

## **Problem Solving Discourse Models: Informing an Introductory Engineering Course**

Nicky Wolmarans<sup>1</sup>, Brandon I. Collier-Reed<sup>2</sup>

<sup>1</sup>Center for Research in Engineering Education, Department of Civil Engineering, University of Cape Town, South Africa

<sup>2</sup>Center for Research in Engineering Education, Department of Mechanical Engineering, University of Cape Town, South Africa

nicky.wolmarans@uct.ac.za; brandon.collier-reed@uct.ac.za

### **Abstract**

This article draws on Gee's notions of Discourse and specifically Discourse Models to explore Engineering Problem Solving<sup>1</sup> and the different ways in which it can be understood in an engineering context. After Gee we attempt to identify aspects of doing, being and valuing that underpin people's Problem Solving Discourse Models. Interviews with three engineering lecturers reveal that they draw extensively on two different Discourse Models of Engineering Problem Solving. The more highly valued Model (Integrated Design Model) reflects engineering practice, is located in engineering design and dependant on judgement. The other is located in the classroom and involves the algorithmic resolution of mathematical models, (Knowledge Construction Model). These Discourse Models form a backdrop to interviews with three students entering an engineering degree programme for the first time. The three students each draw different Discourse Models of Problem Solving, and display characteristics (such as the level of confidence) that align more or less with Engineering Problem Solving, sometimes obscuring their understanding. The implications of these findings in terms of an introductory engineering course are discussed. These include recognising the potential diversity of Problem Solving Discourse Models our students bring to tertiary education, as well as the difficulty of introducing a legitimate design project requiring the level of judgement needed to interpret open-ended, ill-defined problems and then integrate multiple quantitative models with multidisciplinary qualitative judgements in a rigorous manner.

### **Keywords**

Problem Solving, Design, Discourse Models, First Year Engineering Course

### **Introduction**

Although Problem Solving is seen as a key skill required of engineers, problem solving takes on many different forms in different contexts or disciplines. In this article we explore some of the different ways in which engineering lecturers and engineering students make sense of the idea of Problem Solving and what it means to be an Engineering Problem Solver. Our interest lies in the implicit values that Engineering lecturers place on Problem Solving; and the diversity of different ways that first year engineering students may understand Problem Solving. Describing Discourse Models of Problem Solving involves identifying the implicit aspects of problem solving: what *really* counts, what is valued and what is recognisable as

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<sup>1</sup> We have followed Gee's convention of capitalising ideas that encompass aspects of doing, being and valuing in addition to the conceptual meaning usually ascribed to the word. We have chosen this convention in order to distinguish the different ways in which we use the terms throughout the article. When we write of Problem Solving we refer to problem solving plus the tacit values and identities that underpin the steps undertaken to find a solution to the problem.

*doing* it. We conclude by considering what the implications that these different ways of understanding and doing Problem Solving hold for an introductory engineering course.

Many engineering programmes around the world include an introductory engineering course in the first semester of study. These courses typically tend to involve basic skills development (study skills, time management, technical or professional communication), the introduction to various topics that span the engineering specialisation of choice (often in the form of laboratory-type experiments), an introductory design project, or some combination of these. This article has emerged from a larger project involving the critical review of a typical introductory engineering course at the University of Cape Town.

We have designed our course around the idea of an introduction to the Discourse of Engineering. We use the notion of an Engineering Discourse in the way that Gee (2005, p.7) describes a Discourse: the way in which identities and activities are enacted through not only language, but also “ways of acting, interacting, feeling, believing, valuing, and using various sorts of objects, symbols, tools and technologies – to recognize yourself and others as meaning and meaningful in certain ways”. We are interested in providing first year students with an opportunity to immerse themselves in an Engineering Discourse sufficiently that they become recognisable by their peers and lecturers as legitimate student engineers. However, while using Engineering Discourse as a central tenet of the course we do recognise that engineers engage in multiple activities in various contexts. As such, there is no one defining Engineering Discourse. In addition, an Engineering Discourse of a student engineer has many differences to the multiple Discourses of practicing Engineers. However, as Sheppard *et al* (2006, p.430) point out, although Engineering Education typically cannot mimic practice, it “ideally must reflect practice if it intends to prepare future practitioners.”

