Metaphors as boundary objects in preservice primary teacher mathematics education

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Abstract

In this article we draw on ideas of boundary crossing and boundary objects as a way of thinking about preservice teachers' metaphors about the nature of mathematics. During a graduate primary mathematics education paper, the writing of metaphors was employed as a reflective tool to support preservice teachers to conceptualise their beliefs about the nature of mathematics, and to consider implications for their practice as teachers. Focus-group discussions were also held. The metaphors, and focus-group data, were analysed in light of literature about boundary objects and Akkerman and Bakker's (2011) "mechanisms of learning" at the boundary. We suggest that considering metaphors as conceptual boundary objects provides a lens with which to view preservice teachers' beliefs about the nature of mathematics. A deeper understanding of how we could work more effectively with preservice teachers' beliefs about the nature of mathematics has emerged. It is suggested that the action of writing, reflecting, and sharing metaphors has the potential to assist both preservice teachers and teacher educators to recognise and work towards boundary crossing. This is a reciprocal process that results in learning for all concerned.

Introduction

Preservice teachers begin their formal teacher education after having been participants in varying mathematical settings. It has long been realised these past experiences impact on the beliefs preservice teachers come to hold about the nature of mathematics. These beliefs influence and affect subsequent learning about mathematics and what it means to be a teacher of mathematics (Grootenboer, 2008). It is argued that if experiences in teacher education programmes are to have a significant impact, teacher

educators must provide opportunities for preservice teachers to examine their own thinking and beliefs about teaching and learning (Cassel, Reeder, & Utley, 2009). The writing of a metaphor linking mathematics to a familiar commodity is one tool that has been employed to examine thinking and beliefs.

Research on beliefs and metaphors is not new (see, for example, East, 2009; Frid, 2001; Grootenboer, 2008). In this article we shift the focus to an alternative space by drawing on research about boundaries and boundary objects for theorising how metaphors might be more effectively used to bridge between the worlds that are brought to preservice teacher education and the ideas encountered about the teaching and learning of mathematics during preservice mathematics education. It is contended that theorising can add "depth, interpretation, meaning, explanation and significance when making sense of what we do and notice when teaching" (Bell, 2011, p. 1).

Boundaries, boundary crossing, and boundary objects

Much research in education has focused on the learning that occurs *within* a particular domain, such as a school or workplace (Akkerman & Bakker, 2011). However, for the most part the movements and adaptations made as people move from one domain to another are taken for granted (Phelan, Davidson, & Cao, 1991). Learning also occurs when people move across the boundaries that exist between domains (boundary crossing) (Akkerman & Bakker, 2011). Boundary crossing is regarded as a way for communities to reach common understandings (Gal, Yoo, & Boland, 2004). Kennedy, Ridgway, and Surman (2008) state that educators have a responsibility to understand the domains experienced by their learners, and find ways to span these domains.

Boundaries are sites of sociocultural difference, and these differences can lead to discontinuity in actions or interactions. Such discontinuity can be seen not as a problem to be "fixed", but as a possibility for learning (Akkerman & Bakker, 2011). Akkerman and Bakker identify four mechanisms that underpin the learning potential of boundary crossing. These are identification, co-ordination, reflection, and transformation. "Identification" incorporates thinking about one's experience in light of other experiences

thereby leading to the conceptualisation of new identities. "Co-ordination" as a learning mechanism involves a communicative connection between diverse perspectives and translation between varying worlds (Gal et al., 2004). The third mechanism, "reflection", is envisaged as realising and explicating "differences between practices and thus [enabling one] to learn something new about [one's] own and others' practices" (Akkerman & Bakker, 2011, p. 145). The fourth mechanism, "transformation", involves re-considering one's current thinking leading to a change in perspective.

