Relationships with mathematics: Growing primary teachers

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Abstract: Primary preservice teachers (PSTs) often begin their education programmes with fragile relationships with mathematics, which strongly influence their relationships with mathematics teaching and future classroom practice. Making these relationships – encompassing beliefs, knowledge, self-perceptions of capability, macro-feelings, and habits of engagement – visible to PSTs and teacher educators is valuable, yet conventional assessments and survey tools rarely capture them. This study trialed four reflective tools with 147 primary PSTs: drawings of mathematicians, metaphors, personal journey graphs, and problem-solving reflections. The tools enabled their relationships with mathematics and mathematics teaching to become visible. These relationships were found to be dynamic and shaped by their prior experiences. Persistent challenges were apparent, including stereotypes and fragile self-perceptions, alongside aspirations for inclusive and engaging teaching. By offering richer insights than conventional measures, the study demonstrates the potential of reflective tools to support confidence, resilience, and professional growth in PSTs, while informing teacher educators' practice.

Keywords: relationships with mathematics, mathematical affect, identity, reflective tools

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1 Introduction

Mathematics is a powerful tool and a gatekeeper to diverse educational and career opportunities. A key goal of mathematics education is therefore to foster positive and productive relationships with mathematics, including aspects relating to affect, identities and knowledge. Such relationships increase the likelihood that individuals will engage meaningfully with mathematics, continue studying it beyond compulsory schooling, pursue mathematics-related pathways, and use mathematics confidently in their lives (Boaler et al., 2023).

For teachers, these relationships are particularly consequential, as they are closely linked to their relationships with mathematics teaching and their classroom practice. Primary teachers with strong and confident mathematics backgrounds are more likely to teach mathematics with confidence and to employ pedagogical approaches recognised as effective (Berg et al., 2025). However, many primary preservice teachers (PSTs) enter initial teacher education programmes with fragile relationships with mathematics, limited content knowledge, constraining beliefs, and anxiety in challenging teaching contexts, such as working with very young learners or the upper primary classrooms (Ingram et al., 2018; Lin, 2022; Marbán, Palacios, & Maroto, 2021).

These realities highlight the importance of initial teacher education programmes actively supporting PSTs to develop more positive and productive relationships with mathematics and its teaching. A critical starting point is making these relationships visible.

Making PSTs' relationships with mathematics and its teaching visible serves two key purposes. First, it enables PSTs to recognise and reflect on their own relationships, creating opportunities for personal growth and professional insight through a metacognitive process of attending to and reshaping their perspectives. Second, it enables teacher educators to monitor these relationships and provide targeted support, such as purposeful placement with mentor teachers, strengthening mathematical content alongside curriculum and pedagogical knowledge (Ball et al., 2008); attending to the central roles of emotions and identities in engagement and problem-solving (Beswick, 2012; Lin, 2022; Lutovac & Kaasila, 2018); and offering access to positive role models (Ingram et al., 2018).

Despite this, there remains limited guidance on how teacher educators can effectively uncover and understand PSTs' relationships with mathematics within initial teacher education programmes. Existing approaches have often relied on surveys or formal assessments (e.g., Ball et al., 2008; Hourigan & Leavy, 2022), which may not capture the complexity and nuance of PSTs' experiences identities and beliefs.

This study addresses this gap by exploring four tools designed to make PSTs' relationships with mathematics and mathematics teaching visible: drawings of mathematicians at work, personal journey graphs, metaphors for mathematics, and problem-solving reflections. Through trialing and evaluating these tools, the study contributes to mathematics teacher education by offering practical, research-informed approaches that teacher educators can use to better understand and support PSTs' development.

The paper begins by defining 'relationships with mathematics' and 'relationships with mathematics teaching' in the context of primary teaching, reviews existing tools used to illuminate these relationships, and outlines the methodology, and then evaluates the four tools.

2 Primary PSTs' relationships with mathematics: a broad notion

Affective research is well recognised as equally important as cognitive research for understanding mathematical learning (Hannula, 2012). This research encompasses a broad range of constructs, including attitudes, anxiety, motivation, self-efficacy, emotions, feelings, beliefs, identities, engagement, and values (Herges et al., 2017). These constructs are often poorly defined and overlapping, making comparisons difficult. Moreover, research often focuses on single constructs, such as anxiety or attitudes, which may oversimplify the complexity of learners' experiences (Ingram et al., 2020). It is the interconnections among affect, identity, and cognition that make broader constructs particularly valuable for understanding mathematical learning (Grootenboer & Marshman, 2016; Op 't Eynde et al., 2006).

Drawing on my research with school students and PSTs (Ingram, 2011; Ingram et al., 2018), I conceptualize individuals as developing unique relationships with mathematics. This is a broad multi-dimensional construct with five elements: beliefs, knowledge, self-perceptions of capability, macro-feelings, and habits of engagement. The term 'relationships with mathematics', originally coined by my adolescent research participants, aligns with other holistic constructs such as mathematical identity (Ruef, 2020), self-systems (Malmivuori, 2006), mathematical dispositions (Graven et al., 2013), global affective structures (DeBellis & Goldin, 2006), mathematical mindsets (Boaler, 2015), and mathematical resilience (Lee & Johnston-Wilder, 2017), while foregrounding the dynamic and relational nature of individuals' experiences with mathematics.