The literature on engineering practice suggests that engineers are recognised universally as *problem solvers* (Bucciarelli, 1994; Sheppard et al., 2006). Indeed, the accreditation requirements for engineering programmes explicitly include problem solving as an outcome of the degree programme. In South Africa, it is the first of ten outcomes required by the Engineering Council of South Africa (ECSA) for accreditation of an engineering programme. It is against this background that we locate Problem Solving as a single, but important element of an Engineering Discourse.

### *Engineering Problem Solving*

Research in the area of problem solving suggests that students entering engineering programs are often expected to be proficient problem solvers (Burton & White, 1999). In these studies, students considered themselves good or excellent problem solvers while their lecturers typically considered their efforts to be inadequate (Kimmel, Kimmel, & Deek, 2003). Downey and Lucena (2003) have observed the effect of mathematical problem solving on student resistance to more open ended problem solving. We argue that in all these cases, different understanding of what it means to do problem solving and what constitute legitimate problems and appropriate solutions are at play, and often in conflict with each other. It is not that students are necessarily poor problem solvers; rather that they may attach different meanings to the term problem solving and therefore understand what they should be doing *in a different way* to the way in which their lecturers expect them to.

We suggest that while the different aspects and values that underpin Problem Solving remain hidden or implicit, students who share the same values and understandings with their lecturers, or those values and understandings subscribed to in a particular course, are at a

distinct advantage. Those students who are able to modify their understanding and values through engaging in sufficiently similar models should manage to succeed in the course. However, those who don't have access to what could be considered the 'right things' are excluded from this possibility. Critical sociologists (like Foucault and Bourdieu) and educational theorists (for example Bernstein) have long argued that some students come into an educational context with a background aligned with the values of that system and are therefore in a position to pick-up the tacit values needed to succeed. Other students are unable to sense the implicit ways of being and presenting themselves and are often excluded from the system as a consequence. Gee (2005) would argue that they are not recognisable as being in the Discourse; that they do not *enact* the correct identity and actions to be recognised as legitimate Student Engineers by either their peers or their lecturers.

Efforts have been made to support students through the introduction of problem solving heuristics requiring them to step through discrete stages when solving problems (for example in physics (Gaigher, Rogan, & Braun, 2006) and engineering design (Kimmel et al., 2003)). Heylen *et al* (2007) recognise the complexity of integrating multidisciplinary fields inherent in engineering problem solving and design and opt for building the complexity gradually with the guidance of 'coaches' and 'specialists'. Oehlers (2006) introduces an assessment technique which he argues can help students to become better Problem Solvers. Van Meter and Sperling (2005) address the pedagogic knowledge needs of lecturers teaching problem solving. Harper, Freuler, & Demel (2007) argue that different problem types require different solution strategies, and therefore in order to develop useful strategies the type/s of problems set need to be interrogated. ECSA (2004) distinguishes between convergent and divergent problems; and lists Design as a separate and distinct Outcome required of students before they can graduate. Amongst all the different ways of understanding engineering problems and problem solving it is not surprising that there is a plethora of different ideas for helping students to solve problems (see for example (Burton & White, 1999)).

### **Engineering Problem Solving as a Discourse Model**

This article focuses on Problem Solving from a socio-cultural perspective. We look at what it means to *be* a Problem Solver – and to *do* Problem Solving – in an engineering context along with the associated implicit values that underpin these processes. To do Problem Solving in an engineering context is different to doing Problem Solving in, for example, medicine or science. In order to better understand Engineering Problem Solving along with the more tacit aspects of ways of doing and being we draw on Gee's (2005) notion of Discourse Models.

Gee (2005, p.61) describes Discourse models as "... 'theories' (storylines, images, explanatory frameworks) that people hold ... They are always oversimplified, an attempt to capture some main elements and background subtleties ...". These theories function to set up what counts and what doesn't count as *legitimate*, thus excluding certain types of identities and activities. Discourse models are developed through experiences situated within communities and therefore reflect the Discourses of those communities. Discourse models are therefore seen to be shared by socio-culturally defined groups of people who share practices.

Most people understand problem solving as some process or technique for coming up with a solution to a problem; in much the same way as people would define a bachelor as an unmarried man. However, just as Gee (2005, p.72) points out that not all unmarried men qualify as bachelors (by way of example he suggests that while unmarried, the Pope is not viewed as a bachelor because he is not eligible to marry), so too the idea of problem solving

becomes more complex and subtle as one interrogates what it means to be a Problem Solver in the context of an Engineering Discourse.

