MATHEMATICAL IDENTITY OF SCIENCE AND ENGINEERING STUDENTS IN AN IRISH UNIVERSITY

Fionnán Howard

Dublin City University

This paper presents the initial findings of my PhD study investigating science and engineering undergraduates' relationship with mathematics and the contexts that inform this relationship. Thirty-two students completed an online questionnaire consisting of three open-ended questions. The data was analysed using thematic analysis with both inductive (data-driven) and deductive (theoretical) coding. A summary of the background, theoretical perspective and conceptual framework will be presented followed by some initial results. Student responses illustrating two emergent themes will be described.

INTRODUCTION

The purpose of this research is to explore science and engineering students' relationship with mathematics and the contexts that inform this relationship as they transition to higher level education. To investigate this, the concept of mathematical identity was used and the study is thus titled Mathematical Identity of Science and Engineering students (MISE). Understanding mathematical identity helps a teacher to teach more effectively. Not least because

> "... the role of the teacher includes fostering change for the better in students' mathematical identity. To effect such change, requires knowledge about students' mathematical identity in the first instance" (Eaton & OReilly, 2009, p. 234).

Identifying issues relating to pedagogy or the learning experience of students can combat feelings of marginalisation and influence students' decision to continue, or not, their mathematical studies (Grootenboer & Zevenbergen, 2008). Thus, teachers influence the relationship that each student has with mathematics, but by understanding this relationship they can improve the students' learning experience and the efficacy of their own teaching.

Students' preconceptions about mathematics influence their learning and are further complicated by the transition to higher level education where they will be required to learn and demonstrate knowledge in new ways. It is well documented that students struggle with the kind of abstraction that is common in higher level mathematics (Breen, O'Shea, & Pfeiffer, 2013, p. 2317). Reflecting on their own mathematical identity can help students engage more effectively as mathematics learners during this transition (Kaasila, 2007). In the same vein, Sfard and Prusak (2005, p. 16) suggest that "identity talk makes us able to cope with new situations in terms of our past experience and gives us tools to plan for the future."

Background to the study

I was motivated to conduct the current research by my teaching experience. When conducting tutorials with science and engineering students in Trinity College Dublin, it appeared that some of the school of mathematics lecturers who communicated very well with mathematics students, struggled to engage effectively with (or were embraced more fully by) science and engineering students. Research has shown that lecturers teach mathematics students differently to 'service mathematics' students (Bingolbali, Monaghan, & Roper, 2006) and I claim that differences in mathematical identity could explain why the lecturers find different approaches more effective and can help guide such approaches.

LITERATURE REVIEW

Grootenboer & Zevenbergen (2008, p. 244) proposed that identity incorporates students' "knowledge, abilities, skills, beliefs, dispositions, attitudes and emotions" thus placing identity as an important precursor to the learning of mathematics. In their seminal paper, Sfard and Prusak (2005, p. 16) wished to operationalise identity by avoiding the notion of "who one is." They claimed that other authors had relied on this timeless, agentless essence in their definitions, and that this had rendered the concept untenable. Although they treated narrative and identity as equivalent, it has become more common to consider the concepts as related rather than synonymous (Eaton, 2013; Kaasila, 2007) i.e. to see narratives as the action through which identity is revealed.

A series of previous studies in Ireland developed an instrument for exploring mathematical identity of pre-service teachers which has been adapted for this new context. Mathematical Identity of Student Teachers (MIST) used grounded theory to develop a questionnaire consisting of two open-ended questions: a broad opening question and a follow-up question which included some prompts. These researchers wanted to allow the nine participants to make responses that were "indicative of their personal mathematical identity" but not leave them without any direction (Eaton & OReilly, 2009, p. 229). The prevalence of self-reflection as part of mathematical identity became evident (Eaton & OReilly, 2009a) and as a result, the subsequent study 'Mathematical Identity using Narrative as a Tool' (MINT) added a third question about self-reflection. Since MINT involved 99 students from four institutions, they migrated the questionnaire to an online tool (Eaton, Horn, Liston, Oldham, & OReilly, 2013).

METHODOLOGY

Theoretical Perspective

I follow a constructionist epistemology meaning "[t]here is no objective truth waiting for us to discover it" (Crotty, 1998, p. 8). The focus of the research is not events themselves but the meaning of experiences from the point of view of the participants (Creswell, 2009, p. 16) since "... people may construct meaning in different ways, even in relation to the same phenomenon" (Crotty, 1998, p. 9). I believe that it is not possible for a researcher to step outside their biases and conduct research impartially as an objective observer and therefore I present my conclusions as justified beliefs rather than absolute truths. The narratives I produce through data analysis are co-constructed by researcher and participant and thus the research process is shaped by both (Cohen, Manion, & Morrison, 2007, p. 37). What I bring to the study from my own background and identity is embraced as experiential knowledge which informs, while not dominating, the research design since "[s]eparating your research from other aspects of your life cuts you off from a major source of insights, hypotheses, and validity checks" (Maxwell, 2013, p. 45).

