

Development of an engineering identity: Personal discovery of classroom mathematics in “real engineering”

Tracy S. Craig

Academic Support Programme for Engineers in Cape Town, University of Cape Town
Centre for Research in Engineering Education (CREE)

Tracy.Craig@uct.ac.za

Abstract

This article reports on an activity in a first-year engineering mathematics class designed to strengthen students' personal identities as novice engineers. The literature on identity suggests that students are more likely to be retained in an engineering degree programme if they develop an identity as an engineer and that development of such an identity is encouraged and supported if students can see the relevance of their studies to future studies or their future career. The mathematics encountered at a first-year level is often of an unrealistic nature due to its largely algebraic content as well as to the fact that real-world engineering problems are often intractable without using more advanced mathematics than is accessible in a first-year course. The activity described in this article endeavoured to build empirically on the theoretical issues raised in the literature by asking “Can students identify the presence of classroom mathematics in real-world engineering texts and does this recognition encourage the development of identity as a novice engineer?” Sixty-six students studying first-year engineering mathematics in an academic development programme at a South African university took part in the activity. Data consisted of the students' written assignments and their responses to a Likert-style questionnaire. The written assignments were graded on the strength of their alignment with the task's mathematical requirements. Specifically within the course topic of *Applications of Differentiation*, the students were required to use resources from the library and the internet to find examples in real-world engineering where differentiation is used for practical purposes. The examples that the students investigated were necessarily expressed in the discourse of engineering, yet drew on mathematics the students had recently encountered in the classroom. This evident trajectory of knowledge from pure classroom practice to real-world engineering use allowed the students ready access to the discourse of engineering and ideally fostered development of identity as an active novice participant in the world of real engineering. A minority of students did not succeed in the task requirements, but the bulk of the students found the task interesting and informative. Several students expressed surprise and pleasure that they were able to understand what they were reading, revealing to them that they were already participants in the engineering community with some fluency in the discourse.

Keywords: engineering identity, mathematics, real-world engineering practice, discourse

Introduction

Retention of students in engineering studies is currently of interest worldwide as well as in South Africa (Hartman & Hartman, 2006; Suresh, 2006/7; Haag, Hubele, Garcia & McBeath, 2007; Scott, Yeld & Hendry, 2007; Allie et al., 2009). One approach to the issue of student

retention suggests that lack of development of “engineering identity” results in attrition as students leave tertiary studies or move to other fields of study (Allie et al., 2009). Development of identity in the engineering community can be encouraged through breaking boundaries between areas traditionally kept distant, such as first-year mathematics studies and advanced engineering practice (Stevens, O’Connor, Garrison, Jocuns & Amos, 2008; Porter & Fuller, 1998). The activity described in this article intended to encourage the development of identity as a novice engineer by making explicit the connections between classroom practice and real-world engineering (see for instance Reed, 1951). By describing the trajectory between recently mastered textbook mathematics and future practice mathematics the students were challenged to acknowledge their legitimate peripheral participation in the engineering community (Lave & Wenger, 1991). This article presents the activity designed to develop students’ identity as novice engineers and looks at whether the outcomes present evidence of this having taken place.

The content of the first-year mathematics course in the local engineering faculty, the way in which it is generally taught and the prescribed textbook are almost indistinguishable from a course which might be available to mathematics major students. While there are applied aspects to the course, notably applications of differentiation and integration, few of the common examples for use in class are convincingly real-world problems (Gerofsky, 2004). Such an uncontextualised course still serves a valuable role in preparing the students for more advanced engineering courses which will supply them with the skills and necessary discourse literacies for dealing with real-world engineering problems. However, a largely algorithmic, algebraic mathematics course has the disadvantage that it is disconnected from the real world of the engineering discipline and can easily be disconnected from other subjects the students study (El Gaidi, 2003; Holmes & Spilker, 2007).

This article describes a student learning activity which was explicitly aimed at the development of engineering identity without requiring a major restructuring of a course. The activity had low impact on the course design by fitting easily into the existing course curriculum and did not add onerously to the lecturer’s workload. Many other reported activities designed to develop engineering identity, such as service-learning projects (Ropers-Huilman, Carwile & Lima, 2005), require changing a course substantially, with potential impact on other concurrent or future courses.

