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The mathematics teacher educator as broker: boundary learning

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We analyse how two mathematics teacher educators (MTEs) describe, justify and enact their theory of change in a course for practicing teachers that they co-teach. Applying concepts from Communities of Practice, we identify a shared view of the key boundary objects highlighted in the design of the course in our two MTEs, alongside divergent but complementary means of brokering learning at the boundary during enactment. Prominent in our analysis is a working relationship in which one MTE brokering through coordination appears to allow the other to work towards radical transformation, by seeking confrontation that allows her to define the problem space. We consider the implications of this dynamic for their emphasis on teaching as a pair.

Keywords: *Boundary learning, brokers, mathematics teacher educators*

Introduction

Mathematics teacher educators (MTEs) were oddly absent from earlier research on teacher education, perhaps because they were frequently those doing the research. Although they are now a research subject in their own right (see Goos & Beswick, 2021), as Jaworski (2021) notes in her response to contributions in that volume, in many studies of MTE learning and development, “the course or programme is very much in the background” (p.420). In this paper, we bring the course into focus in an exploration of two MTEs’ theory of change as they intervene in mathematics teachers’ practice.

Theoretical/analytical framework

Many of the studies in Goos and Beswick’s collection share a theoretical orientation towards communities of practice (Wenger, 1998). Jaworski (2021) notes the usefulness of this approach as a way of understanding not only teacher learning and change but also MTE learning and development. In particular, she notes the power of the idea of *boundary crossing* in analysing the process of professional development, drawing on Akkerman and Bakker’s (2011) seminal review of the literature. Briefly, Akkerman and Bakker identify four mechanisms of learning potential at the boundary between practices – for example, when MTEs are university researchers, the boundary between MTEs (academic expertise) and teachers (practitioner expertise). These mechanisms are:

Identification: The differences between communities’ practices are made explicit without attempting to reconcile them.

Coordination: A dialogue is established to translate between the communities, and these can co-exist without noticeable discontinuities.

Reflection: Comparing and contrasting brings about (new) insights into the practices of both communities.

Transformation: Confrontation with a problem triggers reconsideration of existing practices, resulting in recognition of a shared problem space. Sometimes this results in hybridisation, a new practice

emerging creatively from the meeting of diverse practices. Finally, crystallisation is the rare phenomenon where the hybrid practice has real consequences and results in new routines.

These learning mechanisms are made possible by *boundary objects*, objects that have different local meanings but enough interpretative flexibility to allow communication across the boundary between communities (Star, 2010): an assignment in teacher education, for example, could be interpreted by students as a requirement that must be met and by the teacher educators as support for future practice.

Literature review

This framework has been used to explore how a diverse group of MTEs (academic researchers and science/mathematics teachers) worked on professional development for teachers which linked authentic workplace situations with mathematics teaching (Bakogianni et al., 2021). Analysis revealed that a range of boundary objects (tasks, course objectives, etc.) enabled a change in MTEs' learning mechanisms over time, as they moved from identification to reflection and coordination. While in this example the boundary learning occurred spontaneously, it can also be fostered by *brokers* (Wenger, 1998). Goos and Bennison (2018) observe that MTEs frequently enter into explicit *brokering* between practices, and that this is enhanced by diversity among collaborating MTEs. In their study, MTEs were either specialists in mathematics or mathematics pedagogy, and success was defined as the integration of their respective disciplinary paradigms, mathematics content and pedagogy. In this paper, we focus not on MTE's disciplinary backgrounds but on differences in how they describe enacting the shared goals in their theory of change. Hence, we ask our research question: What changes do two mathematics teacher educators set out to realise through a course for in-service teachers, and which features do they highlight as essential for realising change?