### **Data Collection and Analysis**

Qualitative data were collected from six interviews – three engineering lecturers and three first-year students at the start of their tertiary study. The interviews with the lecturers were fundamentally different to those with students. In order to draw out the values behind Engineering Problem Solving, the lecturers were asked about what they felt made a ‘good engineer’. Aspects raised about problem solving were then probed. By comparison, students were asked directly about their views of problem solving as a process, what exposure they had to it at school, and to provide examples of problem solving that they had either been involved in or had seen in action.

The interviews took the form of semi-structured questions. The role of interviewer was to pose open questions and then have participants elaborate ideas that were not clear and to redirect the discussion as necessary. The interviews were recorded and transcribed to represent only what was said. Even though the use of Discourse Models comes from discourse analysis methodologies, we were not undertaking a discourse analysis and consequently the transcribed narrative was not as detailed as required by a formal discourse analysis.

In using Discourse Models as an analytical tool to make sense of the interviews an important assumption is made; the assumption that what people say makes meaningful sense when viewed through their own Discourse Models:

“We always assume, until absolutely proven otherwise, that everyone has “good reasons” and makes “deep sense” in terms of their own socioculturally specific ways of talking, listening (writing, reading), acting, interacting, valuing, believing, and feeling. Of course we are all members of multiple Discourses so the analytic task is often finding which of these, and with what blends, are operative in the communication. The assumption of “good reasons” and “deep sense” are foundational to Discourse analysis. It is not only a moral principle. It is based, as well, on the viewpoint, amply demonstrated in work on cognitive science, applied linguistics, and in a variety of different approaches to discourse analysis, that humans are, as creatures, par excellence sense makers” (Gee, 2005, p.93)

The analysis of the interviews thus involved identifying a Discourse Model or Models through which the interview transcripts make sense. The sense making process is an iterative one, involving testing meaning against the words until the idea as a whole makes consistent sense, and checking back and forth between the researchers as the meaning emerges.

Since the lecturers are all part of the same community (that of engineering educators) we would expect them to draw on similar Discourses in the way in which they understand Engineering Problem Solving. We expect them to draw on a Discourse Model of Problem Solving based in the practice of engineering, as well as a Discourse Model of Problem Solving based in classroom practice. During the data analysis we were therefore looking for similarities in what they said in order to describe a common Discourse Model of Problem Solving that we could use in our course. The Discourse Model/s of the lecturers are therefore presented as integrated, although in the extracts of the data presented, the lecturers are identified as L1, L2 and L3.

The interviews with the students were conducted before the formal introduction to problem solving had taken place in their introductory engineering course. All student interviews were conducted by the author not involved in that particular first year course to minimise the

asymmetric power relations between student and lecturer. However, it is clear from the transcripts that in the case of the student interviews, the interviewer is in some cases still seen in a ‘teacher’ type role, which has implications for our analysis and findings.

In the interests of anonymity, the identities of the students are replaced by pseudonyms in the data. Since their backgrounds and demographic profile did not form part of the analysis, the names do not indicate either race or gender. The identity or demographic profile was not considered important because the purpose of the study is to capture a range of Discourse Models, not to assign Discourse Models to people. It is also important to note that a person may draw on different Discourse models at different times depending on the context.

### **Discourse Models of Problem Solving: an engineering lecturer perspective**

All three lecturers interviewed identified problem solving as the defining feature of engineering practice, “I think problem solving is probably the heart of what it means to be an engineer” (L3; 15). However they also recognised that in an engineering context problem solving takes on a particular meaning that may be different from other contexts, “...if I talk to an engineer about problem solving ... talk to a mathematician about problem solving – they will define problem solving differently” (L1, 167). There was a distinct sense that there is more to engineering problem solving than the traditional technical model of problem solving, in which engineers are seen as “*just* a technical animal” (L2, 113), who “generally solve physical problems” (L3, 14). Rather there is a need for a different understanding of problem solving:

