiment where there is only one machine to be used for the session of practical the video is uploaded on the blackboard for student to preview how the practical is going to proceed. The procedure that is used in the laboratory is the same as the one shown in the video. Due to large class number of students in a group to prepare for practical the video is uploaded on the blackboard. The perspective of a lecturer assistant is that the presentation of the video helps because some of the students come with knowing what is going to happen which helps to manage time and the effectiveness of students. The video is more visual than the laboratory guide. The disadvantage is that the video is uploaded on the blackboard and is only accessed by students who registered early. The late registered students get access of the material late and the cost of watching the video if they use personal internet resources.

Group formulation

Due to large number of student the laboratory session are divided into groups to attend for certain time slot equally. The experiments are done in a group formulated in the beginning of a semester. Groups are formed from the class list of the registered students according to the student number. This format of grouping helps the lecturer assistant when entering marks from the report on the system. The perspective of the lecturer assistant is that the people who are repeating the subject are luckily to be in the same group. There is no diversity of the team or the new way of doing things on the group of people who are repeating. The groups were formed with 10 students per group, with each group being assigned to one of the three practical assignments. The limited space in the laboratory and the limited number of apparatus dictated the number of groups.

The perspective of a lecturer assistant is that even though the method of dividing students in groups for practical instruction is effective, there are a lot of challenges. Due to the large number of students for Strength of Materials II, managing this class size proved to be hard of work. Students had to be reminded to remain in their same group and to be in the laboratory during their schedule time. Students who missed their practical instruction due to sickness and to be moved to the last group. The independence of students working in groups created teamwork where everybody contributed to the experiment. Some groups took a longer time to proceed with their practical work, which cause delays for incoming groups who were requested to rotate among the three practical instructions.

Report structure

The submission of reports were done at the same place where the practical instruction were conducted, that created a lot of havoc and time delays for students who were supposed to commence with their work.

Each student submitting a report was supposed to sign for it, thereby helping to avoid the non-submission or loss of scripts. To make sure that students are attending the practical instruction, the lecturer assistant was to go to each group during the session to make sure they sign and mark off those who didn't attend.

The experiment are done in groups but the submission of the report after seven days is done individually with the same experimental results. The sequence of writing the report is the same for all students the Figure 2 below is the cover page for the practical report showing the mark allocation for each experiment.

STUDENT SURNAME & INITIALS:	
SUBJECT:	Strength of Materials II (MSM21AI)
PRACTICAL:	1. TENSION TEST

EVALUATION:		
Description	Marks	Student Mark
1. Aim of the experiment	2	
2. Sketch and describe the apparatus	3	
3. A short summary of the theory	10	
4. Experimental procedure	5	
5. Experimental data and observations	10	
6. Calculations and graphs if necessary	30	
7. Results and discussions	20	
8. Conclusion	10	
9. References	5	
10. Neatness and overall impression	5	
11. Overall Total	100	

DECLARATION OF OWN WORK

I hereby declare that this assignment is my own work and that it has
Not been copied from any other person or document.

Figure 2: Cover page for a practical report

The lecturer assistant perspective the results of the practical reports showed that most of the students when they submit the report they don't have the cover pages this means not all students

access the blackboard .When conducting the practical the report of the certain groups tend to be plagiarism and the students tend to copy experimental results from different groups. Controlling of plagiarism in the large class is a challenge.

Conclusions

The purpose of this paper is to present the perspectives of a lecturer assistant who was tasked with managing large number of students in a mechanical engineering laboratory. Managing large classes requires much work from the lecturer assistant side, both before and during the laboratory sessions. Preparing the mind of the student on what the practical instruction entails requires much time. The importance of time management during the experiment was vital to permit other groups to perform the practical instruction. Students further showed more interest as the lecturer assistant was more of a facilitator than a teacher.

