The story of Maia: I will try to survive!

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Two major concerns in mathematics teacher education research are the role of subject matter knowledge and the development of self-efficacy in teaching mathematics (SETM) in pre-service teachers (PSTs). These two bodies of research are normally not brought together, but I do so by investigating PSTs' SETM using an instrument developed with Skemp's two ways of understanding mathematics as the point of departure, and by exploring the sources of SETM through longitudinally conducted semi-structured interviews over a period of nearly two years. A focus on how one PST, Maia, drew on different sources of SETM, contributing to a new understanding of the agency of those PSTs that are recognised as "weak" because "they don't know any maths".

Keywords: Pre-service teachers, mathematics teacher education, self-efficacy, subject matter knowledge

Introduction

There is an ever-growing body of research investigating what teachers need to know in order to teach (Adler & Sfard, 2016). Unlike most research on subject matter knowledge (SMK) in the context of teaching mathematics, rather than investigating *what* knowledge is needed, this paper gives one particular pre-service teacher (PST) a voice in the matter, allowing an exploration of how *she* perceives the role of, and the need for, SMK as she develops her ideas about the teacher she not only *wants* to be, but *can* be. The importance of such a perspective is supported by Kagan (1992), who noted that PSTs' perceptions lie at the heart of teaching, and Pajares'(1992) comparison of 16 studies, concluding that PSTs' perceptions play a pivotal role in the way they acquire knowledge during pedagogical training.

One way of studying PSTs' perceptions of their own SMK and its role in teaching, is by paying attention to their self-efficacy in teaching mathematics (SETM). Teacher efficacy is considered one of the key motivation beliefs influencing teachers' professional behaviours and pupil learning (Klassen, Tze, Betts, & Gordon, 2011). Because of the situatedness of teacher efficacy, there is a need for more attention to domain-specific explorations (Klassen et al., 2011). Mathematics is an especially interesting context, since PSTs often express doubt about their own self-efficacy in mathematics (Gresham, 2007). Moreover, research indicating that teacher efficacy develops mainly during teacher education (Hoy & Spero, 2005) underlines the importance of investigating how and to what extent SETM develops in PSTs. In this paper, this is done in two ways, by a quantification of SETM through instrumentation, and through interviews focusing on one PST's perception of her own SMK and the need for such.

Theory

Bandura's social-cognitive construct of self-efficacy is concerned with judgements of personal capability (Bandura, 1997). Self-efficacy is defined as a person's judgement of his or her abilities to execute successfully a course of action (Bandura, 1997), a future-oriented

belief about the level of competence one expects to show in a specific situation. It has two components: a personal belief about one's own ability to cope with a task, a personal self-efficacy, and judgments about the outcomes that are likely to flow from such performances, an outcome expectancy (Bandura, 2006, p. 309). In this paper, teacher efficacy is understood as a measure of "the extent to which teachers believe their efforts will have a positive effect on student achievement" (Ross, 1994, p. 4), the 'personal self-efficacy' component of Bandura's theory. Moreover, SETM is understood to be the component of teacher efficacy corresponding to Bandura's concept of personal self-efficacy, seen in the subject-specific situation of teaching mathematics.

Bandura (1997) describes four sources of information that may contribute to the formation of efficacy beliefs: *mastery experiences*, *vicarious experiences*, *verbal persuasion*, and *physiological responses*. *Mastery experiences* are constituted by previous perceived success in performing a particular task, such as actual classroom teaching, and are seen by Bandura as the most powerful source of efficacy information (Bandura, 1997). Because teaching lacks absolute measures of adequacy, teachers can appraise their capabilities in relation to the performance of others (Bandura, 1997). *Vicarious experiences* are situations in which one watches another person successfully perform or the behaviour one is contemplating (Bandura, 1997). *Verbal persuasion* involves verbal input from others with the intention of enhancing a person's belief that they have the capability to perform a given task at a certain level. It "is likely to be effective when it is received from a highly competent individual who is perceived as an expert in the field" (Palmer, 2011, p. 580), such as a PST's mentor in school placement. Verbal persuasion alone may be limited in its power to create an enduring increase in teacher efficacy, but may work together with other sources to provide teachers with encouragement to strengthen their teaching skills (Tschannen- Moran & McMaster, 2009). Bandura (1997) viewed verbal persuasion as a comparatively weak source. *Physiological responses* can be a source of efficacy information, providing indirect information about capability to deal with challenging situations (Palmer, 2011). Bandura (1997) viewed this source as the least effective source as they were not reliably diagnostic of one's capability.