“It was a sense that engineers had lost their place in the world, it was a sense that we had lost our voice, we’d become the technical animal and no more so we were used like you use a car mechanic – my car has a problem go and find a car mechanic who will fix it. Rather than you know, *how do we design this thing and make it work better?*” (L2, 131-34 – emphasis added)

### ***Problem Solving as open-ended and multidisciplinary***

It was clear that for the lecturers, legitimate engineering problems tend to be open-ended: “... open-ended problems are the ones that lend themselves most usefully to that problem solving” (L1, 177). A particular aspect of open ended problems is that a more rigorous approach to understanding the requirements of the problem is needed: “... this community needs some water, or they need this kind of a service – in this case the first question to ask is do they really need that service and if so, is this the best way to supply it? (L2, 121-23)” This is often as a result of open-ended problems being ill-defined: “... I then give them open ended problems to solve ... I give them some rules but I don’t, I don’t deliberately go and give them enough information...” (L3, 116-17).

By contrast, closed form problems, those most often associated with traditional examinations and tutorial questions, are seen as lesser or inadequate problems:

“... problems that you solve there as a consultant were seldom as simple as ‘work out the stress on this beam!’” (L3, 140)

Sometimes they are seen as simply not being legitimate problems at all:

“We use problem solving colloquially to mean ‘the solution to an example’ following a particular formatted approach. It is two different meanings to the same term. I don’t honestly believe that somebody is doing that, that actually means that they are doing ‘problem solving’ – they are doing ‘example solutions’. (L1, 169-71)

This distinction and hierarchy between open and closed form solutions make it clear that lecturers hold two distinct Discourse Models of Problem Solving. Drawing on a typical engineering classroom context, Problem Solving tends to be seen as involving the interpretation of a word sum and going through a set of mathematical substitutions and manipulations in order to find a 'correct' answer that typically takes the form of a number. By contrast, Problem Solving in an engineering practice context is far more open ended in all respects. Since the lecturers find themselves moving between these two contexts, it was not surprising that they draw on both Discourse Models. However, what is clear from the excerpts above is how much more highly valued the Discourse Model located in practice is than that located in the classroom.

There is a role for the more closed form mathematical type problem, but as building blocks either for constructing knowledge in the 'junior years' (L3, 15 and 34) or integrated as parts needed to solve broader problems. For this reason we have called this the Knowledge Construction Model (KCM)

"... classic engineering is often revolved around some sort of reductionism – you break things down to their component parts, you apply known laws of physics or whatever, chemistry and mathematics and you build it back up into a model which represents as closely as possible the system you are trying to identify, trying to understand. (L3, 18)

"...each of those forms a little component part in and of itself, that may or may not be useful on its own, probably isn't, but does become useful when it is pulled together with a whole lot of other little nuggets of information that can be assembled in to an ability to solve a particular type of problem That is one of the reasons why I think it is so important to expose students to a wide range of different types of disciplines and not necessarily engineering as well." (L3, 134 -35)

These statements raise two important aspects of a different Discourse Model more highly valued by our lecturers: that of integration of multiple disciplines and the building of integrated quantifiable mathematical models. In some respects these two aspects are in contention with one another – on one hand measurable quantifiable theories, and on the other more qualitative subjective judgements. And yet they need to be integrated with one another.

### ***Problem Solving as Design: judgement and tenacity***

It is typically in design courses where students are provided with the opportunities to practice some level of integration in their approach to the solution of problems. In fact in an engineering context, more often than not engineering problems are associated with designs, and we have thus labelled our second, more highly valued Discourse Models the Integrated Design Model (IDM):

"The courses where problem solving skills are typically developed are in the design type courses ... where there is the ability to have open ended problems" (L1, 176).

Emerging from the data is the clear sense that embedded within the design tasks is the need for students to develop judgement. Judgement can be seen as the cornerstone of interpreting problem requirements, determining which knowledge bits are needed and then integrating these multidisciplinary subjects, making "reasonable enough estimates, assessments, propositions or whatever it is ..." (L3, 117), and then finally being able to judge how "appropriate" the solution really is (L1). All this is required without losing the technical quantitative modelling techniques for predicting consequences of a solution:

"... take seemingly intractable problem and actually solve it, make it work, even when they don't know necessarily all the answers but they have the ability to make judgments and to provide the sorts of solutions that make things work." (L2, 110)