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Capstone projects in electrical engineering at UNISA

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Background

The concept of gradueness in higher education has become a topical issue worldwide. The quality of a graduate is not simply the ability of a student being able to pass exams, but a measure of the student's ability to enter into the workplace as well as the reputation of the institution itself. There is increasing emphasis on work based learning, as it aims to integrate academic study and practical work experience. Integrating theory and practice in an engineering curriculum is mandated by a number of accreditation bodies in the world, including the Engineering Council of South Africa (ECSA). The exit level outcomes prescribed by ECSA (ECSA, 2002 & HEQF 2007) require engineering students to apply scientific, engineering and complementary knowledge to solve well-defined engineering problems while also completing engineering procedural designs. Unisa is therefore mandated by ECSA to provide quality engineering education programmes which adhere to the high standards set forth by the Washington, Sydney and Dublin accords (International Engineering alliance, 2012).

Design and Industrial Projects

Design Project III is an important part of the National Diploma since it is the subject where the student applies their knowledge of different subject areas in one particular project. It is for this reason that the student is not allowed to do the subject before a significant component of technical subjects has not been mastered. As this subject is a design subject and that it can only be passed by illustrating the ability to apply technical knowledge in a design.

The amount of time that must be spent on the project will give the student and employer a rough estimate of the type of project that must be chosen. The amount of time that should be allocated for the project is at least 120 hours. Ideally a student must work in an environment where they will be able to select a project and carry out the design and experimental evaluation at work with the employer's resources. This will mean that the employer must be supportive and provide the necessary time to spend on the project

The projects we made available are all related to plant automation for a micro-brewery and would include training. We arranged 2 day training sessions on:

- Easy programmable controllers (PLC's), This training enabled the students to do programming in ladder diagram. The second session covered timers, counters and markers and analogue signals.
- XC programmable controllers (PLC's), This training enabled the students to do programming in Instruction List and Function Blocks. The second session covered analogue signals and PID loops.
- Human Machine Interface (HMI). This training enabled the students to do programming in Gallileo. This covered touch screen control and visualisation.
- Variable Speed Drives (VSD's). This training enabled the students to control the speed of an induction motor safely for different applications.

While training the students were given a choice of projects in which they could apply this knowledge. These projects were for temperature control, automating the milling process, visualisation of the brewing process and recipe control for different types of beers.

Each student was given the software so they could do the simulations at home. This way less time was needed to be on campus. Once the students had completed their work they could link their programmes to the actual equipment on campus for final testing. As functionality counted 30% of the final mark this was a very important part of the project. They could now take readings, analyse the results and compile a portfolio. As assessment is integral to meeting the required outcomes; students were required to present their projects at the end of the year.



Evaluation of Engineering Projects

The final evaluation of the subject is based on a year mark and an examination mark. The year mark is earned through the three progress reports.

The examination mark is earned through the final report and an oral presentation/examination. The oral examination is conducted once the quality of the final report is acceptable. During the oral examination the student is expected to demonstrate his/her project.

The Way Forward

UNISA being an open and distance learning institution, we are always looking into better and more efficient ways to support our students in their studies. Currently, we are making instructional DVDs to demonstrate the use of PLCs. We will also expand the types of projects available to students for 2017 to include renewable energy, reticulation design, andrino boards while expanding on the plant automation.

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Assessing the progress of South African planning students' in problem-based learning: A contextual approach based on Work Integrated Learning experience

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Work Integrated learning programmes (practical) in University courses are not new. Work-Integrated Learning (WIL) describes the range of educational programmes that integrate formal learning and workplace experience. Examples of such programmes are work-based projects, unpaid work, apprenticeships, practice firms and co-operative learning activities. Higher education Institutions in South Africa and other countries are continually required to assess the employability of students post-graduation. Studies carried out at various levels have shown that higher education institutions have both a responsibility and accountability for building theoretical knowledge and skills required for professional practice within chosen fields in students. In this research, we explore the factors affecting progress of South African Planning Students in problem based learning based on WIL. According to CHE (2011), WIL is used as an umbrella term to describe curricular, pedagogic and assessment practices across a range of academic disciplines that integrate formal learning and workplace concerns.