Following his review of teacher efficacy research, Wyatt (2014) argued that poor conceptualisations of the role of knowledge have obscured understandings of how teachers' self-efficacy beliefs develop. Moreover, Morris, Usher, and Chen (2017), add that it is clear that teachers' knowledge, and their beliefs about that knowledge, can play an important role in their development of self-efficacy. There is a need to better understand the role of knowledge in the development of teacher efficacy (Klassen et al., 2011). I follow Bandura (1997) and Wyatt (2014), who noted that knowledge is not a source of self-efficacy in itself.

In discussing SMK, Shulman (1986) emphasises that a teacher should not only understand *that* something is so, but also understand *why* it is so. This distinction is related to Skemp's (1976) *instrumental understanding* - 'rules without reasoning', and *relational understanding*, requiring "knowing both what to do and why" (Skemp, 1976, p. 20). Even though Skemp (1976) underlines that to have strong knowledge of mathematics does not guarantee 'success' as a mathematics teacher, he adds that teachers who do not possess such knowledge are likely to be limited in their ability to help students develop relational understanding, which is the

goal in mathematics teaching, and therefor in mathematics teacher education, where theoretical perspectives are often related to reform teaching (Grossman et al., 2009) focusing on relational understanding.

In my work, the emphasis is on how PSTs perceive the role of SMK, how they perceive the need for such knowledge and how such knowledge (or lack of it) influences them and colours their interpretation of their experiences as they progress through teacher education. SMK is central both in the instrument used on cohort-level (reported in Bjerke and Eriksen (2016)), and in the way in which the sources that PSTs draw upon in order to develop SETM are closely related to their perceptions of their own SMK and its role in teaching.

Methodology

This paper reports on data collected for a larger research project within a generalist primary teacher education programme for grades 1 – 7 (ages 6 – 13). Data were collected from a cohort of 191 PSTs admitted to a University College (UC) in Norway. At this UC, PSTs must take a minimum of 30 ECTS in mathematics, where the compulsory course spans the first two of a four-year programme, with 3 – 5 weeks school placement in each semester.

The instrument

SETM was investigated on cohort level through instrumentation. The instrument consists of 20 items, given to the cohort of PSTs at the beginning (pre-test) and the end (post-test) of their compulsory mathematics methods course (at the end of their second year). Each item asks of the respondent how confident they are helping a child to solve a mathematics task, 10 strictly algorithmic tasks focusing on rules and procedures in mathematics as in knowing *that* (i.e. "Calculate -17 + 5"), and 10 focusing on reasoning as in knowing *why* (i.e. "Explain why division doesn't always make a number smaller"). In this way, the instrument asks of the respondents to consider their own SMK (see Bjerke and Eriksen (2016) for a description of the instrument's content and validation).

Through Rasch analysis, items and persons are measured on the same interval scale, in logits, that allows us to avoid using non-equal interval values in parametric analyses that assume linearity (Boone & Scantlebury, 2006). The higher the person estimate, the more self-efficacious a person feels (Boone & Scantlebury, 2006). Selected findings from Rasch analysis of the data from the instrument implementation in Bjerke and Eriksen (2016) and Bjerke (2017a) are reported in this paper in order to place Maia amongst her peers.

