“I don’t like Maths as a subject but I like doing it”: A methodology for understanding mathematical identity

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This paper presents a thematic analysis methodology which uses a hybrid coding process to understand how science and engineering students in higher level education relate to mathematics. This process utilises and builds on previous research on mathematical identity amongst student teachers by using deductive coding while continuing to be grounded in the new data through inductive coding. Many authors have written on both or either of these methods. Most treat it was a simple choice between one or the other. Few have addressed best practice in integrating these approaches.

Keywords: Mathematical identity, transition, higher level education, thematic analysis.

Introduction

To create an effective learning environment for science and engineering undergraduates, an awareness of how they relate to mathematics is vital. Investigating mathematical identity can help educators better understand this relationship and help determine potential issues with pedagogy and the learning experience of students. Such issues may contribute to marginalisation and thus impact students' relationship with mathematics and their decision to continue, or not, their mathematical studies (Grootenboer & Zevenbergen, 2008; Solomon, 2007). Reflecting on their mathematical identity can help students engage more effectively as mathematics learners while they transition to higher level education (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."

Mathematical identity has been investigated in the context of Initial Teacher Education in Ireland since 2008. A series of previous studies developed an instrument for exploring mathematical identity of pre-service teachers which has been adapted for this new context. The 'Mathematical Identity of Student Teachers' (MIST) study used grounded theory among 9 students to develop two open-ended questions: a broad opening question to allow participants make responses that are "indicative of their personal mathematical identity" and a follow-up question which included some prompts "to balance the need for some direction" (Eaton & OReilly, 2009, p. 2). 'Mathematical Identity using Narrative as a Tool' (MINT) involved 99 students and not only converted the questionnaire to an online tool but also added a third question about self-reflection which had become evident as a key element of mathematical identity in MIST (Eaton, Horn, Liston, Oldham, & OReilly, 2013).

Although mathematical identity has enjoyed increased attention in recent years within education (Darragh, 2016), a lack of cohesion and agreement on ontological, epistemological, and methodological issues has produced a fractured body of research (Kaspersen, Pepin, & Sikko, 2017b). Despite this new attention, Hannula and Garcia Moreno-Esteva (2017) found that identity had featured in just four of 100 papers in this working group (TWG8) between CERME4 and CERME9. At CERME10 Kaspersen, Pepin, and Sikko (2017a) in TWG20 focused on the link between mathematical identity and grades much like Cobb, Gresalfi, and Hodge (2009) did. A study by Craig (2013) took a narrower view of identity, thinking only of procedural versus conceptual learning, ignoring the many other facets of identity that interact with this specific strand. In Ireland, MIST/MINT (Eaton & OReilly, 2009; Eaton et al., 2013) focused on developing an instrument to collect narrative data, but the process of analysing this data requires some clarification in order to be reliably used in other contexts or amongst larger groups of students. Although some studies have investigated engineering identity, and incidentally addressed mathematics, studies dealing with the mathematical identity of engineering students are rare.

This paper will outline how we adapted and integrated inductive and deductive techniques to facilitate a thematic analysis. This addresses the need to incorporate the knowledge gained from previous work on mathematical identity in Ireland while also continuing to be grounded in the new data. We refined the MIST/MINT coding process by deconstructing the themes they developed amongst student teachers (which may not accurately represent the mathematical identity of this new cohort) into codes and constructed new themes based on the current data. We will demonstrate how the coding process aided the thematic analysis, already established in MIST/MINT, for cohorts of students not previously considered there. We expect this to advance the drive toward an effective process for accessing students' mathematical identities.

Background and Theoretical perspective

Sfard and Prusak (2005) and Kaspersen et al. (2017a) both noted that researchers in mathematics education had yet to agree upon a working definition of identity while Cobb et al. (2009, p. 41) conceded that it is "vague and ill-defined." Authors often operate from different viewpoints: the sociological viewpoint where identity is an action, constructed and reconstructed over time, which has long characterised identity at CERME (Hannula & Garcia Moreno-Esteva, 2017), and the psychological viewpoint where identity is a core stable phenomenon (Cobb et al., 2009). Sfard and Prusak (2005) detailed the similarities between identity and other concepts such as attitudes, conceptions and beliefs but pinpointed the constantly changing and evolving nature of identity as the key power behind the concept. The sociological viewpoint of identity acknowledges that it is ever-changing and communicated best through narratives authored by the participants. They can communicate mathematical experiences they consider to be influential and reflect on them as they write often leading to realisations or re-interpretations of the experiences.

This study is conducted under a social constructivist paradigm and 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 & OReilly, 2009, p. 228; See also Grootenboer & Zevenbergen, 2008) We propose that empirical information about experiences is not enough to reveal mathematical identity and we aim to establish the meaning of these experiences from the views of participants (Creswell, 2009, p. 16). We follow the narrative approach detailed by Creswell (2009, p. 13) whereby the narrative produced by the research represents a repackaging of the experiences and stories communicated by the participants. The resulting narrative represents a combination of these experiences with those of the researcher, positioning the participants as co-researchers who shape the research process (Cohen, Manion, & Morrison, 2007, p. 37).