In support of the importance of identity development in novice engineers a background of theoretical viewpoints on identity is presented. The activity under discussion is described followed by the research methodology providing details such as numbers and backgrounds of students taking part. The results are presented and are thereafter discussed in the context of the theoretical issues surrounding identity development.

Theoretical background

A number of studies in the engineering education literature (Allie et al., 2009; Stevens et al., 2008) describe a theoretical position that students will be more likely to engage with their studies, attain their undergraduate degrees and remain in the engineering profession if they

have developed an identity as an engineer. This identity can be termed a discourse identity (Brown & Ryoo, 2008) if it is recognised as being constructed within, and with the influence of, the discourse of engineering. The activity described in this article was an attempt to explore the role of mathematics learning in building such engineering identity.

Traditionally, engineering students are told with sufficient authority that mathematics is vital for engineering practice and they believe it. This justification for a mathematics course is what Porter and Fuller (1998) call the “trust me” approach. None of the students ask, “Why do I need to do this course?” However, there is little direct evidence available to the students on where, when and how they will use the skills they are learning in their first-year classroom. From the point of view of the students, they can end up studying subjects that seem to bear little relation to one another. They can move from course to walled-off course with little understanding of how they all integrate, to future studies, and to future practice (Holmes & Spilker, 2007; Crouch & Haines, 2004; El Gaidi, 2003). It is suggested that development of engineering identity would benefit from clearer connections between courses and between present and future studies, providing the students with a clearer picture of their degree as a holistic entity and of their own position and role in the university and engineering field.

Generally, our students’ interest in engineering is very high when they enter the program, but decreases during the first year. By presenting connections to engineering disciplinary thinking early, students should be better able to understand the relevancy and necessity for related basic science courses.

(Porter and Fuller, 1998, p. 399)

The topic of the unrealistic nature of first-year university mathematics has been widely discussed (Gerofsky, 2004; Verschaffel, Greer & de Corte, 2000). The reasons include the fact that real-world problems have too many parameters, are too ill-defined, or require mathematics too advanced to be represented accurately in first-year teaching texts (Noble, 1967). There are well respected textbooks of first-year engineering mathematics which have examples which are convincingly real-world engineering problems (see, for instance, Stroud & Booth, 2007; James, 2008; Trim, 2004; Ravindran, Ragsdell & Reklaitis, 2006). The activity described here involved something different, however. Instead of using real examples in classroom practice, students were required to find examples of classroom mathematics being used in real engineering texts. While any textbook examples, however realistic-looking, could be potentially regarded by students as unrealistic and irrelevant (often justifiably so), the personal discovery of the presence of recognisable mathematics in a non-university text (perhaps a book on fluid dynamics used by chemical engineers in industry) has perforce to make apparent the authentic connections between classroom mathematics and mathematics used in post-university practice.

A subset of the literature on identity in education (Allie et al., 2009; Brown & Ryoo, 2008) uses the term *discursive identity*, which can be defined as “an understanding, either implicit or explicit, that speakers and listeners use to interpret or communicate who an individual is understood to be, as communicated through the use of language” (Brown and Ryoo, 2008, p. 533). While the task discussed here could have demanded stronger interaction with disciplinary discourse, its weak formulation required the students to broadly report what was

being described in the text they had found. The students necessarily had to engage with content described in a discourse valued by the engineering community but could successfully fulfil the task requirements without employing such discourse themselves or without deeply engaging with the discovered text. Rather the task focuses on personal identity as a student engineer – what could be termed “positional identity” (Bingolbali and Monaghan, 2004). In the language of Gee (2001), the activity was perhaps not encouraging a “discourse identity” at all, but rather an “affinity identity” attempting to create the sense within the students that they share access to and participation in a specific community or “affinity group”, which shares interests in specific practices, such as solving real-world engineering problems by appropriate use of mathematical modelling. Hereafter the word “identity” can be understood to be akin to “discourse identity”, identifying oneself as a member of a discourse community through active engagement with and interpretation of the text of that community.