Context of study

The context for this study is a one-year part-time credit-bearing (30 credits, half of a full-time load) course for in-service teachers in a Norwegian university. Many - but not all - are primary teachers lacking the necessary credits to satisfy recent requirements for teaching mathematics. The course aims to introduce teachers to student-centred, inquiry-based mathematics teaching. It promotes a Realistic Mathematics Education (RME) approach to teaching, highlighting a number of key principles, particularly the importance of context in emergent mathematics and the transition from informal to pre-formal to formal models (e.g. Van den Heuvel-Panhuizen, 2003), and guided reinvention (Stephan et al., 2014). In this paper we report on data from two of the MTEs teaching the course, Silje and Daniel (pseudonyms). Both are experienced MTEs (Silje is more senior) who conduct research in mathematics education, and have experience as mathematics teachers in schools.

The course was designed by Silje more than 15 years ago, and has been implemented at this university (cohorts of up to 200 divided in up to 5 classes) for the past 8 years by a group of MTEs working in pairs and led by Silje. Over the years, Silje has co-taught the course with a number of MTEs. Currently, she works with Daniel, who at the start of the data collection was beginning his second year teaching on the course but had previously taught a course for prospective mathematics teachers that had adopted materials from Silje's course. The two had asked to co-teach the course for the second time, as they consider their collaboration particularly fruitful.

Methodology

This paper presents an analysis of a written statement and interviews with Silje and Daniel, as part of a larger project analysing a community of practice of ten MTEs involved in the course. The idea of theory of change in teacher professional development had been raised at a research group meeting, so we asked Silje and Daniel to write down their version for this course so that we might understand the connections between their goals for teacher change and the design and enactment of the course. They did this exercise together, and we reproduce their account here, translated into English by the first author (Table 1). Silje and Daniel were then interviewed together by the first author. The interview focused on the background to their document, and Silje and Daniel's views on what they believed the teachers brought to the course and how they built on this to achieve their aims. They were also asked about the nature and extent of teacher change they hoped might happen. A follow-up interview with Silje aimed to clarify points arising in the first interview including her emphasis on having two MTEs in the classroom during teaching. Both interviews were transcribed in Norwegian and translated into English by the first author. In our translations we have aimed to keep as close as possible to our understanding of intended meaning in the original Norwegian.

We analysed the data by first identifying boundary objects in Silje and Daniel's written statement and then classifying the relevant interview extracts in accordance with Akkerman and Bakker's (2011) four mechanisms for learning opportunities. There are at least four potential communities of practice at play here: the teachers-as-students, the teachers as members of the wider community of teachers, the MTEs as educators with a reform purpose, and the course members as a whole, engaged in a joint inquiry. We limit our interest here to examining the change that the MTEs aim to achieve at the boundary between teachers as members of a wider community and their own community of education reformers. In our analysis, we looked for references to these communities and the differences between them (identification), and references to actions taken by Silje and Daniel in terms of the establishment of dialogue which aims to translate between communities (coordination), comparison/contrast between practices (reflection), and presentation of problems which disturb practice (transformation).

Analysis

In this section we report first on Silje and Daniel's written statement, identifying three boundary objects, followed by an analysis of their interview, highlighting their justification of the theory of change and their account of how the three boundary objects support their goals. We notice who introduces new perspectives, and how the other disagreed, supported or elaborated. We focus in the discussion on the relationships between them as brokers on the boundary between practices.

Theory of change (Table 1)

We identified three boundary objects in Silje and Daniel's account: research-based course literature (while only one conceptual tool is referenced [Ulleberg & Solem, 2018], Silje and Daniel draw on technical vocabulary - pre-formal methods, talk moves, learning landscapes etc - from the field of RME and inquiry learning, which they know we are familiar with); teachers' lived experience of being in the classroom led by the MTEs ('gatherings'); and written assignments on engaging with their school students' mathematical thinking ('missions'). There is an emphasis on creating a learning experience for teachers which they will mirror in their classrooms, and on understanding the student

point of view. In addition to exposing teachers to close investigation of student work and of their own practice, Silje and Daniel seek to model the practice that they promote; in this sense their “theory of change” suggests that they aspire to transform in their work on the boundary by confronting teachers with new experiences which will lead to reconsideration of their existing practice.