I extend this conceptualization to argue that PSTs also develop relationships with mathematics teaching. While closely connected to their relationships with mathematics, these are analytically distinct. Relationships with mathematics are oriented towards participation with mathematics as a learner or user of the discipline. In contrast, relationships with mathematics teaching are oriented towards the practice of teaching mathematics and involve pedagogical decision-making, responsibility for others' learning, and the development of a professional identity as a teacher of mathematics (Ingram, 2018).

The five elements that suit across both constructs are defined in Table 1 in the context of primary PSTs.

Table 1. Elements of relationships with mathematics and mathematics teaching (Ingram 2018).

Element	**Relationships with mathematics**	**Relationships with mathematics teaching**
Beliefs	Beliefs about the nature, value and importance of mathematics.	Beliefs about mathematics teaching and learning
Knowledge	Mathematical content knowledge – the facts, symbols, concepts and rules constituting mathematics and which are shared, external and accepted by the mathematics community.	Mathematical pedagogical content and curriculum knowledge
Self-perceptions of capability	Perceptions of mathematical capabilities	Perceptions of capabilities as a mathematics teacher
Macro-Feelings	Relatively stable overall feelings about mathematics, including general liking or disliking.	Feelings about teaching mathematics
Engagement	Habits of engagement – the general extent and quality of engagement	Emereging and established mathematics teaching practices

These relatively stable, trait-like relationships with mathematics and mathematics teaching provide the context for PSTs' engagement in mathematics doing and teaching. They also shape their more fluid, state-like emotional responses during engagement, which can either reinforce or, if powerful enough, or repeated, alter their relationships over time.

3. Getting to know PSTs' relationships with mathematics

A central question is how teacher educators can make these relationships visible in ways that are informative for them and meaningful for PSTs. Conventional measures, such as mathematics content assessments and evaluations of pedagogical content knowledge through placement observations, capture cognitive and performance aspects (Ball et al., 2008) but do not adequately capture affective experiences, identities, and reflection. Quantitative surveys of constructs such as anxiety, often using Likert scales, are common (e.g., Hourigan & Leavy, 2022; Marbán et al., 2021). While useful for identifying patterns, they risk oversimplifying the complex, evolving nature of relationships with mathematics, offering only snapshots, and little scope for reflection (Boaler, 2015). In contrast, alternative tools offer richer, more nuanced insights into PSTs' relationships with mathematics, including narrative and autobiographical methods, visual tools, metaphors, reflections and dialogic methods.

Narrative and autobiographical methods encourage PSTs to recount experiences of learning mathematics (e.g., Ingram, 2011; Lutovac, 2020; Wilson, 2018), fostering reflection and revealing personal histories. For example, personal journey graphs present a visual timeline of experiences and affective responses, supporting reflection on critical events, patterns in beliefs and emotions, and longitudinal development (Ingram, 2011). They help PSTs connect past experiences and current orientations towards mathematics.

Visual tools, such as drawings of mathematicians or mathematics teachers, expose how PSTs position themselves and others in relation to mathematics. Adapted from Picker and Berry (2000), these drawings surface implicit assumptions, stereotypes, and emotions about who can do mathematics and what counts as mathematical activity (Leppäaho, 2021; Marbán et al., 2021; Hatisaru, 2020).

Metaphors for mathematics (e.g., *if mathematics was a vegetable which would it be?*) generate symbolism that uncovers affective and identity-related dimensions and reflection. These are not easily accessed through direct questioning (Buerk, 1996; Lakoff & Núñez, 2000; Graven et al., 2013).

Reflective and dialogic methods, including journals and structured interviews, prompt PSTs to make their thinking explicit. These reflections link learning experiences with emerging beliefs about mathematics teaching, enabling both self-awareness and pedagogical insight (Lo, 2021).

These approaches can be time-intensive, unfamiliar to the students, and difficult to embed consistently outside research contexts. However, they provide insights into PSTs' affect, identities, implicit beliefs, and the impact of personal histories, which conventional measures may miss.

This study evaluates four tools: personal journey graphs, metaphors, drawings of mathematicians at work, and problem-solving reflections. These were chosen for their potential to illuminate aspects of PSTs' relationships with mathematics while remaining practical for use in teacher education contexts.

4. Methodology

This paper employs a qualitative, interpretive design to explore how four tools – drawings of mathematicians at work, personal journey graphs, metaphors for mathematics, and problem-solving reflections – can make PSTs' relationships with mathematics visible. The design was exploratory and evaluative, focused on meaning-making (Denzin & Lincoln, 2011). Its aim was not to produce generalizable findings but to assess how each tool surfaced aspects of PSTs' beliefs, knowledge, self-perceptions, macro-feelings, and habits of engagement (Ingram, 2018), and explore how these insights might inform PSTs' self-reflection and teacher education programmes.

The five elements of relationships with mathematics and mathematics teaching (beliefs, knowledge, self-perceptions of capability, macro-feelings, and habits of engagement) informed both the design and analysis of the study. They provided a conceptual lens for examining the kinds of responses each tool generated and for interpreting how PSTs' relationships were expressed across different modes (visual, written, and reflective).

