2014

Mathematics: Creating Value for Engineering Students

Eileen Goold
tallaght Institute of Technology, eileen.goold@ittdublin.ie

Mathematics: Creating Value for Engineering Students

Eileen Goold[1]

Lecturer
Institute of Technology Tallaght, Dublin, Ireland

Abstract

While students' attainment in mathematics and their attitudes about mathematics are strongly inter-related, value is an important concept in mathematics education. It is arguable that lecturers, especially in engineering faculties, know little about the relationships students form with mathematics; for example what value do engineering students place on mathematics learning?

Mathematics is often perceived as a difficult subject and it is associated with certainty and with being able to get the right answer. However the narrowness of the assessment process overshadows predictors of achievement behaviour: expectancy (am I able to do the task?) and value (why should I do the task?). At the same time lecturers are tasked with mathematically preparing students for an increasingly technological world, however for many students, the nature of a career involving mathematics is not at all clear. A significant difference between engineering education and practice is the social aspect of work compared to education. In particular engineers' difficulty communicating mathematics is a significant weakness of engineering education.

While engineering mathematics curricula often prescribe a fixed body of mathematical knowledge, this study takes a different approach; second year engineering students are additionally required to investigate and document an aspect of mathematics used in engineering practice. A qualitative approach is used to evaluate the impact students' investigations have on their mathematics learning and whether this approach creates greater value for students compared to curriculum mathematics learning. This paper contains an account of students' engagement with and their emotional responses to their investigations of professional engineers' mathematics usage.

1 INTRODUCTION

Mathematics is important; mathematics is required for successful functioning in society (Ernest, 2010), professional engineers use a broad range of mathematics in their work (Goold and Devitt, 2012) and mathematics achievement is a strong predictor of third level persistence generally (Mooney et al., 2010).

It is claimed that a society of lifelong learning requires individuals with well–developed learning dispositions (Falsafi, 2010). There are different perspectives of mathematics relationships; sociocultural, discursive and psychoanalytic factors that influence people's relationships with mathematics. Research literature indicates that mathematics can be made more accessible in classrooms which encourage exploration, negotiation and ownership of knowledge due to enhanced relationships (Black et al., 2009). Experienced learners seek and engage life experiences with a learning attitude and they believe in their ability to learn. The

[1] Eileen Goold BE MEng PhD CEng MIEI
eileengoold@eircom.net

primary focus of people who see themselves as learners is not on immediate performance or goal achievement but on the on-going process of learning (Illeris, 2014).

Motivation is a major factor in mathematics teaching and learning, however there is some evidence to suggest that mathematics is a special subject compared to other school subjects. (Smith, 2004). Characteristics of classroom mathematics include: tedium; isolation; rote learning, elitism; and depersonalisation (Nardi and Steward, 2003).

Mathematics is often associated with certainty whereby "doing" mathematics means following the rules laid down by the teacher; knowing mathematics means remembering and applying the correct rule when the teacher asks a question and a mathematical "truth" is determined when the answer is ratified by the teacher" (Lampert, 1990). Consequently for many students, the nature of a career involving mathematics is not at all clear (Petocz et al., 2007). Similarly adjusting to the workforce can be problematic for many students as they discover what they learned in university needs to be contextualised for work (Wood, 2010). Trevelyan maintains that engineering practice relies on applied engineering science, tacit knowledge (unwritten know-how carried in the minds of engineers developed through practice and experience) and an ability to achieve practical results through other people (Trevelyan, 2010).

This paper presents the findings of a study investigating the impact of student-directed learning on students' relationships with mathematics.

3. METHODOLOGY

In this study mathematics relationships are studied in the context of Wigfield and Eccles' social cognitive expectancy-value model of achievement motivation. This theory posits that predictors of achievement behaviour are: expectancy (am I able to do the task?); value (why should I do the task?); students' goals and schemas (short- and long-term goals and individuals' beliefs and self-concepts about themselves); and affective memories (previous affective experiences with this type of activity or task) (Wigfield and Eccles, 2002, Schunk et al., 2010). Expectancy-value research has substantiated that students with positive self-perceptions of their competence and positive expectancies of success are more likely to perform better, learn more and engage in an adaptive manner on academic tasks by exerting more effort, persisting longer and demonstrating more cognitive engagement. Students who value and are interested in academic tasks are more likely to choose similar tasks in the future. Interest refers to the liking and wilful engagement in an activity. Interest can be: personal (personal enjoyment or importance of specific activities or topics); situational (interestingness of the context e.g. novel versus textbook) or psychological (heightened interest when personal interest interacts with situational interest) (Schunk et al., 2010, Wigfield and Eccles, 2002, Wigfield and Eccles, 2000, Wigfield, 1994).

