Understanding Changes in Teacher Dispositions Towards Mathematics Teaching Using an Epistemic Network Analysis

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This study seeks to understand the experiences of a teacher who has participated in professional learning that focuses on the values, beliefs, and enjoyment that primary school teachers experience about mathematics teaching. Using a quantitative ethnography methodology, an epistemic network analysis was applied to understand these changes experienced by a teacher over the professional learning period.

Many Australian primary school teachers do not enjoy mathematics teaching (Russo et al., 2023). This situation is likely to have negative consequences for learning and teaching mathematics in primary school. Professional learning for primary school mathematics teachers commonly focuses on developing teachers' curriculum and pedagogical content knowledge (Beswick et al., 2016), but little attention is given to developing teachers' positive attitudes and enjoyment for teaching mathematics (Lamb, 2010).

The focus of this study is to investigate and describe any impacts associated with participating in the Mathematics Identity (MICubed) professional learning activity which investigates the values, beliefs, and emotional dispositions that primary school teachers experience with mathematics teaching. The research reported in this paper is part of a broader PhD study involving teachers from two primary school communities in Victoria, Australia. For the purposes of this paper, results and findings are reported for one participating teacher. This case describes how one teacher's self-perceptions change over time and the influence of this change on their mathematics teaching.

Background Literature

The MICubed professional learning was designed using evidence-based practices for teaching primary school mathematics, grounded in pedagogical content knowledge (PCK) (Shulman, 1987) and mathematical knowledge for teaching (MKT) (Ball et al., 2008). Before examining the role of teacher dispositions towards mathematics in the implementation of effective teaching practices, it is useful to first examine this evidence base.

Bobis et al. (2012) argue that effective mathematics teaching practices are a combination of curriculum content knowledge, beliefs about mathematics, and the social/cultural contexts from which these are being drawn. This builds upon the work of Sullivan et al. (2009), highlighting the importance of teacher pedagogical content knowledge (PCK) for being effective practitioners. In response to the foundational work of Shulman (1987), which took a cross curricular perspective to PCK, Ball et al. (2008) sought to further refine the concept of pedagogical content knowledge for mathematics teachers, arguing that the field of mathematics education requires a more specialised strand of PCK. They refer to this as mathematical knowledge for teaching (MKT). This focus on the specifics of mathematical knowledge is an important foundation for this study. With Ball et al. (2008) recognising the distinct understandings and practices required for the effective teaching of mathematics, it is reasonable to wonder if a distinct set of emotional dispositions are also necessary for achieving this outcome in primary mathematics classrooms.

Considering these discussions with an eye to school improvement through the lens of professional learning actions, key questions arise: What is more important, teacher knowledge, or confidence in their knowledge? Will a teacher with less specific content knowledge but lots

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of confidence and positivity towards the subject, be more effective in creating a learning pathway for student achievement? Lee (2005), through a survey questionnaire completed by 81 randomly selected teachers in Indiana, USA, produced correlations between teacher attitudes to the teaching of mathematics and student learning outcomes. Teachers who showed high enjoyment and positivity towards mathematics teaching tended to favour a more investigative, problem-solving approach that encouraged student independence, whilst teachers with negative attitudes towards mathematics teaching were more likely to teach lessons focused on single answer outcomes and spend less time teaching mathematics as part of the overall curriculum.

With Lee's (2005) argument that teacher positivity and enjoyment towards mathematics can lead to them taking an investigative and problem-solving approach within their teaching practices, we must consider the literature to understand the value of this approach for improved student outcomes. Problem-solving is a particular aspect of MKT and has potential to influence both mathematics learning and engagement. This is highlighted by De Bortoli and Underwood (2025) in their discussion of the most recent Programme for International Student Assessment (PISA) results. For this reason, problem solving was an important aspect of the professional learning that was conducted as part of this study. Not only is problem-solving demonstrated to be a key pedagogical practice in many countries around the word, including high performing PISA (De Bortoli et al., 2023) jurisdictions, it is important to investigate for this study as it can be a trigger for mathematics negativity in primary teachers (Lamb, 2010).