It is clear from the interviews that part of the problem of developing judgement is in how to set up appropriate tasks which enable the type of feedback and assessment required for students to appreciate an engineering Discourse Model of Problem Solving. One aspect of Problem Solving that emerged from the data, albeit in a subtle way was that of tenacity. It would appear that along with the idea of judgement in problem solving is the need to keep trying until the problem can be solved:

I suspect that the best engineers are the bulldogs, the ones that don't let go and even if they are a bit slower than some of their brighter contemporaries it is the not letting go that makes the difference I think. (L3,24)

### ***A Discourse Model of Engineering Problem Solving***

Our lecturers draw on two different Discourse Models of Problem Solving: one reflecting engineering design practice (IDM), and the other reflecting the construction and assessment of knowledge in the classroom or as a small part of a larger problem (KCM). The Discourse Model of Engineering Problem Solving valued most by all three lecturers clearly has more in common with engineering design than with problem solving seen as the resolution of a mathematically constructed model. Engineering Problem Solving, it would appear, involves *designing* a solution rather than resolving an answer. In this respect, legitimate problems were seen as open-ended and multidisciplinary in nature. Mathematical models form small parts of the solution process – parts that need to be integrated with other quantitative models as well as integrated with qualitative judgements. In many respects, for the lecturers, *judgement* forms the cornerstone of an Engineering Problem Solving Discourse Model. They suggest that judgement is needed to interpret problem requirements; to determine which knowledge bits are needed and how to integrate these multidisciplinary subjects; judgement as to what counts as a reasonable estimate or approximation; and finally being able to judge how “appropriate” the solution really is.

### **Discourse Models of Problem Solving: an engineering student perspective**

Set against the Discourse Models that our lecturers draw on: the KCM and the IDM, we present vignettes of the three students interviewed in this study.

#### ***Laurel:***

Laurel displays a particular confidence in her discussion of problem solving. Her first response is that she sees problem solving as “... a technique which people use to solve problems – to find a solution to problems” (111). To support her view, she presents her experience of solving mathematics problems “... in maths if you have an equation – so you solve the equation, so there are certain steps that you have to follow to solve the equation” (115). Her initial response to problem solving is deeply aligned with one of the Discourse Models drawn on by our lecturers, but the lesser valued model. When probed, she also proposes as an alternative type of problem that is required to be solved, the issue of “a quarrel between friends” (121). After reflection, she suggests that problems are everywhere: “I suppose ja – everywhere you find problems – so maybe your remote isn't working because something isn't making contact in the remote” (132).

It would appear that in the case of mathematics problems, Laurel is confident that she can *follow the correct steps* to find the answer – she knows the guidelines as taught to her in the classroom. In her third example of solving a problem – the remote that doesn't work – she posits a solution to the problem during the description of the of the problem itself: “...your remote isn't working *because something isn't making contact* in the remote so you have to maybe open it up, take it out – what's not making contact and then make contact” (132 –

emphasis added). She is less confident in her solution to the quarrel between friends: “So I suppose you never really know whether – with the friends – whether you reached the right solution or not” (128). Laurel needs to know what to do to solve problems; she is clearly uncomfortable with open-ended, ill-defined problems. In her example of a quarrel with friends she is uncertain of the solution because “... you can approach it in any way – so there aren't any constraints – there are no guide lines” (125).

It would appear from an analysis of Laurel's approach to problem solving that it is limited to identifying the correct category or knowledge area into which the problem falls and thereafter stepping through an algorithmic process to resolve the appropriate equations or find what she considers to be the *correct* solution. Her position is clearly illustrated when she talks of the need to make a choice of career: “It's *just* a decision that has to be made ... you don't know if you've got the right answer or not – you can only know further down the line if you've made the right decision or not” (172 – emphasis added) Later, when discussing the AIDS pandemic in the context of being a problem to solve: “I suppose I would have to focus on the moral aspects surrounding AIDS *because I don't have the knowledge* to actually go and find a cure for AIDS” (176 – emphasis added).

Laurel initially relates strongly to the KCM . Here, as long as she can identify the section of work under review, she should know procedurally what to do to arrive at the solution (in this case typically a single answer). The framework for the problem would be where something is missing and requires identification to solve the problem. The interviews with the lecturers indicate that this view is likely to be reinforced through the first years of her degree.