The study was conducted with 147 primary PSTs enrolled in a three-year teacher education programme at the University of Otago, New Zealand. Only 25 (17%) were male, reflecting national trends. Participants represented a broad range of ethnicities, including Māori, New Zealand European, Middle Eastern, and Pacific student teachers. Most were aged 18-25, with seven participants were in their forties. Participation was voluntary, informed consent was obtained, and responses were anonymized.

4.1 Data collection

Each tool was implemented during programme workshops and took 15-30 minutes each.

- **Drawing a mathematician at work.** In their first year, PSTs were asked to *"Draw a mathematician at work. Comment on your drawing"*.
- **Personal journey graphs.** At the same time, participants constructed a timeline of their macro-feelings about mathematics, plotting feelings on the vertical axis ranging from *very good* to *very bad* and commenting on critical events. Two years later, they revised and extended the graph, adding further reflections.
- **Metaphors.** In their second year, PSTs described mathematics using metaphors adapted from Buerk (1996), including: *What is mathematics? How does mathematics make you feel?* and analogies such as: *If mathematics was*

a type of music, what would it be? They then expanded a self-chosen response into a short paragraph, poem, or drawing.

- **Problem-solving reflections.** Also in second year, participants engaged in problem solving tasks and reflected on their affective pathways during their mathematical engagement – their dynamic, evolving emotions, motivations, values, and beliefs (DeBellis & Goldin, 2006). These reflections form the focus of the data reported here.

In their final year the PSTs were given back their data and asked to further reflect on the responses, writing any annotations in a different color pen. The data comprised visual artefacts (drawings, graphs), metaphors, and written reflections, providing multi-modal insights into PSTs' relationships with mathematics and mathematics teaching.

4.2 Data analysis

Data was analyzed iteratively at three levels: within individual PST responses, within each tool, and across participants and tools, using a constant comparison approach. This process supported the identification of recurring patterns, variations, and nuances, leading to a multi-layered and holistic understanding of PSTs' relationships with mathematics and mathematics teaching (Patton, 2014; Strauss & Corbin, 1998).

First an inductive coding process was undertaken. Descriptive codes developed from careful reading of the visual, metaphorical, and written artefacts. For example, drawings of mathematicians at work produced codes like *a mathematician is separate* or *a mathematician is a teacher*. Problem-solving reflections generated codes including *persistence*, *strategy change*, and *emotional response*. For instance, a reflection stating, "I started guessing but then drew a table and noticed a pattern. So happy" was coded as both *strategy change* and *emotional response*.

Second, these descriptive codes were interpreted through the five elements of relationships with mathematics and mathematics teaching. Codes were grouped according to whether they reflected beliefs, knowledge, self-perceptions of capability, macro-feelings, or habits of engagement. In this way, the five elements functioned as an analytical framework that enabled patterns to be examined both within and across tools, and across the two related constructs of relationships with mathematics and relationships with mathematics teaching.

Table 2 illustrates examples of how codes derived from drawings of mathematicians at work were mapped onto these elements.

Table 2. Examples of codes related to drawings of mathematicians at work

Element	**Relationships with mathematics**	**Relationships with mathematics teaching**
Beliefs	Mathematics can be useful A mathematician is a teacher	Mathematics teachers are authoritarian
Knowledge	Mathematics is number Mathematical knowledge is disconnected	Knowledge can be co-constructed
Self-perceptions of capabilities	I am distancing myself from a mathematician I am a maths person Mathematics is exclusive	I am worried I won't be able to teach Year 8 students.
Macro-feelings	Doing mathematics can be fun Doing mathematics makes me feel small	Not much else in their lives but maths
Engagement	You've got to try really hard in maths.	I want to teach in an inclusive and engaging I don't want to have a dictatorial approach

This iterative process allowed for a nuanced understanding of the variety and complexity of PSTs' responses. Thus, over time, stable themes developed for each individual and across the class, and the depth to which each tool illuminated the elements of the PSTs' relationships with mathematics and mathematics teaching was revealed. Throughout the analysis any affordances and limitations in terms of using these with PSTs as part of a programme was considered.

The tools were useful in building a picture of individual PSTs and how their relationships changed over time; however, the results have been presented in this paper at a class level only. In the results, a detailed analysis of each tool is presented, with emergent themes mapped onto the five elements. Then, in the discussion, a summary of how well the tools illuminated each element of PSTs' relationships with mathematics is given.

5. Results

5.1 Drawings of mathematicians at work

Drawings of mathematicians at work provided insight into PSTs' beliefs, self-perceptions of capabilities, macro-feelings, and emerging habits of engagement in relation to mathematics and mathematics teaching. They revealed PSTs' beliefs about the nature and about the nature and importance of mathematics, who participates in it, and what counts as mathematical expertise, while also highlighting tensions between past experiences and emerging identities as teachers. Five themes were prominent: mathematics is a practical tool, gendered representations, stereotypes of mathematicians, the association of mathematicians with teachers, and visions for future teaching.