Table 1: Silje and Daniel’s “theory of change” document

Our overall goals	How
<p>That teachers experience learning through a reform-based approach, and develop this in their own practice</p> <p>That teachers can facilitate practical, inquiry-based and theoretical work that nurtures and develops students' mathematical knowledge and mathematical thinking</p> <p>To develop teachers' dialogical approach to mathematics so that the use of talk moves and opportunities for oral mathematics increase</p> <p>To develop mathematical and didactic competencies so that discussion of student work is nuanced and teachers are explicit about their didactic tools.</p> <p>To create, as an example of practice that teachers can use in their own classroom, a safe learning environment in mathematics, where we listen to each other, dare to ask questions, dare to make mistakes, learn to persevere and give each other thinking time</p>	<p>By discussing authentic student work and directing attention to what the student can do, what lies on the student's closest learning horizon, and how the teacher can challenge students to develop their thinking by:</p> <ul style="list-style-type: none"> • discussing the learning landscape / learning trajectories of the students, cf. RME • analysing and discussing the work of their own students in written assignments • becoming acquainted with, work with and be able to account for, informal and pre-formal methods that can eventually be used as teaching tools <p>By using Solem and Ulleberg’s model of questioning as analysis and reflection tools to develop conversational features / rich discussion in teaching</p> <p>By getting the teachers to work investigatively in and with mathematics throughout the course</p> <p>That we ourselves have a practice that reflects the overall goals of the course.</p>

Learning opportunities: bringing about transformation

The interview analysis suggests considerable complexity in this transformative aim. Asked to explain their theory of change, Silje embeds her account in her personal history as a teacher, and deep convictions about what is involved in learning mathematics. She identifies the core goal of the course as promoting mathematics teaching where students see themselves as sense-makers:

From the moment I started teaching mathematics and discovered that people found it a very authoritarian subject - they didn't understand anything, they felt stupid - I realized that several generations were deprived of the opportunity to feel [...] that they could think for themselves.

Silje justifies the theory of change primarily based on experience, while the research perspective is secondary. Daniel relates it to both his experience as a school teacher and research:

I initially taught as I was taught myself ... it was really these [materials] of Malcolm Swan that were a revelation to me...What occurred to me was that the students started talking in a different

way. It led to a kind of dialogue in the classroom that one could lift up. [The materials] gave me an idea of how I could ask questions and function in a different way in the classroom.

Here, Daniel foregrounds the research (Swan, 2005), spotlighting specific elements of the theory of change (the classroom dialogue). Silje's more holistic perspective emphasises values that she sees as encapsulated in Kierkegaard's writing. Elaborating on this in the follow-up interview Silje explains:

That's what I see in [...] Kierkegaard [...], to meet the student where the student *is* and to lead him by the hand ... By 'lead' [I mean] that we go together and the premises are yours. You are the starting point... your path is not the same as hers! Now it's *you* we're talking about.

This idea captures Silje's ethos, and the essential quality of the community of practice she wants teachers to become part of through the course. For her, the shift towards making the student the starting point of teaching entails a radical transformation that must start with a confrontation; she rejects a passing suggestion from Daniel that the course might rely on teachers wanting to change:

Most of them *don't* want to change. [...] I meet them full of prejudice and assume they will convert, so to speak; [prejudice] that they come with traditional beliefs and experiences of mathematics teaching. And - as far as I can see - it turns out to be largely correct. ... As [one teacher] said, it's a paradigm shift. Something happens during the first gathering, they experience something they never experienced before. [...] So, no, I don't think they need to *want to*. On the contrary.

While Silje's strong identification of difference is not at all concerned to reconcile practices, Daniel takes a less radical view, seeing participation in the course as an opportunity for development, a coordination between the teachers' present practice and the goal of the course. He doesn't see the teachers as "necessarily problematic", but concedes that "one wants to develop their ways of teaching mathematics". In this sense, Daniel speaks more readily as a broker concerned to promote dialogue and reflect on practices both old and new. Next, we analyse Silje's and Daniel's justifications of the three boundary objects - missions, course literature and gatherings – as opportunities for learning.

The 'missions'

Silje describes listening to students as a crucial but unfamiliar practice for the teachers:

We want [...] teachers to learn to listen. Learn to see the student. Understand how this student thinks before going in with my understanding of what I think this student is thinking. That's why we spend so much time on these 'missions'. To get [teachers] to take the student perspective.