A boundary object is an abstract or physical resource that can perform a central role in the crossing of boundaries (Akkerman & Bakker, 2011; Star & Griesemer, 1989). It acts as a bridge between the perceptual and practical differences that exist between communities (Gal et al., 2004), and is something to which people refer and from which they construct personal meanings. An example of a physical boundary object is a preservice teacher's portfolio from their university studies and practicum experiences. It serves a bridging function between the university and school domains. An example of an abstract boundary object identified by Gorodetsky and Barak (2009) was the prevalent discourse within a school community about "inquiry". Discussions regarding "inquiry" were able to bridge varying understandings of the term to include not only an alternative pedagogy but also the possibilities of teacher-centred self-inquiry

Boundary objects can never replace communication and collaboration; their value derives from action rather than their particular form (Akkerman & Bakker, 2011; Star, 2010). Nevertheless, boundary objects contribute towards continuity between domains (Akkerman & Bakker, 2011) by creating a shared space where meaningful communication is enabled between differing groups (Edwards & Fowler, 2007; Pahl & Rowsell, 2010; Star, 2010; Star & Griesemer, 1989). There are likely to be different interpretations in varying communities, but the boundary object can mediate common understandings and co-operation between groups (Akkerman & Bakker, 2011; Gal et al., 2004; Star & Griesemer, 1989). Gorodetsky and Barak (2009) suggest that differences in understanding can support the surfacing of subconscious, implicit understandings within a community.

Metaphors and beliefs about mathematics

Metaphors are part of who we are and what we do (Lakoff & Johnson, 2003). As a figure of speech, a metaphor brings together two discretely different ideas that conceptualise, represent, and communicate thoughts and actions in relation to something else (Fisher, 2013; Lim, 1999). Lakoff and Johnson suggest that metaphors help people gain a deeper understanding of their experiences by contextualising concepts and their relationships. For example, metaphors have been used to compare teachers' ideas about mathematics to objects (see Frid, 2001; Gibson, 1994). Such comparison can reveal teachers' beliefs about the nature of a discipline and the teaching and learning of it (Cassel et al., 2009; Patchen & Crawford, 2011). Furthermore, Fisher (2013) contends that examining people's metaphorical representations can offer a "'truer' picture of their beliefs" (p. 376) than that revealed by traditional research approaches, such as questionnaire items.

The beliefs that teachers hold about the nature of mathematics, and mathematics teaching and learning, have been well documented (see Beswick, 2005; Dossey, 1992). Preservice teachers' beliefs about mathematics are usually well established and influence their perceptions of teaching and learning (Cooney, 2001; Dossey, 1992; Grootenboer, 2008). To achieve consistency with curriculum goals there are likely to be occasions where changes in beliefs about mathematics, and teaching and learning, are needed. According to Wieman (2011), facilitating changes in beliefs about mathematics and its teaching and learning can be complex and slow. Some authors suggest that supporting preservice teachers' work towards practices that are consistent with curriculum goals must include an exploration of their own beliefs about mathematics (White, 2002). Muis (2004) goes further and suggests that the assessing of students' beliefs about mathematics needs to be "a crucial component of the general assessment of students' knowledge of mathematics" (p. 363).

Writing and reflecting on metaphors can highlight new perspectives and insights about one's beliefs (East, 2009; Fisher, 2013; Magee, 2008). Constructing metaphors can help teachers to not only make sense of experiences but also make conversation possible (Bullough, 2010; East, 2009). Sharing and discussing metaphors with colleagues provides an

opportunity to consider one's own metaphor in light of others' thinking (Fisher, 2013). The examining of metaphors can also provide teacher educators with an opportunity to reflectively and critically consider preservice teacher beliefs (Cassel et al., 2009).

The study

When considering the literature about boundaries, beliefs, and metaphors we began to envisage preservice teachers inhabiting a different mathematics domain to the domain of teacher education. Preservice teachers may experience conceptual boundaries between their beliefs about mathematics and the mathematics education domain they encounter during their graduate diploma programme. These differences can be, and often are, regarded as problematic. In line with Akkerman and Bakker's (2011) thinking, however, such discontinuity between domains creates a rich space for learning. This research explores the possibilities of this rich space for learning by theorising a metaphor as a conceptual boundary object.