Stevens et al. (2008) are interested in the process of *becoming* an engineer (rather than simply achieving mastery of course content), one aspect of which they regard as *identification*: “how a person identifies with engineering and is identified by others as an engineer” (p. 356). Such identity is “formed out of a double-sided process of positioning ourselves and being positioned by others” (p. 357). It is this positioning of self both within the community of engineers, within the landscape of university engineering studies and along the trajectory of discipline-specific learning that the task described in this article was attempting to target. Stevens et al. (2008) suggest that access to certain physical spaces and resources (common rooms, laboratories, examination banks) has an influence on identity development by allowing the students to recognise their admission to a specific community. Similarly, access to the discourse of a discipline influences identity, particularly if the student (or otherwise peripheral participant) is allowed to engage with that discourse and gain mastery over its use.

We might name identification among our three dimensions [accountable disciplinary knowledge, identification, navigation] as *the compass* that guides one to make a pathway through engineering. If that compass is lost or broken, students’ commitment to meeting the challenges ... may too be lost.

(Stevens et al., 2008, p. 365, emphasis in original)

Description of activity

The student learning activity described in this article took place in a first-year mathematics course for BSc Engineering students at a South African university. The students in the course study electrical, mechanical, chemical and civil engineering, as well as mechatronics and geomatics. The course is a standard first-year mathematics course consisting of calculus (differential and integral) rules and applications, differential equations, vector geometry, linear algebra, finite and infinite series and complex numbers. The course runs continuous assessment with several strands, one of which is a series of writing assignments. All writing assignments have to be satisfactorily completed in order to obtain permission to write the final examination. The activity described in this article formed one of the writing assignments.

The mathematical topic in the activity described here, *Applications of Differentiation*, was chosen for investigation for several reasons. First, using differentiation in a practical situation is a technique common to the mathematics of all engineering disciplines. This cannot be said

for all mathematical topics covered in first year studies, for example complex numbers. Secondly, the author knew from experience in the library that the students would find it easy to find examples of the requested type, having found several herself within half an hour simply pulling books (almost randomly) off shelves and looking up likely sections listed in the index. Thirdly, engineering, as viewed from the standpoint of a mathematics course, is focussed on mathematical application. The proofs, derivations and abstracted algorithms are valuable in engineering only insofar as they can be practically applied. This activity explicitly focussed on that aspect of mathematics most valued by the students: its applicability. Lastly, the examples in the textbook are quite obviously contrived (for good reasons), leaving the student without a clear sense of when or where these techniques might be applicable in more realistic situations. This activity allowed them to engage sufficiently with applications of differentiation in real-world engineering practice without the disadvantages of bringing those examples into the classroom, that is too complex a context or too complex mathematics. In a sense the students become observers of mathematics in action rather than the protagonist of the mathematical action.

The students were encouraged to search for examples of applications of differentiation either online or in the university library. The students were explicitly discouraged from finding a typical mathematics textbook, albeit an engineering mathematics textbook, in a bid to avoid further contrived examples. Students were given the following assignment guidelines, and two weeks to complete the task:

Find an example of differential calculus, as we have used it in class, being used in real engineering. This could mean related rates, optimisation, complicated curve sketching or Newton's Method for finding roots.

The easiest one to find is probably optimisation. DO NOT take a word problem from a textbook like our maths textbook that just looks like an engineering problem. The source must be unarguably an engineering source. Your submission should include a copy of the maths you have found (photocopy or printout) as well as a brief explanation of what is being done. I have no expectation of you understanding the finer details, but I do want you to be able to say roughly what is going on.

Research Methodology

The course in question was located in a so-called "academic support" programme. The students registered for the course applied to study engineering at the university, but did not have sufficient "university entrance points" to be accepted into their chosen engineering department. Upon application, these students were identified on the strength of their high mathematics and science results to have the potential to succeed at university despite previous educational disadvantage. The approximately 70 students registered for the author's course have, on average, lower school-leaving results than the students in the mainstream programme. To be accepted for either engineering programme, mainstream or academic support, high school-leaving results are required in both mathematics and science. The course content is identical in both programmes, however the assignments, assessment protocol and resources differ, making possible the assignment discussed in this article.

Sixty six students took part in the activity. The gender distribution in the class was 16 (24%) female students and 50 (76%) male students. The group consisted of 56 African students, nine coloured students and one white student. No data is available on the students' main languages, however, from the author's familiarity with the students, approximately 15% of the class spoke English as a main language; certainly the majority of the students would have spoken English as an additional language with a wide range of proficiencies.