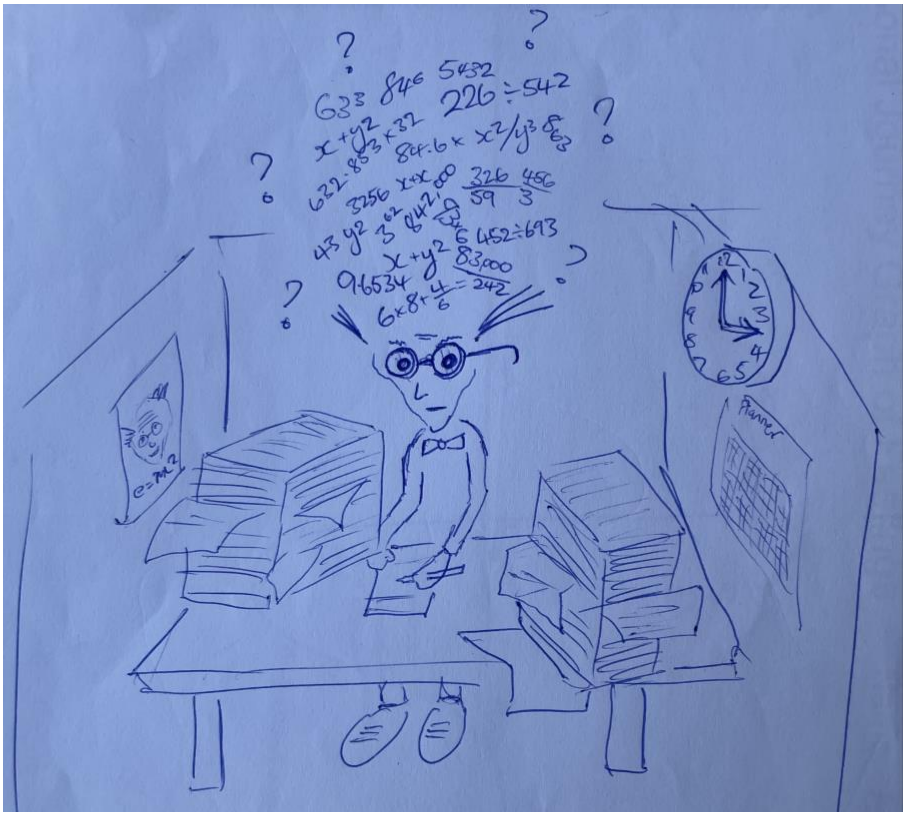
Across the cohort, 15% of the drawings explicitly depicted PSTs' beliefs about mathematics as a practical tool in everyday life. For example, Tammy's drawing (Figure 1) showed a person calculating a percentage discount and managing a budget, while others portrayed occupations such as a tiler, cook, and marine biologist.

Figure 1. Tammy draws a useful tool

Despite 83% of participants being female, only 16% of the drawing depicted female mathematicians, with 27% gender-neutral figures and 56% male. As Holly explained, she drew a male mathematician because it was her self-perception she was “not good at maths” and “the majority of people I know who are good at maths are guys”. This reflects the intersection of beliefs about who can do mathematics and self-perceptions of capabilities, where gendered assumptions contribute to positioning oneself outside the community of mathematicians.

Mathematicians were often depicted as isolated or possessing “magical” abilities, distancing mathematics from everyday life. These portrayals reflect beliefs about the nature of mathematics as abstract and inaccessible, alongside macro-feelings of distance or exclusion. Terrance’s drawing (Figure 2) of an alien-like figure with an exploding brain exemplified this perception. Caricatures were common, particularly of male mathematicians described as “weird”, “geeky”, or “nerdy” typically men with glasses, beards, and balding heads. These portrayals, which interestingly were drawn by females only, reflect media stereotypes and negative personal experiences of school mathematics, suggesting that many participants positioned themselves outside the community of “real” mathematicians, reinforcing constrained self-perceptions of capability. Only four out of 147 participants explicitly stated that “a mathematician could be anyone.”

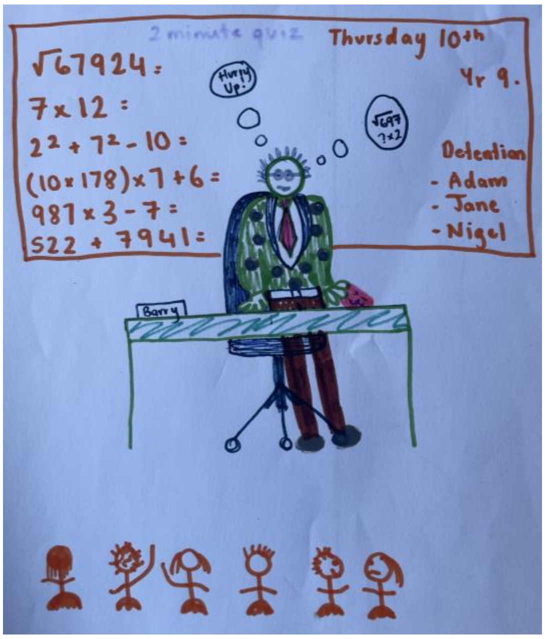
Figure 2. Terrance draws an exploding brain



A notable 63% drew teachers, emphasizing the overlap between their relationships with mathematics and their relationships with mathematics teaching. These drawings often revealed rigid, authoritarian teaching styles, shaped by school experiences, revealing beliefs about mathematics teaching and associated macro-feelings.