Conceptual Framework

Mathematical identity is defined as the multi-faceted relationship that an individual has with mathematics, including knowledge, experiences and perceptions of oneself and others (Eaton and OReilly, 2009, p. 228, see also Grootenboer & Zevenbergen, 2008). This study embraces the view of Kaasila (2007) who explains that "one's mathematical identity is manifested when telling stories about one's relationship to mathematics, its learning and teaching." He acknowledges the narrative mode of thought proposed by Bruner (1986, p. 13) which attempts to deal with "the particulars of experience, and to locate the experience in time and place" emphasising the contextual and situated nature of identity as defined in this paper.

A hybrid process of inductive (data-driven) and deductive (theoretical) coding was used to analyse the open-ended responses to the online questionnaire followed by a thematic analysis guided by the theoretical perspective and research questions. This was adapted predominantly from Fereday and Muir-Cochrane (2006) with influence from Braun and Clarke (2006) and Crabtree and Miller (1999). (For a full discussion of the methodology see Howard, OReilly, & Nic Mhuirí, 2019, in print) The aim of the analysis was to produce a group narrative co-constructed by the participants and the researcher using thematic maps within NVivo. This paper reports on the results of applying the aforementioned methodology with this aim.

Methods

Science (SCI) and Engineering (ENG) students represent a significant portion of DCU's undergraduate population and of students taking mathematics modules, but they have not previously been included in research on mathematical identity. We identified 16 cohorts of SCI and ENG students in DCU who study mathematics in their first year. An adapted version of the online questionnaire from MIST/MINT was used (See Figure 1) with each question appearing on a separate page. There were 32 respondents to the main study (22 SCI and 10 ENG students representing 14 of the 16 chosen cohorts), contributing more than 6500 words.

Q1. Think about your total experience of mathematics. Tell me about the dominant features that come to mind.

Q2. Now think carefully about all stages of your mathematical journey from primary school to university mathematics. Consider:

- Your feelings or attitudes to mathematics
- Influential people
- Critical incidents or events
- Specific mathematical content or topics
- How mathematics compares to other subjects
- Why you chose to study a course which includes mathematics at third level

With these and other thoughts in mind, describe some further features of your relationship with mathematics over time.

Figure 1: Online questionnaire where Q1 and Q2 appeared on separate pages.

To analyse this data, a codebook of forty-seven codes was developed based on a literature review and a pilot study conducted in November 2017. These codes provided the deductive (theoretical) dimension of the analysis. During analysis of the dataset for the main study, twenty new codes were developed. These provided the inductive (data-driven) dimension. Firstly, these new inductive codes were given a definition before all codes were reviewed to develop a narrative for each one. I asked myself the basic question: "What are the extracts in this code saying?" I noted observations, interpretations or ideas using memos in NVivo.

I began a thematic map by including the inductive codes so I could build it from the new ideas expressed by the MISE participants. I included the deductive codes in groups of three or four by reviewing the content of each code and forming some connections in the thematic map with other codes e.g. *I need it explained to me* and *I took charge* are connected since students say that when the teacher is bad at explaining they take the initiative to find another source from which to get better explanations. Each connection in the map was assigned a brief phrase to explain the connection while the memos in NVivo catalogue each one in more detail.

Due to the complexity of the data, it was not possible to partition the codes into themes without any connections between the themes themselves. The aim was to cluster well-connected parts of the thematic map to minimise (rather than eliminate) the connections between themes. Some codes were very well connected to the rest of the thematic map (e.g., - 'Teachers' and 'Exams and LC subject choice') due to the number of extracts they contained and the broad range of issues within these extracts. I removed these temporarily and moved the other codes and potential themes to group them into well-connected clusters. I included the remaining codes in the most sensible potential theme and used a miscellaneous theme to hold codes temporarily before they were placed elsewhere. This allowed external and internal heterogeneity to be analysed (Braun & Clarke, 2006, p. 91).

RESULTS

The analysis resulted in the development of five main themes of which, the first two will be the focus of this paper:

1. Ways of learning mathematics
2. Mindsets and getting started
3. What is Mathematics?
4. Mathematics gets harder as you progress: transitions and realisations
5. Mathematics is a means to an end

Theme 1: Ways of Learning Mathematics

A triad of learning, understanding and teaching mathematics emerged at an early stage. My rationale for this triad came from several perspectives:

1. Learning: Some students mention exams and ways of learning mathematics to obtain good results or improve performance:

ID118: We just learned it for the sake of learning and making the deadline for the Leaving so we could pass.