The data consisted primarily of the written assignments with their accompanying original text (photocopy or printout). Eight of these students were required to resubmit the assignment, giving a total of 74 submissions in the final analysis. Additional data included student responses to a questionnaire completed at a later date. The assignments were graded on the mathematical content of the attached text and the student's own discussion. The marking was lenient inasmuch as the author was sympathetic to the dangers of the students mistakenly seeing applications of differentiation where there was none, such as differential equations or finite element analysis.

The research question was "Can students identify the presence of classroom mathematics in real-world engineering texts and does this recognition encourage the development of identity as a novice engineer?" The assignments which the students submitted clearly demonstrated that they could identify classroom mathematics in real-world engineering texts. The student discussions reveal many of them to be engaging with and interpreting the text of the engineering community, thereby becoming active in the engineering discourse community (Allie et al., 2009). The theoretical position of the identity literature presented in this article maintains that by the students personally recognising connections between first-year mathematics studies and disciplinary practices, they have a greater chance of engaging with their studies, now understood to be more relevant, and of developing an engineering identity (Stevens et al., 2008; Porter & Fuller, 1998).

Results

The assignments were marked A (excellent), B (good) or C (resubmit). All assignments were commented on. The unsatisfactory assignments had the requirement for resubmission explained; in most cases the submitted text had no connection with differentiation at all. Students were allowed any number of resubmissions in theory, although in practice the timing of the students' schedules resulted in only one resubmission for each student who received a C grade. An A or B grading had to be received in order for the student to receive permission to write the final examination, however the assignments did not contribute to the students' final summative results.

Of the 66 submissions received, eight were graded as "C – resubmit", the rest were graded as "A – excellent" or "B – good". It is important to note that a formal analysis of the mathematics represented in the student submissions resulted in 11 of the original submissions being regarded post-hoc as "unacceptable" (and hence eligible for a C-resubmit grade), however three of those students were, at the time of assessment, given a passing grade of B on

the strength of their discussion and potential confusion in terminology and notation. After the eight resubmissions were received, this gave a total of 74 written assignments, all of which are included in Table 1.

The marking was carried out with understanding for the students not recognising certain types of notation (notably differential equations) and with credit given for a good discussion even if the text supplied was not entirely acceptable. The author considered the student text to constitute a “good discussion” if the student had made an effort to engage with the engineering text and used his or her own words to describe how differentiation was understood to be used in the real-world context. Assignments requiring a resubmission were considered unacceptable for simultaneously not including any relevant mathematics (or the appearance of relevant mathematics), nor a discussion from the student indicating that s/he had made an effort to understand the topic under discussion. It is worth noting that the eight resubmissions included five that were still technically unacceptable and, strictly, should have been returned to the student for yet another resubmission.

Twenty of the submissions (see Table 1) were directly on task, almost entirely optimisation examples, although related rates and Newton’s Method also featured. “On task” here refers to assignments which included an unarguable use of differentiation in real-world engineering. Thirty eight of the submissions were deemed acceptable, although a more knowledgeable eye could recognise that they were not entirely on task. A recurring issue was terminology misunderstanding, for instance seeing and misunderstanding non-calculus use of the word “optimisation”. Another recurring issue was mistaking differential equations and their solutions as optimisation procedures. The students had not yet covered differential equations in class; mistaking such systems for an application of differentiation was understandable, particularly as the differential equations were often imbedded in dense text and other mathematics. Further issues included notational misunderstanding (such as regarding dashes as inevitably referring to a derivative), calculus use not being clear although present, and optimisation through the method of finite elements. Three students submitted examples that were clearly contrived textbook examples and not real-world engineering at all. Table 1 summarises the categories found to be present in the completed assignments.

Table 1 Numbers in Assignment Categories (74 in total, including 8 resubmissions)

On Task	20	
Acceptable	38	
	11	Reference to optimisation, but no convincing calculus shown
	9 ^a	Differential equations
	7 ^a	Misunderstanding of notation (e.g. dashes)
	5 ^a	Calculus use is unclear, potentially implicit
	3	Contrived example
	3	Optimisation using finite element method
Not Acceptable	16	
	3	Not Acceptable, yet given a B grade for a good discussion
	8	Returned to the student for resubmission
	5	Second submissions, yet remaining Not Acceptable

^a includes 1 resubmission

The 20 students whose assignments were “on task” as well as the 35 who found the presence of something resembling differentiation in authentic (not textbook contrived) real-world engineering texts together (55 students) represent a substantial majority (83%) of the class who personally and individually made connections to engineering disciplinary practice thereby ideally understanding the relevance of the classroom-encountered mathematics to engineering practice (Porter & Fuller, 1998).