While engineering mathematics curricula often prescribe a fixed body of mathematical knowledge, this study takes a different approach; in addition to their curriculum mathematics learning a class of second year part-time energy engineering students are required to select an aspect of mathematics they had studied in their engineering course and, using whatever resources available to them, investigate how professional engineers use this mathematics in engineering practice. The class group of seventeen students comprises a diversity of students many of whom work part-time in engineering and trades environments. A survey questionnaire was used to capture the students' feelings about the exercise before and after conducting the task. The data was analysed qualitatively using a system of open coding (Miles and Huberman, 1994, Silverman, 2010).

4. FINDINGS

There are five main findings:

- The majority of the class of engineering students are neither confident in their mathematics ability nor demonstrate any value of mathematics other than for the purpose of passing examinations.
- Students present mathematics learning as a chore, they have no mathematics goals and their mathematics learning comprises of repetitive memorisation of solutions to past examination questions.
- There is no evidence of social interaction in the students' mathematics learning; students only discuss how irrelevant mathematics is to their lives.
- Students have difficulty communicating mathematics as evidenced by their reluctance to engage in documenting their investigation of mathematics used in engineering practice. They also show a reluctance to depart from rules or "set procedures" and from seeking a precise goal such as the "correct answer" in traditional mathematics learning.
- Following completion of the assignment, students show improved relationships with mathematics. In particular they demonstrate an increased awareness of the usefulness of mathematics in their future careers. The new awareness of the relevance of mathematics in life and work energises students to "work harder". Another observation is the increased classroom discussion about mathematics arising from the assignment.

Prior to engaging in the exercise it is observed that the majority of students' feelings about mathematics are negative, for example:

- *"I like it [mathematics], I just wish I understood it better"*
- *"I don't like it as I find it difficult and hard to understand"*
- *"I'm not confident … I often make mistakes"*
- *"I don't like maths at all, probably because I find it difficult"*
- *"It is my least favourite subject; most of questions and theories are very difficult to understand unless they are well instructed"*
- *I am really interested in maths, sometimes I find it difficult but I understand it"*

Only one of the seventeen students likes mathematics:

- *"I like maths, I like the logic behind it"*

Students do not exhibit positive mathematics relationships: they do not show commitment to the on-going process of learning and they do not demonstrate any mathematics learning goals; the only learning strategy is practising past examination questions:

- *"I don't have a strategy, I just go by past exam questions".... repetition but it is hard because there is so much to cover"*
- *"I have not got a maths strategy … just questions and past exam papers"*
- *"I try to understand the step by step solutions to exam questions , repetition is essential"*
- *"practice, practice, practice …doing past exam questions with detailed steps and solutions"*

Students' mathematics discussion is sparse and negative**:**

- "*I never discuss maths outside of lectures"*

- *"I often discussed how irrelevant maths topics are to our future careers"*
- *" We discuss how bad maths actually is and question why do we need it"*
- *" Not many discussions, nobody wants to talk about maths"*

Students are challenged by the departure from "set procedures" and getting the "correct answer." When asked if they liked the exercise, students' responses include:

- *"Not all of it, parts of it were too abstract, not sure what relevance it has to course"*
- *"It's different, questions are too abstract"*
- *"Not particularly, I found it difficult to write about something which I didn't particularly like"*
- *"Difficult to put mathematical equations into a word document"*
- *"I did not enjoy this assignment as I did not fully understand what was being asked"*
- *"I didn't because I didn't know how to do it properly … what is the expectation?"*
- *"It was very difficult to do it, I didn't even know how should I start"*

While some students are uncomfortable with the concept of an investigative approach to mathematics learning and report writing, each student state that they benefitted from the exercise. In particular it is noted that the students' insight into mathematics used in engineering practice creates value for them. This new learning about mathematics in engineering practice motivates the students to engage with mathematics that is important to them. Students have acquired a sense of wanting to learn mathematics; they now see themselves as learners preparing for their future careers. Students' responses include:

- *"The one major finding I got was when I looked up potential career opportunities in environmental engineering … in all of the job opportunities in environmental engineering, statistics and probability are fundamental in gathering and presenting your data"*
- *"When I was given this task to write a report on mathematics in engineering, I never realised just how much it would open my eyes"*
- *Before this task I took for granted the amount of engineering and maths in the world but I now understand a lot through the eyes of maths"*
- *"Although before the task I wasn't too sure about its relevance to the course, I enjoyed it largely because of my own interest in the subject and I look forward to learning more in this area in the future"*
- *"The thing that I learned most of all is how useful a tool EXCEL really is. I didn't realise how much maths was to be involved in doing a job like this because usually someone else does it … it was good to see how engineers use maths in day to day tasks"*
- *"I was sceptical as to how much of the maths we are studying would come into use again … I saw real life ways of applying maths … I saw the relevance of trigonometry and how it can be used to calculate many different things in relation to engineering … maths is one of the key ingredients of engineering and I now know to try my hardest to master the discipline so that I can become the best engineer I can"*
- *"Before this report I thought maths was a bit dry and difficult to understand how mathematics can be applied to benefit my job in the future … but after this report, I now have a much better understanding that mathematics is almost everywhere in the engineering world … almost every new invention uses mathematics and mathematics*

is also used in everyone's normal lives … this report helped me develop many new skills and boost my confidence in creating a report"

- *"After doing this assignment I now have a better understanding and respect for maths and algebra in particular than I had before the assignment. Before I began the assignment I felt like it could be a waste of time but on finishing the report I've changed my mind …. My understanding of algebra has improved and so has my respect for the subject … I can now see the relevance of algebra and its close ties to areas of engineering I will be involved with"*
- *"This assignment certainly opened my eyes and helped to understand things a bit better"*
- *"Having done this report I was surprised just how essential statistics are to successful engineering ... it was good to see that some of the course topics will be so important in a future engineering career"*
- *"This assignment highlights the importance of arithmetic"*
- *"This assignment changed my thinking about mathematics because I can now see how engineers can use it in different ways … I can see how engineers use mathematics to connect to their knowledge … I can now see a clearer picture of what we are doing now and in the future"*
- *"This was a challenging and enjoyable assignment that will benefit my future career"*
- *"This assignment was not my most favourite part of maths but before I didn't realise how important maths is especially in the field of engineering practice … I have learned a lot from doing the assignment"*
- *"Mathematics has been one of my more difficult modules since starting this course … I have found maths the most difficult subject to self-learn … I have now realised that at a touch of a button and from the help of Google and similar websites, the information I need and more is available ... I have been introduced to a whole new way of learning and retrieving information"*
- *"I found this assignment interesting and it gives me a feeling for what I can expect after college"*
- *"I learned how some topics in the course and also EXCEL and MATLAB are used in engineering"*

5. CONCLUDING DISCUSSION

The findings in this study highlight the challenges of mathematics education whereby engineering students who have negative feelings about mathematics engage in repetitive learning of mathematics often at the expense of understanding. Students' goals are to learn sufficient mathematics to pass their examinations and they show no desire to learn mathematics outside the curriculum. Students also show low mathematics task value; they are reluctant to investigate and write about useful mathematics (e.g. interesting mathematics or applications of mathematics in engineering practice) or to discuss mathematics generally. They are uncomfortable with the ambiguity of an investigative approach; they prefer the certainty of following set rules in order to achieve the "correct answer".

This study illustrates the impact of students' investigations' of mathematics usage in engineering practice; students, having completed the exercise, show increased mathematics task value; in particular they now see how a variety of mathematics topics and applications can benefit engineers' work. This in turn generates increased student interest in mathematics and particularly in mathematics that is useful to students' future careers in engineering practice.

It is reported that graduate engineers' difficulty communicating mathematics is a significant weakness of engineering education (Goold, to be published 2014). This study introduces students to the concept of communicating mathematics and its relevance. It is also noted that one student who found mathematics difficult to "self-learn", discovered, from the exercise, that mathematics learning can take place outside the classroom given the availability of a variety of mathematics learning resources on-line.