> Stands at the front of the class. (Fiona)
>
> Dictatorial one-approach-only by a hostile teacher who is inflexible and cold. (Sonya)

Figure 3. Annie draws a looming presence

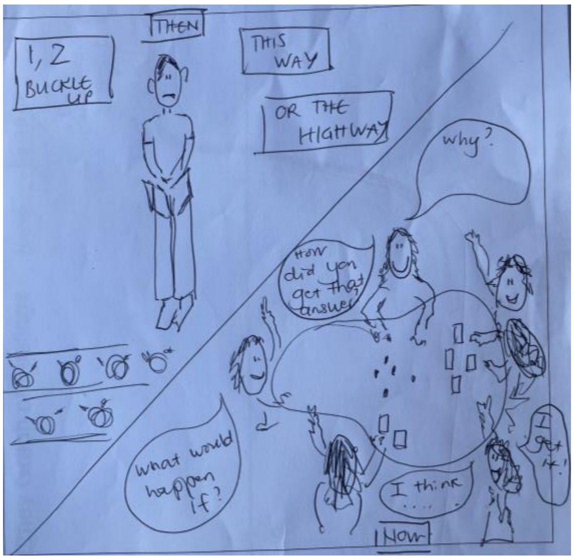


Annie’s drawing (Figure 3) captured this vividly. A teacher sits behind his desk, presiding over a classroom with detentions listed on the board, a timed quiz underway, and vulnerable students lined up beneath him. His looming presence conveys intimidation and disconnection, reflecting how some PSTs experienced mathematics at school and their negative macro-feelings about the subject and the teaching of it.

In contrast, other drawings reflected the kind of mathematics classrooms participants aspired to create, revealing emerging habits of engagement in mathematics teaching. These included group work, hands-on materials, trial and error, technology use, dialogue, rich tasks, and student-directed learning. Jared noted, “everyone has their own way to work problems out and, with the tools and strategies available, [we] can approach any problem how we like”, indicating a shift towards more inclusive and flexible beliefs about teaching and learning mathematics.

Sonya’s drawing (Figure 4) highlights this contrast. One side shows a stern, authoritarian teacher declaring “this way or the highway”. On the other side, a collaborative classroom is portrayed, with students actively discussing, using materials, and learning as equals.

Figure 4. Sonya draws past and future



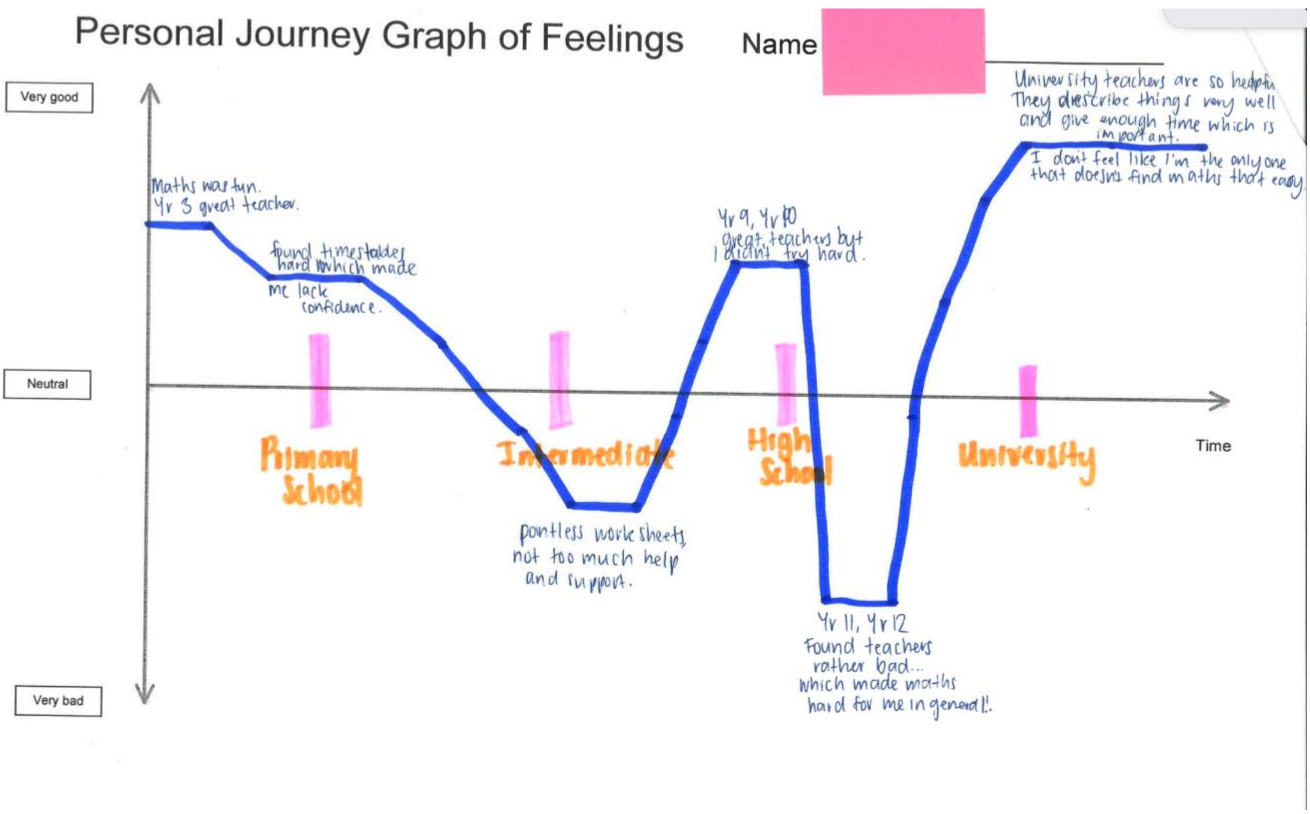
In general, the students relished this task. When presented, there was concern that the PSTs would ‘see through’ this task or be uncomfortable with drawing, and there was some evidence of this, and evidence of internal struggle. For example, Janet said “I know you are expecting a stereotype when a mathematician can apparently be anyone, but I can’t help what popped into my head”.