The context for this study was a compulsory 12-week mathematics education course within a 1-year graduate diploma of teaching (primary). One intention of this 48-contact-hour course was to support preservice teachers to experience mathematics as a creative, constructive, and highly inclusive activity. The teaching was underpinned by a sociocultural perspective of learning in line with Cobb and Yackel's (1996) contention that an individual's mathematical thinking is influenced by participation in surrounding cultural practices. The course was also based on the premise that personal content knowledge, attitude, and beliefs about mathematics influence teaching and learning. Preservice teachers had regular opportunities to work on mathematical problems in small groups, and also worked alongside children in schools. They were expected to reflect on university-based and school experiences and discuss these with reference to mathematics research literature and relevant curriculum materials.

Ethical permission for this research was sought and gained from the university's ethics committee. Particular attention was given to the potential for a conflict of interest, given one author's role included

teaching and assessing students' work as well as gathering data for this research. We were aware that simultaneously researching and teaching can compound issues of power imbalances between student teachers and the lecturer. This situation was ameliorated by sending out letters about the research a week before semester began, thereby providing preservice teachers with time to read about and consider their willingness to be involved in the research. They had a second opportunity to consider their decision regarding involvement during the first week of semester. An additional consideration to avoid undue power imbalances was that the data gathered for the research was not linked to any formal assessment.

Preservice teachers were asked at the beginning of the mathematics education course to write a metaphor that encapsulated their beliefs about the nature of mathematics. Frid's (2001) useful and accessible prompt "If mathematics were a food, what would it be and why?" was provided. This prompt led student teachers to also provide commentary on their reasoning for their metaphors. Immediately following the writing of a metaphor, they were asked to reflect on their metaphor and write a response to a second question: "What might be the possible impact on my teaching (if viewing mathematics in the way surfaced by the metaphor)?" Towards the end of the course this process was repeated. Preservice teachers' writing in response to these two questions was collected, photocopied, and returned. Of the 23 student teachers that contributed to both sessions, 7 were male and 16 were female, and they were of varying ethnicities. This was representative of the gender and ethnic mix of the class. As part of the data, notes of the researchers' observations, collegial discussions, and thinking were also recorded.

Nine student teachers chose to also participate in audio-taped focus-group conversations held after the course was finished (one group of three student teachers, and one group of six student teachers, with both researchers present for each conversation). The questions asked included:

1. Can you recall a significant instance, prior to this mathematics education paper, that impacted on your beliefs about the nature of mathematics?
2. Have your beliefs about the nature of mathematics changed during the semester? If yes, how have they changed?

3. Can you recall an instance/activity/discussion/reading that has impacted on your beliefs about the nature of mathematics during this semester?
4. How do you think these beliefs about the nature of mathematics could impact on your teaching?

Further data were generated by examining the metaphors and focus-group transcripts in relation to the concept of boundary objects and Akkerman and Bakker's (2011) four mechanisms of learning at the boundary. These data included the authors' notes, tables, diagrams, and reflective writing about metaphors in relation to boundary concepts.

Results and discussion: Theorising metaphors as boundary objects

In this section we draw on specific examples of preservice teachers' metaphor writing, focus-group transcripts, and our writing, to illustrate that a written metaphor might be conceived of as a conceptual boundary object. Preservice teachers' beliefs about the nature of mathematics, as exposed by the metaphors, and whether these changed over the duration of the course, are not the only feature of analysis for this article. Rather, it has been in the prolonged collegial discussions and authors' individual and collective thinking, writing, and reading about boundaries, metaphors, and beliefs that an alternative lens with which to view and work with preservice teachers' beliefs about the nature of mathematics has emerged. This process aligns with the ideas of St. Pierre (2011) who suggests data are collected during thinking and writing and states, "if we don't read the theoretical and philosophical literature, we have nothing much to think with during analysis except normalized discourses that seldom explain the way things are" (p. 614).

Analysis indicated 15 of the 23 initial metaphors revealed negativity towards mathematics. For example, Hine wrote, "Mathematics is fruit … too much can make you feel ill!" Eight references were made to mathematics as useful and necessary, but nevertheless unpleasant. Typical of these responses was Jack's simile, which stated, "Maths is like spinach, it's not the best tasting but it can give you Popeye brains."