The students answered a short questionnaire on the writing assignment; the results are presented in Table 2. A Likert scale was used for speed of completion. A space for open-ended responses was provided, however few students made use of this option.

Table 2 Percentage of students answering the questionnaire (N = 56)

	No (%)	Neutral (%)	Yes (%)
1. I found the assignment challenging to complete ^a	36	20	44
2. I understood more in the text than I was expecting to ^a	22	25	53
3. I found suitable text in under an hour of searching	46	18	36
4. I was already convinced that differentiation was useful in engineering	9	16	75
5. The assignment improved my understanding of the place of differentiation in engineering	11	18	71
6. The assignment made me feel more connection with the engineering world	14	34	52
7. I was sure (at the time) that the text I found did include differentiation specifically	11	20	70
8. I specifically looked for text in my engineering discipline	45	7	48
9. I managed to find text in my engineering discipline	30	11	59
10. I felt like I was doing real research	25	20	55
11. I enjoyed the assignment	20	21	59
12. I could not see the point of the assignment	75	13	13

^a N = 55

As Table 2 indicates, 75% of the students were convinced of the usefulness of differentiation in engineering before the activity, yet 71% felt that the activity improved their understanding of differentiation’s utility. These data suggest that strong links being drawn between classroom mathematics and real-world engineering mathematical practice can augment the “trust me” approach and can further strengthen a student’s understanding of the relevance of mathematics in their chosen profession. Approximately half the students, 52%, reported that the activity allowed them to feel “more connection” with the world of real engineering practice. Question 6 was perhaps poorly worded, but suggests that identity, as defined as access to and participation in a community (Gee, 2001), was enhanced in approximately half the class. Both these self-reported statistics indicate an increase in or affirmation of identification with the discourse of engineering practice.

The assignment required the students to describe what the text they found was discussing. While some students simply repeated excerpts of the text itself in their description, many of the students made an effort to understand and to describe it in their own words. It was this active engagement with the text which the activity was aiming to encourage with the anticipation that this might help the students feel some ownership of the engineering task being described through their familiarity with the basic mathematics being used.

Example 1 – Bulelani [all student names have been changed] (A – On task)

Bulelani gave a partial reference. The source is understood to be Reed, M.B. (1951) *Mathematical Methods in Electrical Engineering*. New York: Harper. (p. 126/7)

... we can compute the load power as

$$P_L = \frac{v_T^2}{(R_L + R_T)^2} R_L \quad (3.34)$$

To find the value of R_L that maximises the expression for P_L (assuming that v_T and R_T are fixed), the simple maximisation problem

$$\frac{dP_L}{dR_L} = 0 \quad (3.35)$$

must be solved. Computing the derivative, we obtain the following expression:

$$\frac{dP_L}{dR_L} = \frac{v_T^2(R_L + R_T)^2 - 2v_T^2 R_L(R_L + R_T)}{(R_L + R_T)^4} \quad (3.36)$$

which leads to the expression

$$(R_L + R_T)^2 - 2R_L(R_L + R_T) = 0 \quad (3.37)$$

It is easy to verify that the solution of this equation is

$$R_L = R_T \quad (3.38)$$

Thus, to transfer maximum power to a load, the equivalent source and load resistances must be matched, that is, equal to one another.

The student above accompanied his well chosen text with discussion clearly indicating his recognition of familiar classroom mathematics in this real-world situation. The student has personally discovered valid use of a technique which can be in danger of being “walled off” from authentic practice. It is this boundary crossing between areas of study and practice that is a necessary condition for robust identity development.

Example 2 (in the student’s own words) – Adika (A – On Task)

“I have found an engineering principle that uses related rates in order to determine the growth of an individual grain. What von Neumann’s law does is to find the rate of froth (bubbles) in a 2 dimensional way, by relating the surface area to its radius and then differentiating the radius with respect to time.”

Adika identified the use of the standard technique of “related rates” in real-world engineering text and described the context in her own words. The student recognised the presence of recently-encountered classroom mathematics within a more advanced engineering context

which necessarily made her aware of the relevance of first-year mathematics to at least certain aspects of engineering practice.