The research also is aimed at comparing the competency of students working under multiple tasks with those on one single task throughout the duration of WIL. There is also need to recommend appropriate interventions strategies. The research was a qualitative research with semi-structured questionnaire. The Sample Frame was the City of Johannesburg Metropolitan Municipality (CJMM). Focus group Discussion with City officials were also used to fully explore commonalities and differences in experience. The current interest in WIL in higher education is closely linked to government' and industry's' concern with lifting workplace participation and productivity, address skill and labour shortages and keeping pace with increasing demand and intensifying international competition.

A number of studies from the last decades have raised serious concern about work-readiness of graduates not in terms of graduates lack of disciplinary knowledge but in terms of their generic employability skills. Dressler & Keeling (2004 cited in Heerde & Murphy, 2009) in their review of outcome of co-operative education, noted some mix feeling results. They distinguished among academic benefits, personal benefits, career benefits and work skill benefits. Academic benefits (e.g. increase in discipline thinking, increase motivation to learn, improved performance in the class room). Personal benefits (e.g. increased communication skills, increased use of initiatives, increased team work and cooperation). Career benefits (e.g. improved career identity and clarification, increased employment opportunities and increased salaries) and Work skill development benefits (e.g. Development of positive work values and ethics, increased competency and increased technical knowledge and skills. Other scholars noted that

genuine education comes through experience. Experience in a real life context provides four conditions for effective learning: a knowledge base; a motivational base; learning activity and interaction.

The Department of Town and Regional Planning is used as the case study and it is located at the Faculty of Engineering and Built Environment of the University of Johannesburg. It is one of the planning schools out of the 11 planning schools in South Africa. The programme is accredited by South African Council for Planners (SACPLAN). It comprises of National Diploma & B.Tech programme. The WIL programme is 11 months training in the second year of study and has been in place since 1987. The students are properly guided on what to be expecting at the workplace as it relates to exposure to (spatial planning, statutory framework, land use planning, urban design & layout, strategic planning and management, Housing and GIS).The students are issued with log book in which they record all activities to be counter signed by a mentor. The department together with the coordinator evaluates the log book for final assessment to ensure compliance. Evidence from this research suggest that 60% of the students that took part in the WIL are provided automatic employment at the City of Johannesburg Metropolitan Municipality as compared to the municipality recruiting outsiders to feel vacant posts.

The employability of graduating students tend to be higher with WIL experience as compared to graduates who could not get any work based experience. Conclusion drawn from this research points to the fact that academic institutions should constantly monitor students involved in WIL and to seriously consider their valued feedbacks. It is important to constantly negotiate with employers the expected outcome. WIL should promote meaningful connections between general knowledge, the academic major and career experience. According to CHE (2011) “University teachers should be concerned to ensure that the students that graduate from their programme are prepared for the world in which they will live and work”. Policy changes at all levels is imperative to seriously account for unique needs of WIL. Exposing students to the various work units improves their career preparation and post graduate education prospects.

Keywords: *Work Integrated Learning, Town Planning Students, Career Experience, work skill benefits.*

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Socio-economic impact on engineering student performances: A TUT case study

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Introduction

The Tshwane University of Technology (TUT) has two campuses that offer a National Diploma in Electrical Engineering. Both campuses, Pretoria and eMalahleni, admit students for both mainstream as well as Extended Curriculum programs. In the South African context extended programmes are regular variants of diploma or degree programmes with an extended minimum duration (normally extended by six months) to create the curriculum space needed to enable underprepared students to achieve success. These extended programmes also facilitate equity, especially for the previously disadvantaged black students who does not meet the entry requirements (Ndebele, 2013; et al, 2015). ‘Under-preparedness’ is usually based on National Senior Certificate (NSC) results, an admission test, or both. Extending the duration of a programme to ensure a proper foundation was early on identified by Academic Support and Development units at South African universities over a period of three decades to be more effective than rather providing concurrent support such as additional tutorial programmes, more contact time or additional courses in English and Mathematics, as part of the first year.