During one of the focus-group discussions Juliet recalled previous mathematics experiences being about textbooks, quick recall, algorithms, and answers. She said:

> the majority being taught out of the maths book … stood up in front of the class for little challenges, you know, on the spot … this is the answer, why, who knows why or how, but this is the answer and that's not the answer…

These comments about mathematics were representative of the cohort's views. In contrast the perception of mathematics presented in the course and in *The New Zealand Curriculum* (Ministry of Education, 2007) is one of mathematics as social, creative, constructive, and experiential. This led to us thinking about two distinct domains with a boundary existing between them, with a focus on a one-way movement between the domains (see Figure 1).

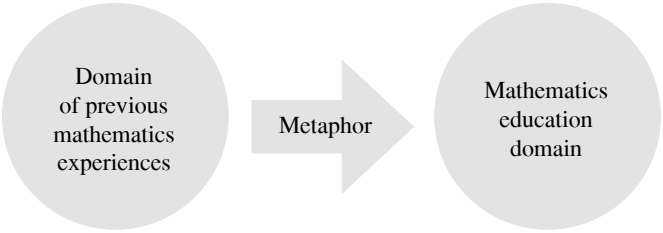

Figure 1. The metaphor as conceptual boundary object

In Figure 1 the student teacher's metaphor, on its own, was conceived as the conceptual boundary object. However, ongoing data analysis, reading, and deliberations revealed shortcomings of this model. Reflection is one of the mechanisms that constitutes the learning potential of boundary crossing (Akkerman & Bakker, 2011) and is recognised to support the sense-making of experiences (East, 2009, p. 22). The second aspect of the metaphor task ("What might be the possible impact on my teaching?") created an opportunity for preservice teachers to engage in such reflection as they considered the impact of beliefs on the domain of their future teaching. For example, Tony was able to express his strong dislike of mathematics but could also then consider the need for change. He wrote, "If mathematics was a food it would be brussels sprouts because it tastes

terrible but is apparently good for you. If I let it stay this way, and taught with this attitude it may transfer to my students." Ongoing deliberations and analyses have highlighted the importance of preservice teachers not only having a legitimate space to honestly and safely surface their beliefs about mathematics, but also having an opportunity to reflect on their metaphor.

A boundary object can afford a communicative connection across domains. Such connection is a part of the "co-ordination" learning mechanism (Akkerman & Bakker, 2011). As we examined the data we became aware of the potential for metaphors to provide the teacher educator and preservice teachers with a conduit for glimpsing one another's worlds. To become immersed in the realm of present-day school mathematics, preservice teachers certainly have to cross the boundary into the mathematics education domain. However, to build common understandings and span the domains we would also suggest a teacher educator needs to cross the boundary into the "space" of their students' previous experiences. In either case the individual is entering a domain with which they are unfamiliar. For example, Tracey wrote in her initial metaphor that, "If mathematics was a food it would be grapes … some are yum like addition and multiplication but some are rotten and sour like fractions, algebra, and division." Having access to such powerful images could alert the teacher educator of some students' need for additional support when topics such as fractions, algebra, and division are encountered during the course.

Further scrutiny of the data in light of the "reflection" learning mechanism suggested that some preservice teachers were developing insights regarding others' frames of reference with regard to mathematics. Taking others into account is part of the perspective-taking aspect of the "reflection" learning mechanism (Akkerman & Bakker, 2011). During one of the focus-group discussions we were alerted to such potential for learning as we listened to Juliet. Juliet said, "I didn't know what it was like not to be able to do maths." It appeared that sharing metaphors in the focus-group discussion sensitised Juliet to experiences that were different to hers.

Discussion also afforded an opportunity to consider beliefs about mathematics more deeply. Following a focus-group discussion Nathan emailed a third metaphor. His first two metaphors were quite similar.