Although she recognizes other types of problems, she sees these as uncertain and social in nature and does not associate these with the ‘mathematical’ process she is most comfortable with. It is possible that this could be because of the uncertainty in affective issues inherent in the problem: “... so maybe someone isn't saying how they feel and then you think everyone is satisfied when actually not everyone is satisfied” (128). She does not draw on judgement to evaluate the solution. Rather, she recognises a lack of certainty as a potentially unsatisfactory solution.

During the analysis, it emerged that Laurel's view of problem solving evolves during the interview to embrace more than the KCM described above. It would appear that the process of engaging in an interview around the subject led to her refining her position. Initially, she was quite confident that she knew what problem solving was and that in mathematics she was quite successful in doing so. However, during the ongoing discussion, it would appear that she begins to place less value in the KCM. When asked if she was formally taught problem solving at school her response is “Yes – certain type of questions, because you know exactly what type of question you are dealing with and so – like with calculus – ja – so we've been programmed to solve certain problems” (140). Already there is evidence that maybe this isn't the view of problem solving that is more widely accepted and possibly tacitly espoused by the interviewer. She calls it being programmed, what could be considered as a fairly negative view of the process – and one that she would appear now to partially discredit. It is interesting to note that by the end of the interview, her response to whether she has been taught problem solving has changed from her earlier position: “No I wouldn't say so – I definitely do think that problem solving skill, is a skill that students lack because I don't think that we were really taught that – we were programmed to do certain things – I can't say that that is my skill – I can do that but I can't take that skill and apply it elsewhere – because we weren't taught that” (164). She has not yet apparently built an alternative Discourse Model

### *Clayton:*

Analysing Clayton's view of problem solving uncovered a very interesting dynamic between him and the interviewer. At one level Clayton does not appear to answer questions; the interviewer tries to elicit an elaboration of ideas, by picking up words and phrases, but the different situated meanings of those words make it look as though they are speaking different languages. The questions and answers when viewed through the eyes of the other seem to be nonsensical. Recall here Gee's contention that humans are sense makers (Gee, 2005, p.93), and that what Clayton says makes perfect sense to him through his own Discourse Models.

Initially, Clayton presents problem solving as a process and infers that the solution depends on the nature of the problem: "From general perspective I think it [problem solving] is about working through something, trying to find a solution but it depends to the nature of the problem" (115). Later in the interview he speaks of analysing a problem: "It needs analysis in terms of how the problem can be addressed" (123). The words that Clayton is using provide a generic definition of problem solving. However, the analysis seems to suggest that these ideas are definitions that he's 'picked up' rather than uses. There is little evidence of a formal process being espoused in the examples of problem solving that Clayton presents. In all the examples that he uses as illustration he seems to define a problem as something that requires 'fixing' (115), whether physical in nature or personal. Right at the start of the interview he points out that the solution "...depends on the problem, *if it is a problem in fact.*" (115 – emphasis added). Clayton has definite ideas about what counts as a problem as will be seen in the analysis that follows.

In contrast to the other students interviewed, Clayton does not use physics or mathematical questions as examples of problems. When questioned about mathematical problems Clayton's responses make little sense until one considers that perhaps he does not consider these legitimate problems at all. In the following extracts the interviewer has asked Clayton to compare and contrast what the interviewer sees as two different types of problems (drawn from the two different Discourse Models that our lectures seem to use): "I'm just going to use a broad issue, say let's look at maths problems on the one side, solving maths problems and then maybe on the other side – solving the housing crisis in the country" (133). Clayton is clearly confused by this question:

- C: "Fundamentally they are problems but their nature is different because it is maths without houses – so it is like their needs are different ..." (135).
- I: "Do you solve them the same way? Using the same information?" (137)
- C: "Maybe if there are things that require maths in the housing I can apply maths – but in maths if there is something that requires houses I can't use houses." (139).
- "I think so because in both there is applied maths depending on the data that you've collected – you still use mathematics." (143).

In the interview, he appears to eventually make sense of the question by constructing a word sum about housing that can be solved mathematically, but even this does not appear to be his own view of a problem, but seems constructed to satisfy the interviewer:

"If there are people let's say for instance in Khayelitsha, people who live in informal settlements, we have this number of them, and people who live in formal settlements – we have this number of them – to work it out mathematically you will use variables – like x and y and you come up with an answer, so basically that is where mathematics applies in that scenario" (155).