2. Understanding: Others refer to concepts behind calculations and how these types of building blocks are important for understanding. They want to understand rather than memorise it and they are aware of a difference between these two types of learning:

ID54: Understanding the maths we were studying instead of just learning off an equation.

ID66: I started to actually understand maths, rather than just do it.

3. Teaching: Many students gave critical evaluations of their classroom experience, comparing teaching methods and teachers themselves. They have developed strong opinions on best practice for teaching, drawing from these experiences.

ID66: The importance of learning through concepts rather than through questions should be stressed a lot more.

The teacher is the first port of call when students encounter difficulty:

ID86: I found that teacher very bad in terms of her ability to explain maths. I moved myself to higher mathematics (2nd year) because of an amazing teacher that was teaching it.

ID125: I sat higher level as the teachers in ordinary level classes were not that good.

As can be seen above, some of the MISE participants (8 out of 32) took matters into their own hands (working by themselves, going to grinds teachers) when searching for a source to help them learn or understand mathematics.

ID66: I was only doing bad in it because of how I was taught. Once I began teaching myself and actually understanding the concepts, I started to really enjoy it.

ID86: Maths became very easy only when I had a private tutor.

The MIST study found that student teachers took a "team approach" to mathematics at higher level, much more so than at post-primary level (Eaton & OReilly, 2009, p. 232). In contrast, no MISE participants' reported that they work collaboratively. This suggested that the individual learning styles and objectives of MISE participants would play a more prominent role than first expected, as demonstrated above. This individual approach to learning had two main elements which I called "I work on my own" and "I took charge." Participants describe working by themselves (by choice or necessity) with one participant stating succinctly that:

ID118 It is between you and the numbers. You have to learn and put in the work or you don't succeed.

Many participants demonstrate responsibility for directing their own learning, by finding a new source of learning or setting their own goals rather than relying on advice from others:

ID34: I dropped into ordinary before the leaving to ensure I would get a good enough grade.

ID66: Was told to drop to ordinary. After that, I took matters into my own hands, and came out with a H3 in the leaving.

ID112: When I took it upon myself to improve my maths as well as the help of my great grinds teacher, I found maths more appealing and myself more capable

I was struck by the depth and awareness with which the students discuss types of learning as well as the self-direction that they demonstrate when making decisions about how, where and when to source such learning. I find it particularly interesting that they appear cognisant that there are other ways of learning that don't suit them. They acknowledge that they want to see the steps, have it explained or understand the concepts, and they seek out sources that provide that type of learning.

Theme 2: Mindsets and getting started

Although not prominent in previous studies among students in Ireland, it has been reported that students sometimes see mathematics as an objective subject, especially compared to other subjects, where pursuit of the right answer is the goal (Eaton & OReilly, 2009, p. 233). This view came through strongly in this study, as did the view that this objectivity does not necessarily make the process easier since:

ID91 I love how in maths there's only one correct answer but lots of different ways to get there.

Participants are clear that you need to think a certain way to work well in mathematics

ID7 Thinking outside the box … seeing the bigger picture.

They particularly focus on getting started as a keystone which includes understanding what is being asked, being able to see non-obvious solutions and trying different approaches:

ID124 I would find difficulty trying to start a problem but once I know how to start I'd be able to finish it … Maths involves more thinking and trying different methods to get to the answer.

ID86 Figuring out what to do and where to start was challenging.

A range of ideas are mentioned by participants that inform this belief. These include problem solving skills, analytical skills, lateral thinking and breaking down a problem. Confidence could improve one's ability to think as above:

ID55 I generally did well in maths exams compared with other subjects, which made me enjoy the subject more, and gave me confidence and a belief that I could do well in the field.

However, participants identify several barriers to such positive growth mindsets including anxiety, the will to persevere and language barriers:

ID69 Maths is very heavy and stress inducing.

ID118 It's the work that has to be put in to persevere … I know I can do it, and I want to, it's just tough

ID15 A lot of maths were taught through Irish which I feel made it slightly harder to grasp certain topics.

Overall The participants are clear that their mindset affects their ability to get started with a question or problem, to persevere with multiple attempts or to interpret and analyse the information given. They think these are key elements to improve upon in order to succeed in mathematics.

DISCUSSION AND FURTHER RESEARCH

In this paper I have presented two initial themes from my research on mathematical identity of undergraduate science and engineering students in DCU. Theme 1 deals with ways of learning mathematics whereas theme 2 deals with how mindset facilitates or hinders effective application of knowledge. Although ways of studying mathematics has featured as a theme in previous mathematical identity research in Ireland (Eaton & OReilly, 2009a), the duality in types of knowledge/learning has not been the focus of such research. Consequently, I was surprised by the maturity and clarity with which participants presented this framework for doing mathematics, especially in only their first year at university.