During the past few years the eMalahleni region in the Mpumalanga province experienced the closure of large industries such as Evraz Highveld Steel and Vanadium, Vanchem, and a number of mines (Goldswain, 2016). Thousands of jobs were lost over a short period of time, resulting in a regional socioeconomic crisis. The purpose for this inter-campus case study is to determine if the socio-economic situation in the eMalahleni region adversely affected academic performance and placement of students. The study aims to correlate the performances of the two campuses by comparing the mainstream cohorts as well as the extended cohorts for the National Diploma in Electrical Engineering. Graduation rates as well as the potential delays that students experience when registering for the Work Integrated Learning (WIL) component of the National Diploma will be analysed and compared.

Methodology

The data used for this study was acquired from the university’s central Information Technology System (ITS). The cohorts considered were those who were newly registered between the periods of 2010-2014 in the mainstream as well as extended groups. Students were tracked up to the middle of 2016 resulting in a longitudinal study spanning 7 years. The cohorts analysed for the Pretoria campus Electrical Engineering department comprise 480 mainstream and 921 extended program students. Similarly, the cohorts analysed for the eMalahleni campus Electrical Engineering department comprise 297 mainstream and 524 extended program students. An analysis and comparison was done focussing on the graduation rates and the Work Integrated Learning (WIL) component between the two campuses.

Results

Figure 1 shows the graduation rates between of the two campuses. While the Pretoria campus mainstream program shows an 8% higher graduation rate than the eMalahleni campus, which has a mainstream rate of 37%, the extended program at the Pretoria campus shows a significantly better graduation rate of more than 16% above that of eMalahleni, which is just over 33%. Furthermore, the cohorts can be seen starting to graduate from the first semester after the minimum three-year duration of the National Diploma.