Semi-structured interviews

The sources of SETM were identified through analysis of interviews with 10 PSTs in the current cohort. The semi-structured interviews were conducted over a period of nearly two academic years. Interviews 1, 3 and 5 are conducted before three consecutive periods of school placement, while interviews 2, 4 and 6 are conducted after the same periods of placement, resulting in six individual interviews with 10 PSTs who volunteered to participate (by indicating this on their instrument response). The overall aim was for PSTs to tell their story, from their very first thoughts as novices, through two years of experience of repeated placements and the role of the UC in their preparation for teaching mathematics, up to the

point where they had considerable placement experience and were ready to look ahead and reflect on the mathematics teacher they can be. The semi-structured interviews were informed by their answers on the instrument.

To analyse the data, references to the role of SMK in UC and school placement contexts were identified, noting connections to experiences of success and failure as applied to accounts of being and becoming a mathematics teacher. In analysing accounts of success and failure, particular attention was given to Bandura's (1997) four sources of self-efficacy. A later, more contextually bounded, holistic case study approach, enabled me to note common trends across the group. More importantly for this paper, it enabled me to identify and explore one PST, Maia, who acted as a foil to the presentation of the data from the other nine participants (Bjerke, 2017a), and was for that reason selected as a case study. This paper gives Maia's story.

Findings

As expected, there is a spread in novice PSTs' SETM (Bjerke & Eriksen, 2016), with Maia among those with lowest SETM within her cohort (with a measure of -.69 logits in a cohort with mean 0.55 and SD = 1.16 (Bjerke & Eriksen, 2016)). On cohort level, PSTs report being more confident helping a child to solve mathematics tasks focusing on rules and procedures in mathematics than tasks focusing on reasoning. Maia is representative of this trend, and a closer look reveals that Maia is 'Not confident' or 'Somewhat confident' on 15 of the 20 tasks in the instrument. She reports being 'Very confident' on one rules-task; she is very confident that she can help a child "Calculate 342 – 238". This stands in stark contrast to the thematically related reasoning-task, "Explain why, when subtracting, you can sometimes borrow from the place to the left", where she reports being 'Not confident' (Bjerke, 2017a). Holding Maia's responses to these two tasks up against each other highlights the impression the analysis gives of Maia: she is more confident when mathematics is limited to calculations following algorithmic procedures without questioning *why* these procedures work.

It is not first and foremost her placement amongst her peers that makes Maia an interesting case, but rather how she, during interviews, elaborates and explains her low SETM. A dominant theme in Maia's story is her own experience of mathematics, which she says she was 'OK at' in upper secondary school, where indeed she gained above average marks. In the first interview, Maia states that she likes mathematics when she is able to do it, but when she does not 'get it', she does not like it. This and related statements highlight the role of emotion in her novice story, looking back as well as looking forward: she does not know if she likes the thought of becoming a mathematics teacher, and she has few ideas and thoughts on what to expect from teacher education; she simply hopes that it 'fits' her way of doing mathematics. As it turned out, it did not 'fit' and Maia found it challenging at UC, because of the focus on a relational understanding.

Following her first school placement in her first semester, whereas other PSTs began to see the possibility that UC could support them in developing the kind of knowledge they need for teaching, Maia was hazy about what she might learn from the UC way of doing mathematics. Consistent with her response on the instrument, she expressed awareness of, and concern

about, her inability to explain mathematics, but she did not see UC as a potential source of support. Instead, she relied heavily on her mastery experiences in placement learning:

> Learning by doing … it's totally different in school placement, it can't be compared to what is presented to us at UC (interview 2)

An issue of 'fit' between her way of learning mathematics (instrumental focus) and the teaching at UC (relational focus) persisted in her second semester, in interview 3. In the period immediately before the third interview, UC teaching had focused on 'The Family of Quadrilaterals'. The PSTs had investigated how the different classes of quadrilaterals connect to each other, and the fact that, for instance, a square meets all the requirements of a rectangle, and hence can be described as a rectangle. Maia expressed confusion about this inclusive definition, and was critical of the UC mathematics curriculum:

> I'm getting more and more confused ... It's a bit uncomfortable to know that I have to teach things I didn't learn myself when I went to school ... It's hard to learn something that doesn't make sense. I don't want to talk about a square as a rectangle (interview 3)

While at the novice stage other PSTs took a generally positive emotional stance focusing on building their sense of development as mathematics teachers on the recognition that a different and more relational kind of SMK, focusing on knowing *why*, might be required and possible (Bjerke, 2017a), Maia's account of the teacher she would like to be reflected her new negativity about mathematics. The sense of building relational understanding based on underlying principles was strikingly absent in Maia's sources of SETM. This appeared to contribute to her insecurity in general: She simply hoped to be able to make her pupils understand that

> …it [mathematics] might be alright, there are worse subjects (interview 3)

After the second school placement, in interview 4, Maia's story was noticeably more positive: her narrative was far more grounded in her mastery experience in school placement, with major emphasis on the benefits in terms of *feeling* like a teacher:

> I've learned so much that it's hard to put it into words. It's another world ... I felt we [the PSTs in her group] were one of the teachers (interview 4)

She described how she felt at home in school placement. She relied on verbal persuasion in the form of praise in order to gain a sense of SETM. Success in placement was crucial:

> It was nice to get feedback after lessons, because [the mentor] pointed out positive things … I need to show that I'm meant to be here ... (interview 4)

In her third semester, in the run-up to her third placement, she still doubted her ability to be a mathematics teacher:

> A part of me wants to be [a mathematics teacher] … but I don't know if I'm capable of teaching this subject ... I struggle so much myself (interview 5)

After the third placement, in interview 6, she felt more confident due to guidance from her mentor as a source of vicarious experience:

> My mentor taught me how to show to children how to calculate and why [the mentor] did it this way (interview 6)

She gave several examples of what she meant by this: "when to say 'digit', when to say 'number', when to say 'decimal' rather than 'decimal number'". Instead of dealing with these issues in the UC-context, she relied on copying her mentor, trying to remember 'when to say what', as a vicarious source of self-efficacy. In this way, Maia's account of how she learned to be a mathematics teacher remained heavily dependent on her learning in school placement, copying her mentor, building on vicarious experiences against a background of insecurity in her mathematics knowledge:

> That's where I learn everything; that's where I learn to become a teacher (interview 6)

However, the decontextualized nature of this source of self-efficacy and the role of SMK in it, meant that Maia had to employ a particular strategy in order to manage her mathematics teaching, involving preparing which calculations to do on the blackboard, doing them herself before the lesson and thinking through how to explain every step in a way that pupils would understand. She worried about the demands of this strategy:

> I'm afraid it will be too tough, that I'll fall badly behind and almost drown (…) I'll try to survive the last years in teacher education and get through it (interview 6)

While both pre- and post-test analysis on cohort-level places Maia amongst those with lowest SETM, it is important to notice that, despite the negative outlook of her developmental story, Maia is closer to the mean by the end of her 2nd year than she was as a novice (Bjerke, 2017a), revealing that her SETM has developed more during these two years compared to the average PST. During the mathematics method course, spanning the two first years of teacher education, Maia's responses on the pre- and post-test show that she has gained confidence in all items in the instrument that are comparable (five are not comparable due to how they are interpreted differently by the students as novices and as 2nd year PSTs (Bjerke, 2017b)). She is no longer 'Not confident' on any tasks, and on all comparable tasks, she has ticked one confidence-level higher on the post-test compared to what she did on the pre-test. From this we can read that the difference in confidence-level between rules- and reasoning-items is still an issue towards the end of the course.