Methodology

We identified 16 cohorts of science and engineering students in DCU who study mathematics in their first year. They represent a significant portion of the undergraduate population and of students taking mathematics modules, but they have not previously been included in research on mathematical identity. Participants were recruited in lectures where the lead author explained the study, distributed plain language statements and returned one week later to voluntarily sign up students who were interested in taking part. An online questionnaire (adapted from MIST/MINT) consisting of three open-ended questions was employed with each question appearing on a separate page. A pilot study conducted in Winter 2017 involved 18 respondents (10 science and 8 engineering students). There were 32 respondents to the main study (22 science and 10 engineering students), contributing a total of 8000 words. The first two questions are the focus of this paper and are presented in Figure 1. Note that third level is an Irish term for higher level education.

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: First two questions of the online questionnaire which were presented on separate pages

To analyse the open-ended responses to the online questionnaire we used a hybrid process of inductive (data-driven) and deductive (theoretical) coding adapted predominantly from Fereday and Muir-Cochrane (2006) with influence from Braun and Clarke (2006), Boyatzis (1998) and Crabtree and Miller (1999). The latter authors noted that codes "can be constructed a priori, based on prior research or theoretical perspectives or created on preliminary scanning of the text" and that "...some initial codes are refined and modified during the analysis process." (p. 167) Their claim that constructivists tend to lean towards co-created codes fits well with Braun and Clarke's categorisation of thematic analysis as “grounded theory ‘lite’” (Braun & Clarke, 2006, p. 81) since this research builds on the grounded theory research of MIST/MINT.

Our approach consisted of seven stages (of which, the first four will be described further on):

Stage 1 Development of codebook from literature review of MIST/MINT and pilot study.

Stage 2 Code stratified sample of main data.

Stage 3 Broad reading and summarising of entire data set.

Stage 4 Code data using inductive and deductive codes. Elaborated in detail below.

Stage 5 Group codes to develop thematic map.

Stage 6 Review themes and use the data to check for internal and external homogeneity.

Stage 7 Define and name themes.

Stages 3-7 broadly align with the five steps suggested by Braun and Clarke (2006) who treated inductive and deductive coding as separate techniques. Stages 1-5 correspond to steps from Fereday and Muir-Cochrane (2006) but with a significantly expanded fourth stage as well as stronger interplay between the data analysis stages. Crabtree and Miller (1999) have a simple four step model (with stages 2-4 combined) which omits the testing stage although they do go on to discuss such a step (p. 168). All authors participated in stage 2 coding but stage 3 and 4 were conducted by the lead author.

Although most authors recommend an iterative line-by-line coding process where codes are developed, applied and immediately examined for groupings without reference to the data (Braun & Clarke, 2006), we realised that the density of these responses (on average every 9 words resulted in a code) meant that it was considerably more difficult to extract meaningful codes from the data in a single round of coding without including multiple perspectives (Strauss & Corbin, 1998). We thus developed stage 4 significantly beyond what is described by other authors. The remainder of this section will describe stages 1-4, which have been completed, with particular emphasis on stage 4. It is intended that Stages 5-7 will follow the recommendations given by Braun and Clarke (2006).

Stage 1

MINT/MIST participants’ responses were used to develop seven main categories: self-reflection, influential people, ways of working in mathematics, comparing other subjects, nature of mathematics, right and wrong and mathematics as a rewarding subject (Eaton, Oldham, & OReilly, 2011, p. 32). These categories were expanded into codes using the examples and discussion from five MINT papers, three MIST papers (one unpublished) and two papers from an interim ‘bridging’ study. Codes that did not clearly fit in any of these categories were simply left uncategorised.

The pilot study helped to further demarcate the codes under each category. We followed Fereday and Muir-Cochrane (2006, p. 85) and Boyatzis (1998) by naming the codes, providing a description, some keywords (if possible) and giving at least one example from the pilot study of an instance of the code. From the start we adopted the use of an extra miscellaneous code for items which do not fit any existing category. This step is used to check the comprehensiveness of the codebook and to ensure nothing relevant is overlooked the coding process because it is difficult to categorise. For example:

ID86	I think its good that I'll be practicing something I'm bad at.It means I'll be eventually not so bad at it.

Stage 2

A codebook consisting of 37 codes was applied to a stratified sample of 8 from the 32 respondents, based on grouping, cohort, gender, word count and age. All three authors coded this data separately. We discussed the results with reference to the codebook and adapted the codebook by splitting, combining or creating codes as appropriate changing the number of codes to 47. The definitions were also updated, keywords added and examples from the sample included in line with the relevant codes. Our initial main coding principles were derived from the sample coding at this stage. They are given here with examples to show their effectiveness:

1. Code in-line by including a number at or near each instance. Codes can run across sentences, overlap and a single statement may require multiple codes.