Problem-solving links mathematical content knowledge and procedural understanding with social and emotional functions such as collaboration, engagement, challenge and creativity. Gervasoni et al., (2012) assert that the collaborative process of finding answers and solutions to problems results in the development and display of more sophisticated thinking in individuals. In addition to Hunter (2009), these authors also draw these conclusions from the work of Askew (2012) and Williams (2008), noting Williams' linkage of student mindsets towards problem solving (specifically their levels of optimism) as a key consideration for teachers when they are scaffolding group interactions.

Looking at mathematical teaching practices through an emotion lens, Russo and Russo (2019) claim that teachers who have greater autonomy over curriculum and engaging with their own interests and areas of enjoyment as well as the interests and enjoyment of their students, are more likely to achieve a positive outcome for student learning. These authors highlight that there is an iterative relationship between teacher and student enjoyment. When teachers enjoy what they are teaching, students enjoy their learning more. Teachers enjoy teaching when students are engaged and responsive (Russo & Russo, 2019; Frenzel et al., 2018).

Extending the argument for the positive correlations between teacher enjoyment and student outcomes by Russo and Russo (2019), Frenzel et al. (2018) in their longitudinal study, asked teachers and students to assess their levels of enjoyment in lessons over the period of a term, with assessment taken at the beginning, middle and end of the time period. Students were also asked about their perceptions of the teacher's enthusiasm. This study indicates that it is the teacher perception of the levels of engagement and enjoyment of their students that is the greatest driver of sustained teacher enjoyment and enthusiasm. Essentially, teachers derive enjoyment from the enjoyment of their students. Indeed, this is a reciprocal process rather than a teacher driven model of enjoyment for both parties. Essentially, as Russo and Russo (2019) found, positive emotional responses are reciprocal in classrooms – teachers and students feed off each other. On the surface, this conclusion seems rather obvious. In responses to the fact that many primary school mathematics teachers do not enjoy teaching mathematics, the study presented in this paper investigated a professional learning approach to assist schools to proactively build enjoyment of mathematics and teaching mathematics for teachers, and ultimately feed into the reciprocal loop of enjoyment of mathematics between teachers and

students. Indeed, it is likely that approaches for improving students' enjoyment of mathematics often need to ensure that teachers are enjoying themselves too.

There is a clear thread through the literature of agreed practices for effective mathematics teaching, the importance of problem solving as a pedagogical approach within this, and that the emotional dispositions of teachers towards mathematics can influence the implementation of these. This study adds to these findings through an exploration of professional learning that focuses on developing teachers' positive emotional dispositions towards mathematics teaching and linking this with the established knowledge base.

Context for the Study

MICubed is a professional learning activity that was designed for this study in which teachers participated in group-based mathematics problem-solving activities. This professional learning had a dual purpose: developing the mathematical and pedagogical knowledge of teachers; and fostering enjoyment, confidence and engagement with the doing and teaching of mathematics. MICubed sought to develop and enhance positive dispositions of teachers towards both the doing and teaching of mathematics, using evidence-based practices. MICubed involved four, 60-minute sessions which were conducted in schools over the course of two terms. In each session, participating teachers engaged in discussions about their mathematical identity and beliefs, what they valued in a mathematics classroom, and how they can foster positive mathematical interactions through inquiry-based problem solving with their students. MICubed was conducted in two primary schools in Victoria, Australia.

The findings discussed in this paper are drawn from the experiences of a single teacher, Alice from Hawke Primary School (pseudonyms). From Hawke Primary School a total of 12 teachers participated in the MICubed professional learning (including the principal). These teachers had diverse experiences with and attitudes towards mathematics.

Method

Mixed methods, including a longitudinal ethnographic case study, was selected as most appropriate for this study. Both qualitative and quantitative elements of data collection and analysis were employed through a quantitative ethnography approach (Shaffer, 2017). Quantitative ethnography enables elements that form the basis of a learning culture (such as teaching), to be analysed in a way which gives visual and statistical representations of both qualitative and quantitative data. Kaliisa et al. (2021) describe these elements as ways of listening, talking, reading, writing, acting, interacting, valuing, feeling and believing that are specific to a learning culture. These elements are then coded and identified within data sets and mapped using an Epistemic Network Analysis (ENA) to analyse the connections between elements within the data.