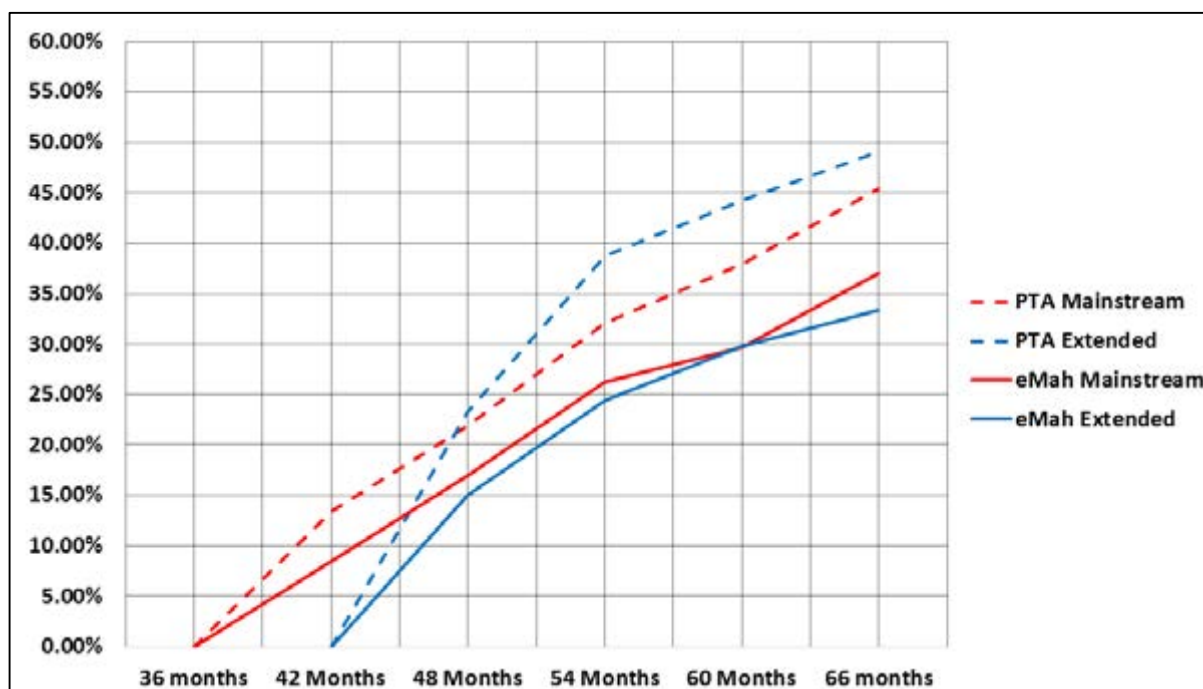


Figure 1. Cohort graduations comparing Pretoria and eMalahleni campuses for 2010-2014 new registered students. 1401 students for Pretoria campus and 821 students for eMalahleni campus represented.

Table 1. The number of semester taken between meeting the minimum requirement for WIL placement and actual WIL placement.

Semesters	Pretoria	eMalahleni
0	78.92%	61.54%
1	17.84%	21.37%
2	2.16%	14.53%
3	0.54%	1.71%
>3	0.54%	0.85%

Table 2. The number of semesters between WIL placement and qualifying to graduate.

Semesters	Pretoria	eMalahleni
2	77.42%	85.57%
2 to 4	20.53%	14.43%
>4	2.05%	0%

Table 1 reveals that on average the eMalahleni cohorts have more difficulties with placement directly after being eligible to be placed for WIL. 17% more students are being placed in the minimum time at the Pretoria campus. On the other hand, Table 2 reveals that the Pretoria campus cohorts are seen to take longer to finally graduate after registering for WIL.

Conclusion

Although differences can be seen in graduation results between the two campuses, further work is required to determine if this is a result of the students' academic ability, perhaps linked to the problematic secondary feeder schools in the eMalahleni region, or the socio-economic climate of the region. Although not too prominent, the problems that eMalahleni experiences with initial WIL placement may well be as a result of the socio-economic situation, forcing students to look for placement opportunities outside the immediate eMalahleni area, resulting in a longer WIL placement time delay. The continuing social unrest in the eMalahleni region, often resulting in the closure of the campus, might also be a contributing factor. The reason why some students from the Pretoria campus take longer to complete WIL, will also be investigated in future.

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Quantitative literacy practices in civil engineering study: Responding to a changing higher education landscape

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In the recent past the higher education landscape has been affected by student actions which clearly indicates that there is a need for the higher education landscape to respond more appropriately. Developing a better understanding of the demands made on students and the challenges faced by students to meet these demands is one way in which the higher education sector can facilitate the higher education transitions including the one from school to university.

Curriculum design for effective teaching and learning within quantitative disciplines need to consider how texts are constructed through language, images such as charts, maps or diagrams, and mathematical notation, which together form the repertoire of quantitative semiotic resources. It is useful to analyze how these semiotic resources work together, especially in terms of fulfilling specific functions in particular disciplinary contexts (O'Halloran 1999, 2009), such as the engineering sciences.

Civil engineering practices include graphical procedures for determining properties and/or factors that are important when working on or with soils, for example. These graphical procedures require of students that they construct and manipulate graphical representations of soil conditions. Embedded therein is the expectation that students possess the required quantitative literacies for successful undertaking of these procedures. Such assumptions are built into higher education curricula as a matter of course.

However, two problems emerge with this. On the one hand, fewer than 1 in 5 South African school-leavers are proficient in the quantitative literacy (QL) practices expected in higher education (Frith and Prince, 2016). On the other hand, academics are not necessarily able to articulate these assumptions as they are so enculturated into the discipline that they accept these practices merely as common sense (McKenna, 2009), that is, underlying QL practices are often tacit (Collins, 2001).

This paper applies a framework for quantitative literacy events (Frith and Prince 2006, 2009) in the analysis of two graphical procedures commonly used during undergraduate civil engineering courses throughout South Africa. The framework applied draws on the New Literacies Studies' view of literacy as social practice (Street 2005; Street and Baker 2006; Kelly, Johnston and Baynham 2007) and examines the specific practices that students need to engage with during individual QL events, defined here as instances in which individuals solve problems within disciplinary contexts using mathematical and statistical information that appears in verbal, graphic, tabular or symbolic forms (Frith and Prince 2006, 2009, 2016).