The first was recorded as, "Mathematics would be pizza. Everybody has the potential to like it, you just need to put the right toppings on" and the second stated, "If mathematics were a food, it would be Weet-Bix because you have it every day, even though it's not the tastiest breakfast. But you can put all sorts of stuff with it to make it more exciting and tasty." His third metaphor was different, indicating that discussion had afforded an opportunity for more and possibly deeper reflection. It read, "Maths is surfing big waves. You need to have time and experience in the smaller surf to feel comfortable out in the bigger stuff, but once you have that grounding and confidence you can really enjoy the challenge."

Our thinking evolved to consider the conceptual boundary object as the wider process of writing, reflecting on, and sharing the metaphor with others, not only the metaphor itself. A further change occurred to the model when we considered the variation in metaphors. Hine's metaphor revealed her dislike of mathematics, which was a contrast to Kahu, who wrote, "If mathematics was a food it would be lettuce because you work your way through the layers." These deliberations led to thinking there are multiple boundaries between the varying personal experiences as well as boundaries between past mathematical experiences and the current domain of teacher education. This led to a refining of our model (see Figure 2) where we

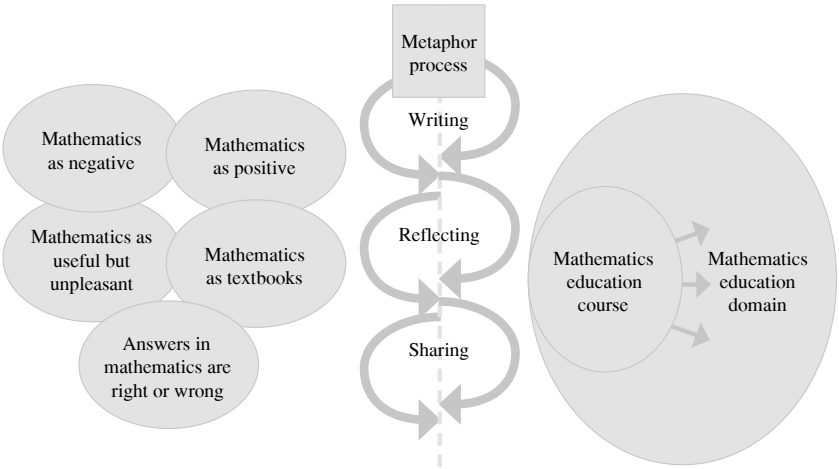

Figure 2. Revised model: The metaphor process as conceptual boundary object

more explicitly acknowledge multiple domains prior to teacher education; the potential for teacher educators to cross into the domain of preservice teachers' previous mathematical experiences; and the wider metaphor process to be conceived of as a conceptual boundary object.

"Identification" is another of the learning mechanisms at the boundary. Akkerman and Bakker contend that identification processes occur by "defining one practice in light of another" (2011, p. 142). The opportunity for coming to understand one's co-existing identities as a past learner of mathematics and future teacher was afforded by the writing and reflecting process. In analysing the initial metaphors alongside this learning mechanism we observed 20 of the 23 preservice teachers to have developed an awareness of their beliefs about mathematics in relation to their identities as a future mathematics teacher. For example, Andrea wrote, "If mathematics was a food it would be an onion because it can look ugly on the outside but contains many helpful layers that are used in lots of good recipes." She then wrote, "The ugliness could maybe become prominent so have to be wary and make sure the importance and usefulness of maths is emphasised." It would seem that this metaphor and reflection process was valuable in alerting preservice teachers to potential challenges regarding their identity as future mathematics teachers.

At the end of the mathematics education course 16 student teachers' metaphors indicated a more positive disposition towards mathematics. Although it was evident that not all preservice teachers had crossed a boundary and shifted domains, some experiences during the course seemed to enable some to view mathematics from a different perspective. Damian said:

> My beliefs have changed … There are so many different approaches to it [mathematics] and all that problem-solving stuff we did really sort of impacted on me. It made me think 'Hey, we can actually do things in these ways'. And even if you give a kid a problem and a little bit of guidance it's still maths. You are letting them do it themselves and it might be more meaningful that way rather than force-feeding them on rote teaching.