5.2 Personal journey graphs

Personal journey graphs provided insight primarily into PSTs' macro-feelings over time, while also revealing how beliefs, self-perceptions of capability, and habits of engagement developed in response to key experiences. Around one third of the cohort reported persistently negative or neutral macro-feelings. Teachers played a major role, as seen in the drawings. Common triggers included frequent teacher changes, explanation quality, lack of approachability, streaming, and monotonous use of worksheets and textbooks.

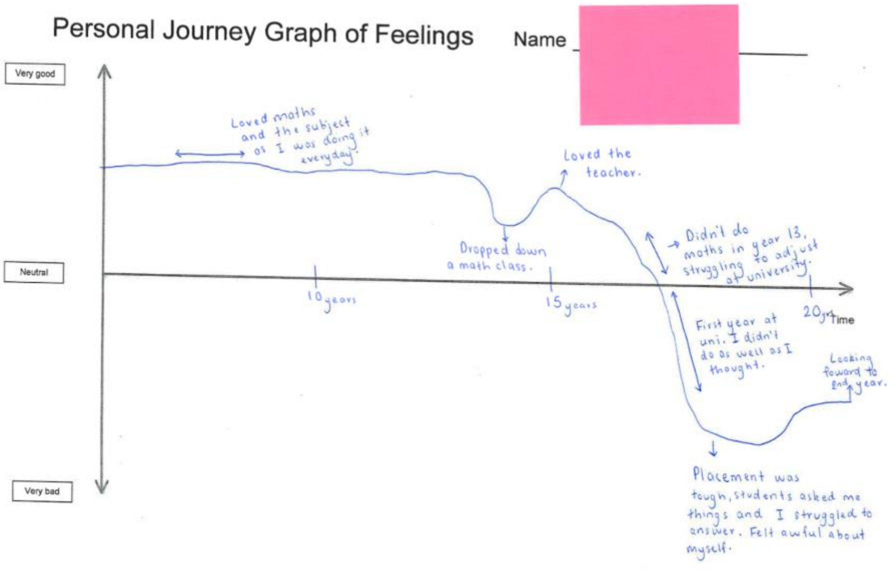
Michaela recalled her primary teacher made her "feel scared to get things wrong – I felt stupid", highlighting the interplay between macro-feelings and self-perceptions of capability. Similarly, Connie's references to "pointless worksheets" and "bad" teachers illustrate how beliefs about mathematics teaching shaped her engagement and disengagement over time (Figure 5).

Figure 5. Connie's personal journey graph



Positive feelings were often linked to achievement, recognition, engaging in mathematics in everyday life, and discovering they were not alone in their experiences with mathematics. For Bailey, initial confidence gave way to challenges during placement (Figure 6), illustrating how teaching mathematics for the first time could either buoy confidence or raise concerns about their capabilities.

Figure 6. Bailey's personal journey graph



5.3 Metaphors for mathematics

The metaphor task provided rich insight into PSTs' macro-feelings, beliefs, and self-perceptions of capability, often revealing internalized experiences of mathematics. Several framed it as necessary but unappealing, likening it to "broccoli" or "exercise". Others were more negative, describing mathematics as "roadkill" or "hard shards of grey metal", highlighting struggle, fear, and avoidance. Negative metaphors frequently revealed fragile self-perceptions of capability alongside negative macro-feelings and habits of engagement, as in Sasha's description of feeling "stupid, incompetent, frustrated, scared. I avoid it like mushrooms". Esther described mathematics like a snake, "creeping and slithering, sneaking up to bite you on the bum".

Positive beliefs and macro-feelings also appeared. Sara called mathematics "totally important," Tracey described it as "fresh and bright", and Bob compared it to Lego – bringing order to chaos. For others, feelings were conditional on the topic, class, teacher, or progress.

> At times it can seem really hard and gloomy – like weather – impossibly hard when it buckets down and no end in sight for your relentless struggles. When it suddenly clicks, those moments you are bathed in the sun – moments of pure joy. (Jean)

Some metaphors revealed habits of engagement during problem-solving. Phoebe talked about "getting through the sour lolly to the sweet part", and Albert developed a poem:

> When a southerly passes through
> And the front appears
> It rumbles and tumbles and blows through the town.
> The ending is a long way off
> A spot of blue is seen near the horizon
> The problem dissipates,
> The air is fresh and the sun shines

This captures the challenge and confusion of problem-solving in the first stages. The spot of blue sky represents finding a way through or recognizing a pattern, which leads to solving the problem and thus sunshine. Another well-developed poem from Sonya was rich in explaining her relationship with mathematics.