The analysis demonstrates that these graphical procedures constitute QL events in which students engage in practices such as 'knowing' quantitative terms, phrases, symbols and conventions; identifying and distinguishing relevant information; understanding representations of quantitative concepts; undertaking mathematical and/or statistical operations; reasoning and interpreting using quantitative concepts and representations; and, finally, communicating the results of this reasoning and interpretation. The benefit of such

analysis is that it makes explicit the practices deployed in such QL events, which can assist academics in improving the quality of teaching and learning in their classrooms.

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To ‘read’, or not to ‘read’, that is the question faced by undergraduate engineering students: Using the cloze procedure to reveal their choice

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Introduction

“To be, or not to be, that is the question”. These famous words, uttered by Hamlet in a soliloquy, written by William Shakespeare in the early 1600’s, point to a dilemma that people face when undergoing a trial some or unbearable situation (Bruster, 2007). Should they continue to exist, yes to tolerate the unbearable situation, or should they choose to end the suffering with a “bore bodkin” or naked blade.

Some aspects of this soliloquy may be applied to a task that many undergraduate engineering students face, but do not really enjoy, which involves *reading*. This includes a wide variety of texts in order to build student vocabulary, background knowledge, and genre knowledge (Dunn, 2014). However, it is a fact that many students do not like to read a lot (Mahmudi, 2013). It has also been noted that, in general, South African students are not meeting the reading and writing levels of achievement that their peers in other countries are reaching, even in other less well-resourced countries of Africa (Heugh, 2013). Some may thus come to view reading as a trial some or unbearable situation, one that is best cut-away by using a “naked blade”.

The research question thus arises “What percentage of undergraduate electrical engineering students are choosing to read their assigned prescribed course material?” The purpose of this paper is to reveal the percentage of students who are choosing to read by making use of a cloze test that was administered online using a higher institution’s learning management system (LMS). The cloze procedure is firstly explained and adapted to this study. The research methodology, results and conclusions follow.

The cloze procedure

The cloze procedure was first introduced by Taylor in 1953, who developed it as a reading test for native speakers (Kumar & Jena, 2013). Cloze tests are tests in which every n-th word is deleted randomly (Stevenson, 2015), usually being a consistent number somewhere between 5 and 12 (Iranrad & Ghonsooly, 2013). It has become widely accepted as a reading comprehension test among students whose mother tongue (first or home language) is not English. For example, researchers in South Africa made use of the cloze procedure to assess reading comprehension of marketing students (majority non-English mother tongue) by removing every 9th word from four specific passages of text (Berndt, Petzer, & Wayland, 2014). Various criticisms have been levelled against the cloze procedure, but despite these criticisms, it is still regarded as being ‘very helpful’ as a ‘general proficiency indicator’ (Hadley & Naaykens, 1999).

Cloze procedures are often used as a diagnostic style of reading assessment technique in which the purpose is to identify students' knowledge and understanding of their reading and to assess how well they know which words fit in to the syntax structure related to their (McBain & Mhunpiew, 2014; Xiang et al., 2015). Cloze tests are usually a minimum of two paragraphs in

length in order to account for discourse expectancies, using two approaches for scoring, namely exact word and appropriate word approaches (Purwaningsih, 2013). However, the nature of the context differs across studies, ranging from a single sentence to a text passage and/or a picture (Ionin & Zyzik, 2014). A strength of the cloze procedure is ease of construction based directly on reading materials that individuals are expected to read, usually in academic settings (Meier, Keith, & Dwyer, 2014; van Rensburg, Coetzee, & Schmulian, 2014). This is how the cloze test was applied in this study, not to measure reading comprehension, but to determine the percentage of students who chose to read the portion of prescribed course material assigned to them. Several single sentences were extracted from each portion of prescribed course material, where every 5th word was deleted. Undergraduate students were then required to supply the missing words.