ENA is a methodology designed to identify and quantify the connections among elements in coded qualitative data (Shaffer, 2014). These connections are visualised in dynamic network models. The generated models are useful for analysing how connections between codes change and evolve, which is relevant when studying professional learning processes and outcomes. An advantage of using ENA to produce networks of connections, is that results can be compared visually and statistically. ENA software (https://www.epistemicnetwork.org/) is used to display coded data elements as nodes within a network and shows connections between these nodes to represent their co-occurrences or associations. Thicker connecting lines between nodes represent more frequent co-occurrences or associations.

The use of ENA is relatively new in education, and particularly as a tool for analysis of teacher emotional dispositions towards primary school teaching and curriculum areas. The following explanation is included as a guide for the interpretation of findings made in this study.

Epistemic Frame Theory is the basis from which the learning and understandings from an ENA are derived. Epistemic frames model how a community of practice might think, act and be (Shaffer & Ruis, 2017). The community of practice refers to a group with a culturally distinct repertoire of methods, beliefs and actions. Kaliisa et al. (2021) made the following link between epistemic network analysis and its basis within epistemic frame theory, "ENA stems from the operationalization of epistemic frame theory, a learning theory that models learning as ways of thinking, acting, and being in the world of some community of practice" (p. 5).

Data Collection Instruments

Data was collected via three different instruments across the cycle of the study. These were: (1) Teacher beliefs surveys (pre and post participation) using the Mathematical Beliefs Instrument (MBI) developed by Peterson et al. (1989); (2) Mathematical identity graphs that investigated emotional dispositions towards mathematics across a lifetime. These involved participants identifying particular experiences, periods or events in which they recalled a specific feeling towards the doing of mathematics; and (3) Individual interviews (pre and post participation). The aim was for the data to provide insight about how teachers arrived at their current dispositions towards mathematics teaching, how these dispositions changed over the course of their participation in the professional learning, and any impacts this process had on their mathematics teaching values, beliefs, and practices.

Data Analysis

The data generated and collected in this research were coded by the researcher to identify practices, beliefs, values, and dispositions related to teaching mathematics. Using a thematic analysis approach (Braun & Clarke, 2006), a specific sequence of data analysis was undertaken. This involved an initial familiarisation with all of the collected data, and then the generation and identification of codes. From these codes, themes were identified, defined and named. Once his process had been reviewed, links between themes were generated for the individual teachers using the ENA software. This process mapped connections between coded teacher practices, dispositions, values and beliefs. The thickness of lines in the network models indicate the strength of these connections.

Results and Findings

Alice, the teacher whose experiences have been investigated in this research, is a generalist primary school teacher, and in 2024 taught a composite Year 3/4 class. Alice had been a teacher for 8 years; however, teaching is not her first career. Despite formally becoming a teacher in her forties, Alice indicates in Interview 1 that she has always had an affinity for the profession. “I think I’ve always been a teacher, just not in this capacity”.

Figure 1 is an ENA generated from data collected from Alice’s pre- and post-interviews, her mathematical identity graph and her MBI surveys. These data have been analysed using the codes listed above in Table 1. The connections between data codes from Interview 1 are represented by the red lines in Figure 1, and the connections between data from Interview 2 are represented by the green lines.

In Interview 1, Alice’s strongest connections (indicated by the thickest lines) are between her Mathematical Confidence, Mathematics Positivity and Mathematical Enjoyment. These were clearly strong themes that Alice spoke about repeatedly in her first interview. Alice referenced her own personal enjoyment of engaging with mathematical procedures as a student herself, stating, *“I love maths, it just kind of made sense. It was like everything is just add, subtract, multiply, divide.*” It is interesting to note that despite this love of mathematics, there is a much weaker link between these sentiments and the nodes of teaching confidence and positivity.