> Nowhere to hide
> Intimidation, revelation, freedom
> Giraffe's random markings don't count
> In the symmetry and balance of what man has communicated

Sonya's poem explores the tension between constraint and freedom in mathematics. Her beliefs about mathematics seem related to rigid mathematical structure, where there is "nowhere to hide", which she contrasts with the natural variation of a giraffe's markings. The second line captures an emotional journey common in problem-solving: intimidation, followed by insight, and eventually a sense of freedom through understanding. The poem suggests Sonya's view of mathematics is as a human construct that is logical but disconnected from nature.

Importantly, metaphors rarely aligned with a single element. Instead, they illustrated the interdependence of beliefs, feelings and self-perceptions of capability, reinforcing the multi-dimensional nature of relationships with mathematics and mathematics teaching.

5.4 Problem-solving reflections

Problem-solving reflections provided particularly strong insight into PSTs' habits of engagement, as well as shifts in self-perceptions of capability, macro-feelings, and beliefs during mathematical activity.

For some, mathematics initially provoked anxiety. Nadine described adopting a "get-it-over-with" mindset:

> I did guess and check but that took ages. I drew up a table and started to notice a pattern forming – I felt more confident in my working. However, I could not figure out a rule for the pattern. I need to work on developing more skill and confidence in my algebraic thinking.

Through this experience, Nadine valued perseverance and recognised areas for growth, demonstrating a shift in both engagement (strategy change and persistence) and self-perceptions of capability, while also identifying areas for further development. Similarly, Maggie realized that rushing through problems hindered her understanding and enjoyment:

> I am not as bad at maths as I think I am, but I know I need to slow down and understand the questions better instead of rushing… I really enjoy maths once I discover that I know what I'm doing.

Her reflection illustrates how attention to process, rather than outcome, can mark a turning point in her confidence and willingness to engage in mathematics.

Some participants extended these reflections to their future teaching, indicating developing relationships with mathematics teaching, particularly in terms of beliefs about learners and engagement. For example, Angela, who previously dismissed puzzles, was surprised by her own engagement:

> I am not a puzzle person. I get impatient and quickly lose interest. However, this particular problem has changed this … If this is possible for me, it's possible for my future students.

Maureen described a similar transformation when she changed strategies.

Patterns began to emerge and I felt excited … I said out loud 'maths is fun'.

These examples illustrate how new strategies and perspectives enabled PSTs to reframe both affective responses and pedagogical outlooks. Participants demonstrated awareness of their mathematical thinking, affective responses, and the importance of strategy. Many appreciated that engagement is not just about getting correct answers quickly but about sustained thinking, curiosity, and confidence-building. These insights have implications not only for their learning but also for their future teaching. Such experiences show that relationships with mathematics are dynamic and responsive to new challenges. For teacher educators, reflecting on problem-solving tasks create opportunities for PSTs to confront, and reconstruct their relationships with mathematics in ways that inform their future practice.

6. Discussion

This study set out to examine how four tools can make visible PSTs' relationships with mathematics and mathematics teaching. The findings show that each tool illuminated different, but overlapping, elements of these relationships, reinforcing their multi-dimensional and interconnected nature.

Across the tools, as seen in Table 3, beliefs, self-perceptions of capability, macro-feelings, and habits of engagement were consistently visible, while knowledge was the least accessible element. Although the tools revealed beliefs about what counts as mathematical knowledge, such as viewing mathematics primarily as number, they did not provide sufficient insight into PSTs' mathematical or pedagogical content knowledge. Rather than this being a limitation of the tools, it suggests something important about the construct of relationships with mathematics itself. Affective and identity-related dimensions may be more readily articulated through reflective and representational forms, whereas knowledge, particularly when tacit or underdeveloped, may be less easily expressed in such formats. This reinforces the need to complement these tools with approaches that more direct assess mathematics content knowledge and knowledge for teaching.

Table 3. How well each of the tools illuminated elements of relationships with mathematics and mathematics teaching.

✔ strong indication ~ some indication × no indication	Drawings of mathematicians at work	Metaphors	Personal journey graphs	Reflections on problem solving
Beliefs	✔	✔	✔	✔

Self-perceptions of capabilities	✓	~	✓	✓
Knowledge	~	~	~	~
Macro-feelings	✓	✓	✓	~
Engagement	✓	✓	~	✓

The drawings of mathematicians at work provided a particularly powerful entry point into PSTs' relationships with mathematics. They revealed enduring stereotypes, gendered assumptions, and feelings of exclusion, highlighting how beliefs and macro-feelings, often grounded in prior experiences, continue to shape PSTs' self-perceptions of capability and their positioning in relation to mathematics. These findings align with research showing that mathematics is frequently perceived as reserved for a particular type of – often male - person (Hatisaru, 2020; Picker & Berry, 2000), contributing to exclusionary identities and self-perceptions of capability (Lutovac & Kaasila, 2018).