Pay attention to context between sentences or along entire paragraphs.

ID 118	Physics is about explaining everything essentially, and making sense of everything. That's why maths is interesting to me...

This student talks about making sense of everything but the second sentence makes clear that mathematics also plays a role either intrinsically or in tandem with physics.

2. Codes should be broad enough to allow a range of responses to be grouped. Especially where a continuum exists, e.g., mathematics is exciting/boring or hard/easy.

3. Often participants will express a combination of both positive and negative, e.g., elements they like and elements they don’t like or parts they find hard or easy:

ID124	I enjoy certain parts of it.
ID78	Certain aspects came easier to me than others...
ID98	Leaving a hard topic and starting to learn a harder one makes the first hard topic seem very easy.

They may give a ‘middle-ground’ response:

ID96	Generally ok experience...
ID120	I found mathematics okay.

Students sometimes mitigate their opinions:

ID40	I don't like Maths as a subject but I like doing it.

Stage 3

The entire dataset was read through for "close contact and familiarity" (Boyatzis, 1998, p. 45) and to make the important first step towards understanding the narratives therein. To accomplish this the data was read through repeatedly, "taking notes or marking ideas for coding" (Braun & Clarke, 2006, p. 87) as well as noting the key points made by participants (Fereday & Muir-Cochrane, 2006, p. 86). These notes were used later for comparison with coding.

Stage 4

To enact the principles stated at the beginning of this section, the coding process consisted of several steps (ways of looking at the data):

(a) Apply codes using a fine-grained, line-by-line approach.

(b) Write a summary of each participant's response and compare with the codes allocated.

(c) Compare with original notes from broad reading of the data.

(d) Code each 'piece of interest' by removing chunks of text and re-reading them in isolation.

(e) In tandem:

   i. Pick each code and read through data for possible extra occurrences of the code.

   ii. Use keywords to identify possible extra occurrences of each code.

(f) Interrogate data coded as miscellaneous to determine if re-categorisation is possible.

This resulted in the creation of 20 inductive codes to be reviewed at the next stage. Each step shown above added to the exhaustiveness of the coding by illuminating more opportunities for codes to be applied but was also useful for adding new ideas as notes under each participants' response. Step (a) arose because we found that students' responses contain a lot of information even in short pieces of text:

ID 55	I generally did well in maths exams [*good at maths*] compared with other subjects [*comparing subjects*], which made me enjoy the subject more [I *enjoy maths*], and gave me confidence and a belief that I could do well [*origin of interest in maths*] in the field [*confidence in maths*].

In step (c) almost every initial note had been encapsulated in the coding. Of the remainder, most notes were now either obviously unfounded or involved too high a level of interpretation to be included:

ID 118	...explaining the reasoning behind what we were learning. We just learned for the sake of learning...

This was initially considered as "I like to understand the content rather than learn it off" which requires a leap of interpretation. It fit much better in the inductive code "Learning/doing maths without knowing why."

In step (e) we discovered that searching for keywords often resulted in hits from the summaries in part (b). This was useful for identifying via a paraphrasing whether the correct codes had been applied. Searching for ‘pace’ brings up my comment “Pace. Quicker (because I was good?)” Original statement was “I would be finished far ahead of everyone in my class” (ID69).

In (f) the miscellaneous code proved useful for collecting statements that were hard to categorise or would require a new code to be classified. Of the 36 statements coded, 28 were reclassified leaving only 8 statements remaining as miscellaneous.

Discussion

This paper outlined a hybrid inductive and deductive methodology to facilitate a thematic analysis which incorporated the knowledge gained from previous work on mathematical identity in Ireland while also continuing to be grounded in the new data from this study. We built on the previous grounded theory research by MIST/MINT while acknowledging that we do not yet have a fully validated and reliable process for accessing mathematical identity. The categories developed by MIST/MINT were particularly helpful to determine whether a code might be present in a statement. Adopting a finer, detailed coding approach at stage 4 with many steps acknowledges that students’ narratives are a link or window to their identities rather than being their putative ‘actual’ identities. The ever-changing nature of identity necessitated a semantic approach where one does not look “beyond what a participant has written” when coding. The interpretative stages happen during analysis after coding has taken place. This is in line with the advice of Braun and Clarke (2006, p. 98) but contrary to that of Boyatzis (1998). All steps of coding proved useful for combating discounting of evidence in uncoded text (Crabtree & Miller, 1999, p. 171) particularly coding ‘pieces of interest’ and using keywords. Using a miscellaneous code represented 53 of the 116 (or 46% of) code changes made and thus was the most effective way to ensure that meaningful responses did not go undetected. The small sample size of 32 facilitated this multi-step coding.

We expect this methodology to advance the drive toward an effective process for accessing students’ mathematical identities. We see this approach as providing insights for students to improve their learning experiences and for educators to ease the transition to higher education for such students.

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