Example 3 (in the student's own words) – Katlego (B – Acceptable, the finite element method)
“In this problem, the sides are varied to get the accurate dimension of the valley damming walls. The best shape is to be designed. The varied dimensions are the parameters. But it will not be easy to vary the dimensions in a prescribed range, however in this problem the dimensions' derivatives are to be considered with respect to material properties to attain generality, to get less uncertainty if there may be any.”

Katlego struggled to describe the context of the multivariate calculus he had located, a form of calculus not yet encountered in the classroom, further complicated by solution using the finite element method. Unlike Adika's more explanatory original text, the context was not entirely clear from Katlego's available text and he had to engage deeply with the text in order to draw his conclusions. To have understood the details, quite correctly, as he has done, Katlego had to grapple with and understand applications of familiar mathematics in an unfamiliar context. Not only has he been able to draw links between classroom mathematics and real-world engineering but he has had to advance his symbolic understanding of mathematics to some extent in order to do so.

Example 4 (in the student's own words) – Pamela (B – Acceptable, use of differential equations)

“I got this content from a book that discusses processes of a plant simulator. Here the autor is calculating various quantities:

[Pamela lists three objectives of the attached text, all related to drainage]

So all this calculations can be used in a couple of engineering applications for instance, environment engineering, checking if land is suitable for any developments. Civil Engineers, to see if the plant simulator can simulate exactly what is happening above.”

The mathematical text supplied by the student uses differential equations, which were unknown to the students at the time of completing this assignment. It is unsurprising that Pamela would understand this to be an application of differentiation similar to those few we had covered in class. She describes the context confidently in her own words and extends her discussion by suggesting uses of this process in contexts not supplied by the text, for example, environmental engineering. Pamela's interest in environmental engineering resonates intriguingly with the findings of Jawitz and Case (1998), at the author's institution, that black female engineering students (like Pamela) often choose engineering as a career as it is one where they will be able to serve their communities. The potential of activities such as the one discussed here to lend support to students' already existing robust engineering identities raises intriguing possibilities for future assignments designed with identity development in mind.

Students enter a university degree programme with an existing (possibly naïve) understanding of what it means to be an engineer. As such they begin the programme with an engineering identity. Classroom activities which support already existing engineering identities as well as

activities which (further) develop identity formation are valuable. Somehow discerning with what engineering identities student enter the programme has implications for further interventions designed to support and encourage identity development.

Example 5 – Refilwe (B – Acceptable, notation error: misunderstanding integration)

“This is a problem chemical engineers deal with everyday. Basically what is happening is that we have an isothermal reactor. Temperature and pressure are kept constant. What they want to do is convert the chemical substance ethane into other substances, ethylene and hydrogen. So we are looking at the rate of change in concentration of ethane against the rate of change of the volume of the reactor that is occupied by ethylene and hydrogen.” The student’s discussion continues at some length.

From the author’s point of view, the mathematical text supplied makes brief mention of a differential equation and the calculus thereafter present in the text is integral calculus. Refilwe’s discussion appears aligned with the mathematical processes shown, however her explanation is either entirely her own or sourced from further references which she has consulted to understand what she is reading. She has included hand-drawn graphs to further illustrate her discussion and altogether appears to be engagingly deeply with the advanced context of reactor theory which she has chosen. Refilwe was registered for a degree in Chemical Engineering and took on the challenge in this mathematics assignment of grappling with mathematical processes strongly aligned with her chosen discipline.

Example 6 – Lerato (C – Not Acceptable, no evidence of any mathematical processes)

Lerato submitted a discussion on heat exchangers and water networks designed to minimise length of piping and freshwater usage. While the discussion had some merit, the student drew heavily from the text instead of using his own words and the text he submitted was the abstract only of an unreferenced paper. No evidence of a mathematical process was present although the paper title included the word “optimization”. While the connection to *Applications of Differentiation* was apparently inferred by the use of the word “optimization”, evidence of any mathematics beyond the use of that one word was not apparent in the text. There was no indication that the student had understood himself to have found evidence of classroom mathematics in real-world engineering, thereby obviating the purpose of the activity which was for the student to isolate evidence (with whatever degree of true mathematical accuracy) of classroom mathematics in real-world engineering.