At the same time, the drawings also revealed emerging relationships with mathematics teaching, particularly in the form of aspirational pedagogical goals. While many PSTs reproduced images of authoritarian teaching shaped by past experiences, others depicted inclusive, collaborative, and engaging classrooms. This tension suggests that negative experiences of mathematics do not simply constrain PSTs' development; they may also motivate the desire to teach differently (Lutovac, 2020). In this way, the drawings made visible both restrictive and potential aspects of PSTs' relationships, spanning both mathematics and its teaching.

Personal journey graphs complemented this by foregrounding the development of macro-feelings, and how these are intertwined with beliefs, self-perceptions, and engagement over time. The findings highlight the longitudinal nature of relationships with mathematics, showing how they are shaped by key experiences, particularly interactions with teachers. Consistent with prior research (e.g., Graven et al., 2013; Lutovac & Kaasila, 2018), perceptions of teacher practices were pivotal in shaping trajectories, with unsupportive pedagogy associated with negative turning points and supportive teaching linked to recovery and growth. These findings reinforce the view that emotions are socially situated and develop through participation in classroom practices (Hannula, 2012) and further demonstrate how affect and identity co-evolve over time (Ingram, 2011; Lutovac, 2020).

Metaphors offered a more internalized perspective, making visible the interplay between beliefs, macro-feelings, and self-perceptions of capability in personally meaningful ways. Unlike drawings, which often externalized stereotypes, metaphors revealed how these experiences had been internalized. Consistent with Goldin's (2000) work, they highlighted how emotional pathways are integral to mathematical meaning-making, rather than peripheral to it. Importantly, metaphors rarely aligned with a single element; instead, they demonstrated the fluid and interdependent nature of relationships with mathematics, with beliefs, feelings, and identities shifting depending on context.

Reflections on problem-solving provided the clearest insight into PSTs' habits of engagement, capturing persistence, strategy use, and evolving affective responses in action. These reflections showed how engagement, self-perceptions, and macro-feelings interact dynamically during mathematical activity, and how new experiences can disrupt or reshape existing relationships. In several cases, PSTs re-evaluated their capabilities and began to develop more productive ways of engaging with mathematics. Importantly, these reflections also extended into relationships with mathematics teaching, as PSTs connected their own experiences to their future practice, particularly in terms of supporting student engagement and persistence.

Taken together, the findings highlight that PSTs' relationships with mathematics and mathematics teaching are dynamic, interconnected, and responsive to experience. The tools made visible not only the current state of these relationships, but also points of tension, possibility, and change. PSTs' past experiences continued to shape their beliefs, feelings, and identities, while new experiences within teacher education created opportunities for these relationships to be re-examined and, in some cases, reconstructed.

7. Conclusion

This study found that drawings of mathematicians at work, personal journey graphs, metaphors, and reflections on problem solving each offered valuable ways of making primary preservice teachers' relationships with mathematics and mathematics teaching visible. Used together, these tools provided complementary perspectives that extended beyond conventional assessments, offering richer, more nuanced insights into PSTs' affective and identity-related experiences.

Conceptually, this study strengthens the distinction between relationships with mathematics and relationships with mathematics teaching, showing that these may develop in tension rather than alignment. PSTs often held constrained or fragile relationships with mathematics while simultaneously expressing aspirational and inclusive visions for their teaching. This highlights the potential for teacher education to act as a site for bridging and reshaping these relationships. Methodologically, the study demonstrates how a suite of complementary tools can operationalize a multi-dimensional construct in ways that are both analytically robust and practically feasible within teacher education programmes.

For teacher educators, the study underscores the value of making PSTs' relationships with mathematics explicit. The PSTs entered teacher education with relationships shaped by prior teachers, classroom practices, and beliefs about who can participate in mathematics. Structured activities that fostered reflection, narrative expression, and active problem-solving enabled the teacher educators to identify areas where support was needed and created space for PSTs to reframe negative experiences. These tools also supported PSTs in connecting their personal histories with emerging identities as teachers of mathematics.

The findings suggest that no single tool is sufficient to capture the complexity of PSTs' relationships. Instead, a combination of approaches is needed to illuminate different dimensions, including affect, identity, engagement, and knowledge. Making these relationships visible creates opportunities for targeted support, enabling teacher education programmes to attend not only to what PSTs know, but also to how they feel about, engage with, and position themselves in relation to mathematics and its teaching.

A limitation of this study is that it was conducted within a single teacher education programme, and the data relied on PSTs' self-representations, which may be influenced by context or perceived expectations. In addition, while the tools provided rich insight into affective and identity-related dimensions, they were less effective in capturing knowledge. These limitations suggest directions for future research, including the use of these tools across different contexts and in combination with approaches that more directly assess knowledge for teaching.

Ultimately, this research reinforces the centrality of relationships with mathematics and mathematics teaching in shaping future practice. Without explicit attention to these relationships, teacher education risks reproducing the very dispositions it seeks to transform. By incorporating tools that bring these dimensions into view, initial teacher education programmes can support PSTs to develop more positive and productive relationships with mathematics, laying the groundwork for teachers who not only teach mathematics effectively, but who actively reshape their students' relationships with it.

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