This boundary crossing was illustrated by Damian's metaphors. His first metaphor referred to mathematics being akin to an onion that made you

cry but was nevertheless good for you, and the second metaphor aligned mathematics to "Baking. Different ingredients are combined to create a whole … icing and sprinkles are added to improve it and creativity has its place." Conversely, Charlotte's metaphor at the end of the paper indicated her belief that mathematics remained something to be endured. Her first metaphor stated, "Mathematics would be a banana if it was a food because bananas are very good for you and extremely useful in certain situations but I find it really hard to enjoy them"; and her second referred to "Any type of fruit because it is very good for you but tedious to eat." Repeating the metaphor task had value as an informal way of assessing whether preservice teachers had crossed boundaries into a mathematics education domain. Additionally, writing a metaphor more than once would be consistent with Akkerman and Bakker's (2011) contention that exploration and discussion of boundary objects over time is needed to affect the discourses of participants.

Muis (2004) suggests that assessment of beliefs is a critical aspect of assessing preservice teachers' knowledge of mathematics. Assessing beliefs at a mid-way point, rather than at the end of the course, could alert teacher educators to those who are not crossing the boundary into the mathematics education domain. We suggest it could also provide the teacher educator with cues indicating where further support and/or challenges may be needed to facilitate transition from one domain to another.

It is relevant for preservice teacher educators to assess boundary crossing via metaphors for all preservice teachers, not just those who regard mathematics negatively. For example, Matthew's original writing revealed that he perceived himself as a capable mathematician and viewed the discipline of mathematics positively. Analysis of his writing at the end of the course showed no evidence of new learning about the teaching of mathematics. Matthew's static view suggests that the boundary into the teacher education domain, where he could have considered a range of possible approaches for teaching primary mathematics, was less permeable for him. It became apparent that preservice teachers who view themselves as capable mathematical learners also require attention. Viewing a metaphor as a boundary object can thus provide opportunities

for informing teacher educators about shifting understandings, or a lack of movement between domains.

Akkerman and Bakker's (2011) final learning mechanism, "transformation", refers to the difficulties of embedding change into one's practice. While this study is not able to verify whether transformation would be enacted in future teaching practice, the metaphor task at the end of the course provided an opportunity for preservice teachers to further crystallise their thinking about future teaching practices. Three months after the beginning of the course initial metaphors were readily recalled during each of the focus-group discussions. This suggests a metaphor can be a simple but powerful boundary object that enables preservice teachers to reflect on their initial and current positions about mathematics in relation to the mathematics education domain.

Conclusion

Thinking of a metaphor as a conceptual boundary object and developing a "boundary model" has provided an alternative lens with which to view and work with preservice teachers' beliefs about the nature of mathematics. The model takes account of sociocultural differences at the teacher education boundary. Beliefs about mathematics are not regarded as problematic, but are positioned as a rich starting point for the anticipated crossing of boundaries between past mathematical experiences and the mathematics education domain.

We acknowledge focusing on food metaphors as a possible limitation of this study, given this may not be an appropriate task for some cultural groups. Another limitation of this study is there has been no opportunity to observe the possible transformation of beliefs in preservice teachers' mathematics teaching in the classroom.

By examining the data in light of Akkerman and Bakker's (2011) four mechanisms that comprise the learning potential of boundary crossing we have reached a deeper understanding of how we could work with preservice teachers' beliefs about mathematics. The analysis indicated the value of exploring the affective dimension of mathematics education with preservice teachers. Implications for future practice include: providing

multiple occasions for surfacing beliefs through the writing of metaphors coupled with considering possible impacts on future teaching; planning more deliberate reflection time; and providing opportunities to share metaphors with others.

We contend the action of writing, reflecting on, and sharing metaphors has the potential to assist both preservice teachers and teacher educators to recognise and work towards boundary crossing. It is a reciprocal process that results in learning for all concerned. Further research could explore these suggested implications as teacher educators work with preservice teachers and their metaphors.

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Acknowledgement

We would like to acknowledge the helpful comments of all reviewers.

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