The majority of the students used their own words to describe the processes they were reading about while simultaneously using terminology learned in the mathematics classroom. They displayed confidence in taking on technical discourse practices to make connections between familiar classroom mathematics and real-world engineering practice. It is unfortunate that students’ verbal commentary on the assignment was not recorded by the author as all students who had such a conversation (approximately ten students) were enthusiastic about their discoveries. Surprise and pleasure were expressed at having found clear use of classroom mathematics in texts ranging from doctoral theses to academic journals.

Discussion and Conclusions

It is reasonable to ask “Is there a relationship between the assignment and the development of identity; also did the measured output (submissions and questionnaire data) reflect this construct of identity development?” In other words, does the assignment have construct validity? Porter and Fuller (1998) state that “by presenting connections to engineering disciplinary thinking early, students should be better able to understand the relevancy and necessity for related basic science courses” (p. 399). The assignment discussed in this article had as its core the discovery of basic classroom mathematics in engineering disciplinary texts, making explicit the relevance of differentiation, in this case, to real-world engineering practice. By the students investigating a range of texts and discovering the mathematics for themselves, they are reifying their access to and participation in the world of engineering, thereby encouraging what Gee (2001) calls an affinity identity. Similarly Stevens et al (2008) emphasise the importance of identification and its relationship with access to discipline-specific resources in the process of becoming an engineer. The measurable output of the assignment perhaps did not lend itself to particularly insightful analysis of the degree of success in identity enhancement. Focus group interviews would have been far more informative, yet there was no unproblematic way of inserting such into the already densely packed course. Any future repeats of this assignment in the author’s course would be run similarly with perhaps a longer and more sensitively worded questionnaire.

As for external validity, our ability to generalise the activity to other classroom settings appears straightforward, certainly for any applied mathematical context. Certainly different mathematical contexts might require more specific instructions, such as specific individual texts to investigate, whether to focus on books or journals or online resources, or specific terminology or notation to look out for or avoid. Discussion of the assignment with an academic subject librarian could both help the instructor with setting a workable assignment and prepare the librarian for queries with which the students might approach them.

The majority of the students engaged with the literature of “real-world engineering” in agreement with the requirements of the assignment. There were multiple instances of incorrect interpretation of terminology and notation which were accepted, due to understandable confusion on the part of the first-year student, but there were also multiple instances of on-task submissions of applications of differentiation in real-world engineering contexts accompanied by thoughtful discussion. Optimisation examples formed the bulk of the applications provided, although a few students found instances of related rates applications and one student contributed an example of Newton’s Method in use. Of the 58 “acceptable” entries, 55 described a context unarguably real-world. Only three of the submissions with a passing grade contained obviously contrived examples. Indeed, even the examples graded as “C – resubmit” were in a real-world engineering context, they simply did not meet the mathematical requirements of the task.

Allie, et al. (2009) suggest that the development of identity in a community is necessary to become a core participant in that community and that the development of such an identity is a contributing factor to remaining in the community. In the context of concern over student

attrition, there is a need for decreasing any sense of alienation the students might experience during their degree. One way of decreasing a sense of alienation is to attempt to make connections between different subjects studied and to make connections between classroom practice and the professional world of engineering. The lecturer bringing real-world engineering problems to the classroom is a necessary part of connecting classroom mathematics to the real world, but the students actively seeking out such mathematics themselves necessitates a level of agency that is otherwise missing from the classroom. It is impossible to tell from one assignment within one first-year university course whether identity development plays a role in student retention. Such identity development or enhancement should take place throughout the degree programme over several years and multiple courses.

The activity described in this article was a satisfactory empirical extension of the theoretical position on identity encouragement through interaction with authentic and valued disciplinary discourse. A majority of students reported an increase in their understanding of the use of differentiation in engineering and half the class felt more connection to engineering real-world practice. Future assignments similar to this one might choose a different mathematical topic to identify in the literature or might require deeper interaction with the mathematics discovered in the authentic texts. Such interaction would necessarily require a mathematical level with which the students could become familiar in a short space of time. A cooperative project with library staff might be able to facilitate such deepening of the interaction with the mathematical engineering discourse and still allow for an acceptable level of student-centred discovery. The results of the assignment as it stands, however, suggest that it did have a positive effect on at least some students' ability to see connections between classroom practice and authentic industry or academic practice. It is to be hoped that such making of connections did encourage the formation of engineering identity in the students and an increase in the expectation that they will choose to continue their studies in engineering.