Again, in order to make 'deep sense'(Gee, 2005, p. 93) of the following apparently strange statement one needs to consider that Clayton is being asked about problem solving and

perhaps he doesn't consider mathematical word sums to be problems. The response can then be seen as making reference to the contrived manner in which mathematical problems are constructed for a classroom context. The following exchange between the interviewer and Clayton illustrate this proposition:

- I: "... Has that been your experience when your lecturer gives you a question to work on through a tutorial that there are lots of answers? Has that been your experience so far?" (189)
- C: "From my personal perspective, even though *there might be a prescribed answer* for that particular question but like in nature you've got different consciousness of thinking – so you can't like vow and say a certain answer is wrong or right – it is just that it is not acceptable or not relevant to what was required then. So generally what I am trying to say is that *every answer* might be correct" (191 – emphasis added).

Clayton appears more comfortable when speaking about the problems that he has identified, for example when discussing the construction of physical things:

- I: "What sort of things did they teach you about problem solving?" (1121)
- C: "It was basically about the construction of fires, bridges, a suspension bridge – we were taught what one is generally meant for. I think it was basically about that." (1123)
- I: "Did you focus on problem solving at all or was it just about building things?" (1125)
- C: "*I can say fundamentally it was about problem solving* because it was informing us about what to expect whenever we get involved in such things, what we must do and with our companies, to understand companies who build bridges and so on." (1127 – emphasis added)

The analysis suggests that Clayton has a definite idea about what constitutes a problem, and classroom word sums are not it. His experiences suggest that word sums contrived for the classroom require interpretation and an answer that coincides with a fairly arbitrary interpretation held by the teacher. He neither subscribes to the KCM nor does he recognise the features central to the IDM. Rather he seems to build a Discourse Model out of his view that engineers construct things. If he understands engineering to be about problem solving, problem solving is consequently about constructing physical things associated with engineers, like, for example, bridges.

### ***Samantha:***

Samantha was not that forthcoming in her discussion during the interview, possibly aggravated by the asymmetric power situation often found in the interview situation. Throughout the interview, it appears as if she were trying to cue what she hoped would be the 'correct answers' from the interviewer. The analysis of her data shows that she appears to be resistant to exploring ideas beyond what she believes to be correct. Furthermore, she steadfastly holds that she has no prior knowledge of formal problem solving techniques.

Samantha's view of problems appears to fall into two distinct categories. In the first category, problems require the resolution of mathematical relationships, while in the second, problems deal with 'real life situations' (1135). The examples that she uses to illustrate her position clearly locate abstract mathematical type problems as located in the classroom and removed from the outside world. The analysis suggests that failure to find a solution to a mathematical problem is more likely to be associated with being tested academically than with a problem solving process that includes searching for alternate routes or approaches to the solution:

- S: "*Well there are equations that I can use* to for solve for 'x' and OK ...Ja. I think of equations – it depends on what type of equation it is – there are different types of equations and it depends on the problem."
- I: "OK so it depends on the problem and then you look for the equations to use. What happens if you don't have any equations?"

- S: "If I don't have an equation? *Then there is no solution* – I don't know? There is no solution for 'x' "
- I: "OK and then what do you do then? If you've been given a question and there is no equation and now you can't solve for 'x' what does that mean about the problem? What does it mean about the person that set the problem?"
- S: "Maybe they are trying to test us if we are good in what we are doing and if we can think ..." (139-51- emphasis added)

This exchange suggests a fairly restricted view of problem solving, located firmly in the KCM. However, a much more complex view of problem solving is revealed in her discussion of what she terms a 'transport problem' (159). These 'real life situations' (1135) (even if posed in a classroom context) appear to be more concrete. Interestingly, she places physics problems into either category depending on the problem itself. This suggests that she doesn't make the distinction based solely on the need to resolve equations – a view confirmed when she says that "there are not *always* equations in real life solutions like there in the maths" (1151 – emphasis added). The analysis of Samantha's position suggests that mathematics can either be a tool for solving problems (linked to the IDM), or the process itself.