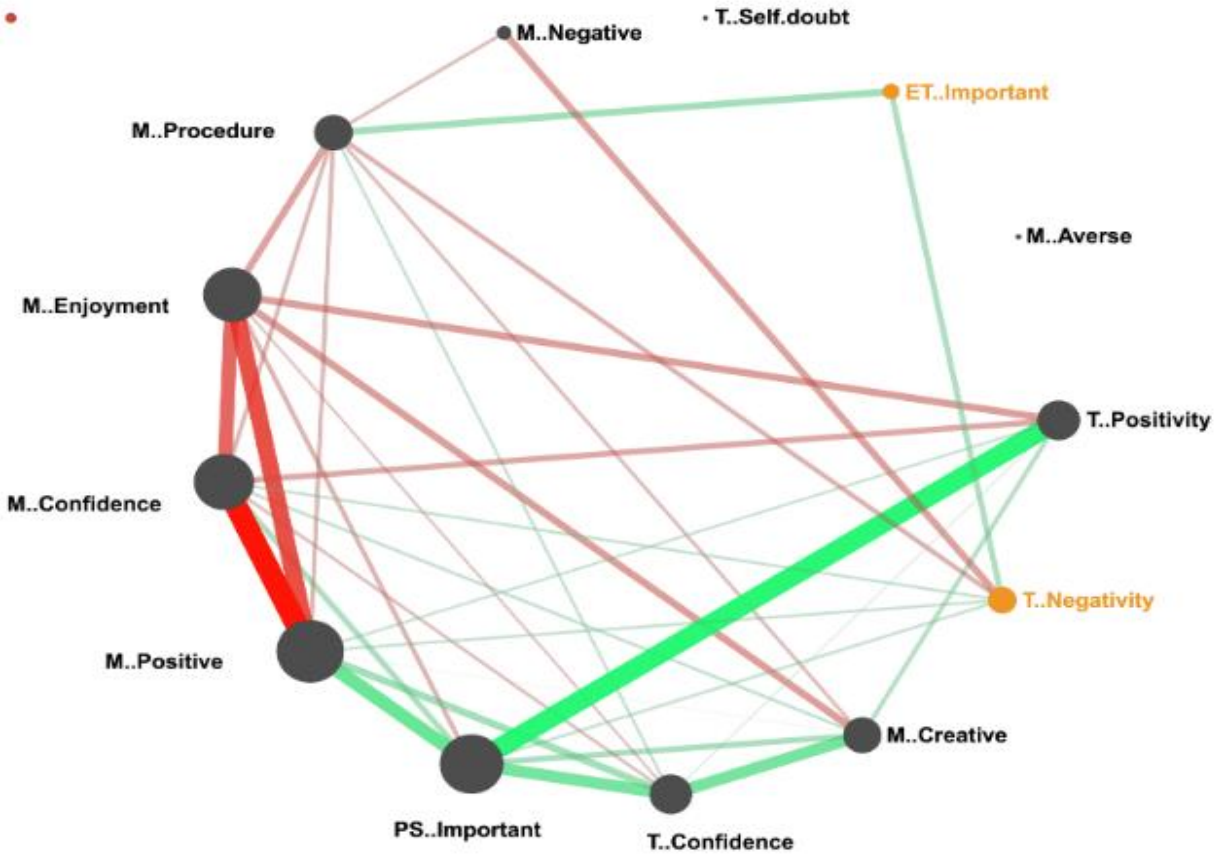
Table 1

Participant Interview Data Codes

Participant interview data codes
1. Problem solving is important (PS. Important)
2. Explicit teaching is important (ET. Important)
3. Mathematical enjoyment (M. Enjoyment)
4. Mathematics averse (M. Averse)
5. Mathematical confidence (M. Confidence)
6. Mathematics creativity (M. Creative)
7. Mathematical procedures (M. Procedure)
8. Mathematical positivity (M. Positive)
9. Mathematical negativity (M. Negative)
10. Teaching confidence (T. Confidence)
11. Teacher self-doubt (T. Self-doubt)
12. Teaching positivity (T. Positivity)
13. Teaching negativity (T. Negativity)

Figure 1

ENA Model: Alice



Mathematical Creativity and Mathematical Enjoyment are also clearly connected for Alice. These red lines tell the story of a teacher who loves mathematics, who understands algorithms and formulas (Mathematical Procedures). It tells the story of a teacher who loves mathematics but is still building her confidence as a mathematics teacher, "*finding extension tasks that don't just feel like more work, yeah. It's really tough*". It is notable for interview 1, that there is only a minimal connection made between Problem Solving is Important and Mathematical Enjoyment. There were no connections in Interview 1 data between Problem Solving is Important and Teaching Confidence, Teaching Positivity or Mathematical Creativity.