The study illustrates the positive changes in students' mathematics attitudes arising from their insight into engineering practice and how mathematics is used in the workplace. The study also illustrates that feelings about mathematics are an important factor in mathematics learning and that mathematics communication skills benefit engineers.

It is concluded that engaging students in exercises that do not solely rely on the "precise" rules of mathematics and the "correct answer" improves their relationships with mathematics and their motivation to engage with mathematics generally.

REFERENCES

BERNSTEIN, B. & SOLOMON, J. 1999. Pedagogy Identity and the Construction of a Theory of Symbolic Control *British Journal of Sociology of Education,* 2**,** 265-279.

BLACK, L., MENDICK, H. & SOLOMON, Y. (eds.) 2009. *Mathematics Relationships in Education,* New York: Routledge.

ERNEST, P. 2010. Add It Up: Why Teach Mathematics? *Professional Educator* 9**,** 44-47.

FALSAFI, L. 2010. *Learner Identity a Sociocultural Approach to How People Recognize and Construct Themselves as Learners.* Doctorado Interuniversitario de Psicologia de la Educacion.

GOOLD, E. to be published 2014. Putting Mathematics "into a Form that a Non-Engineer will Understand". *SEFI 2014 Annual Conference: Educating Engineers for Global Competitiveness.* Birmingham, UK.

GOOLD, E. & DEVITT, F. 2012. *Engineers and Mathematics: The Role of Mathematics in Engineering Practice and in the Formation of Engineers,* Saarbrücken, Germany, Lambert Academic Publishing.

ILLERIS, K. 2014. *Transformative Learning and Identity,* Oxon, Routledge.

LAMPERT, M. 1990. When the Problem is Not the Question and the Solution is Not the Answer: Knowing and Teaching Mathematics. *American Educational Research Journal,* 27**,** 29-63.

MILES, M. B. & HUBERMAN, A. M. 1994. *Qualitative Data Analysis: A Expanded Sourcebook,* Thousand Oaks, London, New Delhi, Sage.

MOONEY, O., PATTERSON, V., O'CONNOR, M. & CHANTLER, A. 2010. A Study of Progression in Irish Higher Education. Dublin: Higher Education Authority.

NARDI, E. & STEWARD, S. 2003. Is Mathematics T.I.R.E.D? A Profile of Quiet Disaffection in the Secondary Mathematics Classroom. *British Educational Research Journal,* 29**,** 345-367.

PETOCZ, P., REID, A., WOOD, L. N., SMITH, G. H., MATHER, G., HARDING, A., ENGELBRECHT, J., HOUSTON, K., JOEL, H. & PERRETT, G. 2007. Undergraduate Students' Conceptions of Mathematics: An International Study. *International Journal of Science and Mathematics Education,* 5**,** 439-459.

SCHUNK, D. H., PINTRICH, P. R. & MEECE, J. L. 2010. *Motivation in Education: Theory, Research, and Applications,* Upper Saddle River, NJ, Pearson Educational International.
SILVERMAN, D. 2010. *Interpreting Qualitative Data,* London, California, New Delhi, Singapore, Sage.
SMITH, A. 2004. Making Mathematics Count: The Report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education. London: Department for Education and Skills (DfES).
TREVELYAN, J. 2010. Mind the Gaps: Engineering Education and Practice. *Australasian Association for Engineering Education (AAEE) Conference.* Sydney.
WIGFIELD, A. 1994. Expectancy-Value Theory of Achievement Motivation: A Developmental Perspective. *Educational Psychology Review,* 6**,** 49-78.
WIGFIELD, A. & ECCLES, J. S. 2000. Expectancy-Value Theory of Achievement Motivation. *Contemporary Educational Psychology,* 26**,** 68-71.
WIGFIELD, A. & ECCLES, J. S. 2002. The Development of Competence Beliefs, Expectations for Success and Achievement Values from Childhood through Adolescents. *In:* WIGFIELD, A. & ECCLES, J. S. (eds.) *Development of Achievement Motivation.* San Diego: Academic Press.
WOOD, L. N. 2010. Graduate Capabilities in Mathematics: Putting High Level Technical Skills into Context. *International Journal of Mathematical Education in Science and Technology,* 41**,** 189-198.