The small sample size is a limitation of the study. However, the small number of participants allowed an in-depth analysis that would not have been practical with a larger group. In this paper, the validity of the themes is established by multiple references and participants describing the same phenomenon. However, since some students wrote much less than others, themes may not represent the views of all 32 participants, and this remains to be verified. Once the analysis has been completed, the next phase of the study involves a focus group. The purpose of this is twofold: to present the themes and narratives to a selection of participants in order to check the validity of the themes (Creswell, 2009, p. 190-191) and to allow the participants to elaborate on, or add to, their questionnaire submissions.

During analysis I found that some codes were not helpful for developing a group narrative but may be useful for interrogating the data for specifics (e.g. for finding out which students think mathematics at secondary school is about understanding or rote learning.) The third phase of my PhD study will focus more on such codes when I look longitudinally at the participants' individual journeys as they transition to higher level education. I expect the benefit of hindsight through some experience of mathematics at university level to affect the mathematical identities expressed by the participants in this first phase of data collection.

REFERENCES

Bingolbali, E., Monaghan, J., & Roper, T. (2006). Service teaching: Mathematical education of students of client departments. In J. Novotná, H. Moraová, M. Krátká, & N. Stehlíková (Eds.), *Proceedings of the 30th Conference of the International Group for the Psychology of Mathematics Education* (pp. 169−176). Prague, Czech Republic: PME.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77−101.

Breen, S., O'Shea, A., & Pfeiffer, K. (2013). The use of unfamiliar tasks in first year calculus courses to aid the transition from school to university mathematics. In B. Ubuz, C. Haser & M. A. Mariotti (Eds.), *Proceedings of the Eighth Congress of the European Society for Research in Mathematics Education (CERME8)* (pp. 2316−2325). Ankara, Turkey: Middle East Technical University and ERME.

Bruner, J. (1986). *Actual Minds, Possible Worlds.* Cambridge, MA: Harvard University Press.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education.* Abingdon, UK: Routledge.

Crabtree, B., & Miller, W. (1999). *Doing qualitative research.* Thousand Oaks, CA: SAGE Publications Inc.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed methods approaches.* Thousand Oaks, CA: SAGE Publications Inc.

Crotty, M. (1998). *The Foundations of Social Research.* Thousand Oaks, CA: SAGE Publications Inc.

Eaton, P., Horn, C., Liston, M., Oldham, E., & OReilly, M. (2013). Developing an instrument to explore mathematical identity: A study of students from several third level institutions in Ireland. In E. Arntzen (Ed.), *Proceedings of the Association for Teacher Education in Europe 38th Annual Conference* (pp. 280−296). Halden, Norway: ATEE.

Eaton, P., & OReilly, M. (2009). Who am I and how did I get here? Exploring the mathematical identity of student teachers. In D. Corcoran, T. Dooley, S. Close & R. Ward (Eds.), *Proceedings of Third National Conference on Research in Mathematics Education (MEI 3)* (pp. 228−236). Dublin, Ireland: St. Patrick's College.

Eaton, P., & OReilly, M. (2009a). Exploring mathematical identity as a tool for self-reflection amongst pre-service primary school teachers: "I think you have to be able to explain something in about 100 different ways." In Paditz, L., & Rogerson, A. (Eds.), *Models in Developing Education: Proceedings of the 10th International Conference on Mathematics Education into the 21st Century* (pp. 153−156). Dresden, Germany: ME21.

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods*, *5*(1), 80−92.

Grootenboer, P. J., & Zevenbergen, R. (2008). Identity as a lens to understand learning mathematics: Developing a model. In M. Goos, R. Brown, & K. Makar (Eds.), *Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 243−250). Brisbane, Australia: MERGA.

Howard, F., OReilly, M., & Nic Mhuirí, S. (2019, in print). "I don't like Maths as a subject but I like doing it": A methodology for understanding mathematical identity. In *Proceedings of the 11th Congress of the European Society for Research in Mathematics Education (CERME11)*. Utrecht, Netherlands: University of Utrecht and ERME.

Kaasila, R. (2007). Using narrative inquiry for investigating the becoming of a mathematics teacher. *ZDM: The International Journal on Mathematics Education*, *39*(3), 205–213.

Maxwell, J. A. (2013). *Qualitative Research Design: An Interactive Approach.* Thousand Oaks, CA: SAGE Publications Inc.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher*, *34*(4), 14–22.

Strauss, A. L., & Corbin, J. M. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory.* Thousand Oaks, CA: SAGE Publications Inc.