Acknowledgements

I gratefully acknowledge the helpful comments of reviewers of previous drafts of this paper. I am similarly grateful for the support of colleagues in the Centre for Research in Engineering Education, CREE.

References

- Allie, S., Armien, M. N., Burgoyne, N., Case, J.M., Collier-Reed, B.I., Craig, T. S., Deacon, A., Fraser, D.M., Geyer, Z., Jacobs, C., Jawitz, J., Kloot, B., Kotta, L., Langdon, G., le Roux, K., Marshall, D., Mogashana, D., Shaw, C., Sheridan, G., Wolmarans, N. (2009). Language as acquiring a discursive identity through participation in a community: A theoretical position on improving student learning in tertiary science and engineering programmes. *European Journal of Engineering Education*, 34(4), 359-367.
- Bingolbali, E., & Monaghan, J. (2004). Identity, knowledge and departmental practices: Mathematics of engineers and mathematicians. *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education*, 127-134.
- Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A “content-first” approach to science teaching. *Journal of Research in Science Teaching*, 45(5), 529-553.

- Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education*, 92, 708-732.
- Crouch, R., & Haines, C. (2004). Mathematical modelling: Transitions between the real world and the mathematical model. *International Journal of Mathematical Education in Science and Technology*, 35(2), 197-206.
- El Gaidi, K. (2003). Reforming engineering education: The CDIO initiative. *Industry and Higher Education*, December 2003, 431-434.
- Gee, J. P. (2001). Identity as an analytic lens for research in education. In W. Secada (Ed.), *Review of Research in Education* (Vol. 25, pp. 99-125). Washington, DC: American Educational Research Association.
- Gerofsky, S. (2004). *A man left Albuquerque heading east: Word problems as genre in mathematics education*. New York: Peter Lang Publishing.
- Haag, S., Hubele, N., Garcia, A., & McBeath, K. (2007). Engineering undergraduate attrition and contributing factors. *International Journal of Engineering Education*, 23(5), 929-940.
- Hartman, H., & Hartman, M. (2006). Leaving university: Lessons from Rowan University's college of engineering. *Journal of Engineering Education*, 95(1), 49-61.
- Holmes, M. H., & Spilker, R. L. (2007). Linking undergraduate mathematics education with engineering. *International Journal of Engineering Education*, 23(2), 338-348.
- James, G. (2008). *Modern engineering mathematics* (Fourth ed.). Harlow, England: Pearson - Prentice Hall.
- Jawitz, J., & Case, J. (1998) Exploring the reasons South African students give for studying Engineering, *International Journal of Engineering Education*, 14, 4, 235 -240.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Noble, B. (1967). *Applications of Undergraduate Mathematics in Engineering*. New York: Mathematical Association of America.
- Porter, R. L., & Fuller, H. (1998). A new "contact-based" first year engineering course. *Journal of Engineering Education*, 87(4), 399-404.
- Ravindran, A., Ragsdell, K. M., & Reklaitis, G. V. (2006). *Engineering Optimization: Methods and Applications*. Hoboken, New Jersey: John Wiley and Sons.
- Reed, M.B. (1951) *Mathematical Methods in Electrical Engineering*. New York: Harper.
- Ropers-Huilman, B., Carwile, L., & Lima, M. (2005). Service-learning in engineering: A valuable pedagogy for meeting learning objective. *European Journal of Engineering Education*, 30(2), 155-165.
- Scott, I., Yeld, N. & Hendry, J. (2007). *Higher Education Monitor No. 6: A case for improving teaching and learning in South African higher education*. The Council on Higher Education, Pretoria.
- Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, 97(3), 355-368.
- Stroud, K. A., & Booth, D. J. (2007). *Engineering Mathematics* (Sixth ed.). Basingstoke: Palgrave MacMillan.
- Suresh, R. (2006/7). The relationship between barrier courses and persistence in engineering. *Journal of College Student Retention*, 8(2), 215-239.
- Trim, D. (2004). *Calculus for Engineers* (Third ed.). Toronto: Pearson - Prentice Hall.
- Verschaffel, L., Greer, B., & de Corte, E. (2000). *Making Sense of Word Problems*. The Netherlands: Swets & Zeitlinger.