Research Methodology

A longitudinal study involving quantitative data is used. This is done for a period of three years (2014 – 2016) by obtaining quantitative data for each year from a different group of undergraduate electrical engineering students at a University of Technology in the Free State Province of South Africa. The target population involves all undergraduate engineering students enrolled for a specific module in electronic communication ($n = 41$), thereby requiring no sampling technique.

Students were given a specific portion of prescribed course material to read every second week. During every third week, they were required to complete a self-assessment on the institution's LMS, called eThuto, which included a cloze test. Correctly inserting more than 50% of the correct words into the missing spaces would serve as an indication that the students chose to read the assigned portion.

Results

The majority of students were male (80%) and older than 25 years of age (59%). Only 12% indicated that their mother tongue was English. Of the 41 students, 3 inserted more than 80% of the correct words, while 10 students never achieved more than 20%. The average number of students who correctly inserted more than 50% of the correct words over the three-year period equalled 21 (51%). A statistically significant correlation was not found between the percentages of correct responses and the final grade awarded to students at the end of the semester. However, all the students who achieved more than 70% correct responses (8 students in total) successfully completed the module.

Conclusions

The purpose of this paper was to reveal the percentage of students who are choosing to read their assigned portion of prescribed course material by making use of a cloze test that was administered online using a LMS. The results indicate that more than half of the students seemed to choose to read the assigned portion, with all students passing the module if they filled in more than 70% of the correct words. To read, or not to read, will continue to be a question that engineering students will have to answer for themselves. Their decision should not be taken lightly, as it will bring them either beneficial or disastrous consequences.

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The manufacturing sector's response to the lack of appropriate technical expertise in South Africa

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Introduction

Industry dissatisfaction with 21st century engineering graduate abilities is a global concern when employers across 42 countries cite 'lack of required technical skills' as the key reason for not hiring graduates (manpowergroup.com 2015). This may explain why South Africa (SA) – which was included in the survey – saw 10 000 technicians as unemployed in 2012, and 31.2% of all Science, Engineering and Technology graduates of the Western Cape universities (CHEC, 2013), despite the ostensible scarce skills crisis (Du Toit & Roodte, 2008). In attempting to address graduate inability to 'apply knowledge' (Griesel & Parker, 2009), we see increasingly practice-orientated educational initiatives, such as project- and problem-based learning, and the compulsory Workplace Learning (WPL) period for University of Technology (UoT) students. However, 65% of the latter are unable to find WPL positions (Mutereko & Wedekind, 2015). The unacceptably low number of graduates thus available for employment and the perceived deficiencies of existing graduates have a significant impact on how the SA engineering sector responds to their human resource (HR) needs.

An ongoing research project investigating engineering practices seeks to provide theoretically-informed, empirical insights into what it is that employed UoT engineering graduates actually do and are expected to do in the field. The intention of the research is to be able to respond more effectively to the education-to-profession 'articulation gap'. Based on 34 comprehensive case studies to date, this paper presents three different approaches taken by the manufacturing sector in response to the 'technical skill deficiencies' crisis in the Western Cape region.

Objectives & methodology

Over the course of seven years a wealth of data has been gathered on three different research projects designed to understand engineering practice at industrial sites. The methodologically pluralist studies draw on semi-structured video interviews, participant and company profiles, "records of discussions, chance conversations, ... observational notes, ... and quantitative data" (Case & Light, 2011, p. 195). One common complaint to emerge from employers is the lack of local expertise in high-end automation technologies, particularly where new technologies present a great deal of uncertainty (Leonardi, 2011). The added pervasive lack of accurate documentation (Briand, 2003), and inability of (usually) international suppliers to understand different contextual applications result in significant challenges for local manufacturers. This paper looks at how three different companies respond to this challenge.