Discussion and concluding remarks

The analysis reveals that SMK is indeed an issue in Maia's developmental story: she finds mathematics challenging at UC, much due to the focus on relational understanding. She looks upon teacher education as something to be 'survived'. While her perception of her own SMK and the role of such is indeed an issue, her reflection of this situation, and how she dealt with it, is equally important. She expresses awareness of, and concern about, her inability to explain mathematics, but she does not see UC as a potential source of support. The role of SMK in sources of SETM in the sense of understanding connections and underlying principles is strikingly absent, and it appears to contribute to her insecurity in general. But still, we see that her strategy of over-preparing in exhaustive and rigid details in order to manage her mathematics teaching. Drawing on her placement as a strong source of mastery has resulted in positive development in her SETM.

In line with Bandura's (1997) understanding that mastery experience generally has the strongest effect, Maia's story of her development as a mathematics teacher is dominated by a strong emphasis on mastery. She deals with the demands of teaching by focusing her learning in school placement, drawing on vicarious experiences when trying to copy her mentor. A longitudinal reading of her interviews reveals a repeated negativity in her story after periods of lectures at UC (in interviews 1, 3 and 5), and a positivity after each period of school placement (in interviews 2, 4 and 6). In the interviews where she talks about UC-teaching, there are not many signs of sources of SETM. She focuses on experiences of failure and what she finds hard, and the fact that UC teaching in mathematics does not seem to "fit" her way of doing mathematics. Meanwhile, in the interviews taking place after periods of school placements, she points to both mastery experience, verbal persuasion and vicarious experiences as sources of her SETM. She notices the role of her own SMK in these sources, tending to avoid the difficulties arising due to the UC's focus on relational understanding and instead focusing on praise from her mentor, strategies of copying her mentor, and over-preparation with an overall instrumental focus. She appears to find a strong source of SETM in her placement relaying heavily on praise, which in turn might prevent her from further development, given that verbal persuasion is found to be a comparatively weak source (Bandura, 1997) and on its own may be limited in its power to create an enduring increase in teacher efficacy (Tschannen- Moran & McMaster, 2009).

Bringing together research on SMK and on teacher efficacy enabled me to explain in more detail the complex role of SMK in Maia's story. Bandura (1997) argues that self-efficacy is central to the exercise of human agency. My investigation of this construct, in PSTs from novice to more experienced, offers a new way of recognising the agency of "weak" PSTs. The story of Maia is an example of someone with low SETM, who seems unwilling to reflect on the role of SMK, and unwilling to engage in the 'new dimension' of mathematics - the focus on relational understanding and the ability to *explain* mathematics - and who sees teacher education as something to survive; she is easy to describe as a "lost cause".

Based on my own experience as a teacher educator, I suspect that there are many PSTs like Maia in different teacher education programmes, struggling with the focus. Maia wants mathematics to be like it was in upper secondary school, which she saw as a set of rules to learn and use, requiring a purely instrumental understanding. Teacher education demands that she engage in knowing *why*, being able to explain *why* it makes sense to use rules, not only *how* to use them. My findings suggest that such "hopeless cases" are not solely "those who cannot do any maths", but rather, might be someone who has a hesitation to engage with SMK in a new way.

Applying these insights, building on the recognition of Maia's positivity after each school placement where she finds strong sources of SETM, I suggest there is a need to bring in new pedagogies of practice in teacher education that focuses on mastery of reform teaching where relational understanding is considered a key to success. Building on Grossman et al.'s (2009) suggestions, teacher education should seek to offer PSTs opportunities to experience alternative ways of teaching through *representations of practice* (e.g. by participating in reform teaching led by the course instructor), *decompositions of practice* (e.g. by using videos

and analysing those based on theoretical frameworks such as Skemp (1976) on relational understanding), or through opportunities where PSTs are enacting teaching practices, rather than contemplating them as in *approximations of practice* (lesson planning, rehearsals, co-teaching with experienced teachers where SMK is focused).

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