Contrary to her position that she has not formally been taught problem solving, there is clear evidence in the data of the knowledge of formal steps often associated with problem solving heuristics. She explicitly mentions all of the following:

She identifies a need:

"...maybe you want to get from one point to another..." (155);

She recognises the need to integrate multiple knowledge areas:

"...I'd look at road issues ..." 163 "...you have to look at environmental issues..." 155 "I'd have to consult other people...171 ..They'd give me advice." 175 "You have to look at the road conditions, the cost of building the road ..." 1107;

She is comfortable using quantitative modelling within the process of problem solving:

"There are not always equations in the real life solutions like in the maths one there are certain types of equations that we use." 1151;

She appreciates the idea of legitimate alternate solutions:

"... you have to look at the benefits – the benefit of having chosen that road." 155.

"... it might not include building a road in that place maybe they want to go from point A to point B.

Many people might have to use another way to get from point A to point B." 195; and

Those solutions can be compared based on criteria:

"... you have to look at the road conditions, the cost of building the road ..." (1107)

### Comparing Models

Samantha may in fact have a Discourse Model most closely aligned with the IDM, although from her interview, this was not immediately apparent given the tentativeness – or timidity – with which she approached answering the questions posed. This illustrates Gee's point that there is more to Discourse than words; how and what we do contribute greatly to building meaning and identity. Being recognised as a legitimate engineer requires more than just having similar conceptions of problem solving – it also requires enacting a particular approach to problem solving; in this example a self confidence in one's own understanding. This raises an additional element of the IDM, that of portraying self confidence in one's solution. Even though Samantha's concepts might be better aligned to the IDM, by not displaying self-confidence, she appears to be outside of the Discourse.

Laurel displays the self-confidence inherent in the Discourse, and although she starts out with clearly drawing on the KCM, she is sufficiently cue conscious to recognise that she needs to modify her understanding of Problem Solving. She has not yet recognised the role of

integrating mathematical modelling and judgement, but appears likely to be able to modify her Discourse Model as she progresses.

Clayton's identification with the construction of physical things associated with engineers, like, for example, bridges as problem solving might suggest that others also recognise engineering problem solving linked more with design. However, his adamant alienation from the role of quantitative mathematical models in Problem Solving clearly alienate him from the IDM

### **Concluding remarks**

What we have attempted to do in this article is to add a socio-cultural view of 'doing, being, and valuing' to the typical problem solving heuristics taught in school and in engineering programmes. Analysing lecturer and student interviews through the lens of Discourse Models has helped to identify important aspects of Problem Solving often held tacitly. These tacit aspects include what counts as a legitimate problem for engineering lecturers; as well as aspects of *doing* and *being* embedded in Problem Solving.

In the case of the lecturers, they slipped between two different Discourse Models. The first, the more highly valued model (IDM), reflects the practice of engineering and is located in engineering design and dependent on judgement. The other model reflects classroom contexts and depends on algorithmic mathematical manipulations. While design processes and problem solving processes have much in common, engineering lecturers tend to conflate the two. If anything, design problems seem to be held up as the more legitimate problems. Engineers, tend to *design* solutions.

Students entering our engineering classrooms draw on Problem Solving Discourse Models in a much more diverse way. We need to recognise the extent of this diversity if we are to successfully introduce *all* our students to Engineering Problem Solving. How does Clayton make sense of the need to build a mathematical model that is not arbitrary, but which models a system realistically enough to be used to base decisions on? If Laurel with all her confidence works in a team with Samantha who actually has a closer Discourse Model of Problem Solving that we are trying to invoke, which understanding of problem solving is most likely to be used? Would Laurel's self-confidence receive tacit acknowledgement from lecturers encouraging her version of Problem Solving? And yet for Laurel, if she's not been taught the content she needs, she probably won't want to integrate it into her considerations for a solution.

When looking at these findings in the context of a first year introductory course intended to introduce engineers to the Discourse of Engineering, the results of the analysis suggest that it would be hard to exclude a major design project. In order to align the requirements of the design project with the Discourse Model of Problem Solving that we have seen, the design project chosen would need to include integration of multiple disciplines and the integration of quantitative mathematical models; the solution would also require fairly formal evaluation of the assumptions used and the final solution proposed. Yet since we argue that *judgement* has emerged as the cornerstone of design, the more important question is what level of judgement can be expected from students freshly out of school with, in many cases, very limited exposure to the knowledge that they need to make judgements about.

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