Theoretical tools

A useful analytical tool - developed from the Legitimation Code Theory (LCT) *Specialization* concept of *epistemic relations* (Maton, 2014) – is the *epistemic plane*. This is a graphic way of representing the relationship between a phenomenon (what) and its approaches (how) in any particular knowledge practice (figure 1). The two axes – *what* and *how* - are strong/weak

continua which give us four quadrants. The strongest quadrant (*purist*) sees an unambiguous ‘what’ and ‘how’ in that the phenomenon being addressed is commonly accepted and has standardised protocols. The weakest quadrant sees an ill-defined phenomenon with open-ended approaches. The alternate quadrants represent either strongly bounded phenomena with multiple approaches or strongly bounded procedures that could apply to any phenomenon. In this paper, the *epistemic plane* is applied to how companies approach ‘the lack of technical expertise’. The *purist* quadrant represents the firm belief in expert knowledge and protocols; the bottom-right (*doctrinal*) sees decontextualized training-for-training’s-sake; the bottom-left quadrant sees the foregrounding of existing company capacity and needs (*knower insight*).

Different approaches to scarce skills shortages

Company A is a large automotive component manufacturing branch of an international company. Their priority is to remain productive and competitive. So, to avoid local operator error, they increasingly integrate situation-specific automated systems, even when the most cost-effective solution is operator training. Their approach suggests a lack of faith in the ability of existing employees to adapt or acquire new skills. The second case – machine builders (B) - sees a firm belief in expert knowledge and practice (*purist*), which requires standardised application in multiple contexts (*doctrinal*). Company B is a SA company, but has begun to move most of its manufacturing activity abroad, citing the lack of local expertise. In contrast, a local beverage production company (C) has explicitly begun a training programme that recognises the dire need to upskill local capacity (*knower insight*), not only technically, but also acknowledging that “there is a need for developing understanding in the longer term”.

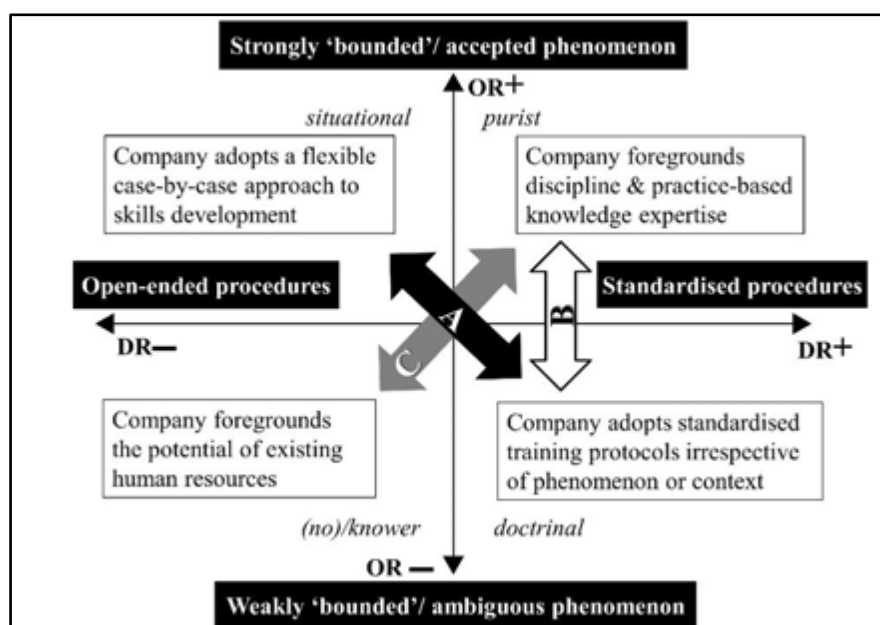


Figure 1. The *epistemic plane* – company approaches to technical expertise

These industry examples of how manufacturers approach the lack of technical expertise present useful insights for educators. Firstly, the *epistemic plane* highlights the significance of *different* approaches to contextual problem-solving, whether HR or technical. Applied to curriculum and pedagogy, the analytical tool could aid in shifting our perspectives on *how* we teach *what*. Secondly, the data suggest that Higher Education faces the challenge of regaining industry’s trust in our potential ability to equip graduates. This can only be accomplished through better education-industry collaboration. Much is at stake should we fail.

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