For Interview 2, represented in *Figure 1* by the green lines, there is a visually different map of connections between the data codes. We can now see very strong connections between Problem Solving is Important and Teaching Positivity, as illustrated by the following excerpt for Interview 2, *"So that has changed and I'm able to incorporate (problem solving) activities that help all the kids shine"*. Strong connections are also shown between Problem Solving and Mathematical Positivity / Teaching Confidence. An utterance from Interview 2 which supports this is, *"I love kids showing the way they get answers, because they all get it differently"*. This indicates a possible change in dispositions and beliefs for Alice towards mathematics teaching over the four-month period of professional learning.

This correlates with some changes in Alice's responses to the pre and post Mathematical Beliefs Instrument survey. After initially agreeing with the statement in Item 1 of the MBI pre-survey; *Problem solving should be a SEPARATE, DISTINCT part of the mathematics curriculum*, in the MBI post-survey, Alice changed her position. This was confirmed in Interview 2. When asked to describe her enjoyment levels with mathematics teaching compared with prior to the professional learning, she responded*, "I'd say it is definitely different. I definitely enjoy it more"*. When asked about how her teaching practices have changed, Alice talked about how problem-solving activities had been effective for encouraging students to work independently and in a differentiated way.

The pre-post differences in connections describing Alice's beliefs and dispositions highlighted in the ENA were also reflected in another response in the MBI post-survey compared to the MBI pre-survey. For Item 20; *Good mathematics teachers show you the exact way to answer the maths question you will be tested on,* Alice initially strongly agreed with this statement, however, in the post survey, Alice disagreed with this statement. This is a direct correlation to the increased emphasis on problem solving represented by the green lines in the ENA in *Figure 1*. With this in mind, we can return to the underlying research question of this study; How does participating in MICubed impact primary teachers' enjoyment, beliefs, and pedagogical values when teaching mathematics? Based on this analysis of the data generated for Alice, there is some evidence to suggest that her participation in MICubed may have contributed towards increasing her enjoyment and confidence when teaching mathematics as well as her value for problem solving as an effective pedagogical approach.

Discussion and Conclusion

This research highlights the potential of the MICubed approach in improving teachers' emotional dispositions towards mathematics, which could foster a culture of high mathematical achievement in Australian schools. Empowering teachers to create engaging environments can promote more positive attitudes and self-belief in both teachers and students. While existing professional learning in Australia often focuses on student engagement and teacher PCK, the findings from this study suggest that improving a teacher's dispositions through professional learning, centred on mathematical problem-solving, can be effective.

Using ENA to understand different phenomena within teaching pedagogies and practices (Elmoazen et al., 2022) has emerged over the past decade as an effective data analysis tool.

ENA models offer a unique way to interpret and understand different data sets concurrently. The use of ENA to describe and analyse data from the research presented in this paper is unique in its application towards understanding the emotional dispositions of primary school teachers towards mathematics teaching, and for describing changes in these dispositions following professional learning.

This paper is an early contributor to the knowledge base of quantitative ethnography using epistemic network analysis in this particular area of study. The identification, understanding and description of the emotional dispositions of teachers is an inherently qualitative process, commonly approached through interviews and observations. By employing ENA within a quantitative ethnographic approach, statistical rigour is applied to the analysis of these qualitative data sets, and nuanced analysis can be made. The findings presented in this paper, whilst limited by its analysis of only a single teacher, indicated that ENA has the potential to describe changes in teachers' beliefs and values towards, and enjoyment of, mathematics teaching. Further research is needed to investigate whether ENA is useful for describing changes in these areas for other individual teachers, and also for describing changes across larger groups of teachers who participate in professional learning.

Through this analysis of Alice's participation in the MICubed professional learning, we can see that she has experienced some positive changes in her dispositions towards the teaching of mathematics. Alice indicated potential changes in her beliefs about what constituted good mathematics teaching, as well as what she valued in the mathematics classroom. Aater participating in the MICubed professional learning, Alice applied problem-solving as a key pedagogical practice in her mathematics lessons, and the ENA strongly linked this to positive feelings towards the teaching of mathematics.

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