The 'missions' create learning opportunities through transformation in which teachers are confronted with a problem space they weren't aware of, valuing and building on students' surprising ideas. She stresses their role as confrontations between reform teaching and their habitual practice:

I believe it is because of these missions, where they have to sit with the students and have to analyse what they say and think about what to answer, that they discover sometimes - and they write so in the assignments in the start - that they took the answer out of the mouth of the student. This is something they need to experience, too. You need to discover how *not* to do it. And the joy to discover how incredibly lush children are! They think about so many fun things that we've forgotten to think about. I am very happy every time I discover it!

While Silje emphasises missions as opportunities for new discoveries and sheer difference which is not (and cannot be) reconciled with existing practice, Daniel describes them as enabling coordination in the sense of demonstrating the day-to-day ‘reality’ of theory:

For the teachers, it’s the ‘missions’ that truly pull together all the threads of the course. In the oral exam they reflect on the missions and [say] that “we read about all these things, and then we did the observations - and the students said exactly the things we had read about!” It was almost a surprise for them that the theory could actually happen in their own day-to-day reality [laughs].

The research-based course literature

The role of the substantial research-based reading list generates similar differences in Silje’s and Daniel’s accounts of brokering. Although she values the opportunities for reflection that this brings for teachers, Silje believes it is necessary but not sufficient for impacting practice (“it’s lethal to assume that literature alone can persuade teachers”), thus justifying the inclusion of missions. This is not to say that Silje thinks that engaging with literature is not important. She recalls her excitement, as a novice MTE, on discovering writing on mathematics pedagogy and its usefulness as a tool for thinking. The RME orientation of the course, too, stems from literature that fits her ethos (“I had read the books from the Netherlands and took [in ideas] [...] - they hit me right in my thinking”). For Silje, rooting the course in research is a given, but it must connect to prior or ongoing experience. Daniel, too, is selective: since joining the course he has consolidated the theoretical aspect of the RME orientation (“I read a lot on RME. [Including] the idea of learning landscapes was a bit my influence”) but stresses that the aim is not mere alignment - choices are based on their own assessment (“there is some influence from others, for instance Malcolm Swan ... we are free to mix in other things”).

Silje returns to missions and Daniel’s coordination argument, adding that translation is bi-directional:

If it is going to be research-based ... reading is valuable, also to go back and get the theory confirmed. Isn’t this what we try to achieve with the missions? They read something - they have the experiences from the gathering - and then go out [to do the ‘mission’] and go back and read the theory again?. [...] I claim that the value is in the back-and-forth between theory and practice.

While Silje focuses on the details of this dialogic relationship between reading and experience as part of a process of reflection, Daniel focuses on specifics of what the literature can contribute, pursuing his theme of coordination as translation between practices:

We take examples of student work ... and try to lift the conversation about what the students did, what they thought - and frame it in the context of theory: both mathematical theory, say associativity and distributivity for multiplication, but also [theory] on development. [...] Where they are in a mathematical landscape. [...] Even though the metaphor is limited, it helps! Because I think nobody is in a point in a landscape, but it helps teachers to think “What are the possibilities for this student now? What can he do and how can he develop from here?”

The ‘gatherings’

During gatherings, Silje is less concerned with theory, focusing more on defining the problem space by modelling the practices she promotes, with the teachers experiencing the student perspective:

We go around and listen... It gives us an insight into the dialogue in each group [...] and it teaches us an awful lot about how we interact with them - when you jumped in too soon, when you didn't really know what to say, when you were wondering about ... when you left that group to make time for another. We can't teach them another practice if we aren't participating and helping them.

However, she is mindful of the danger of the experience amounting to identification rather than transformation and the need to broker the process through articulating her choices:

We can design a session that [they] experience as very good. And it may well be good as a session where you teach mathematics. But if the goal is for them to learn to be teachers, then they need to know about the decisions behind. They can't see it unless we say it, I think.

Daniel sees the interaction between MTEs and teachers as coordination, an opportunity to translate between theory and practice. Interactions between the teachers are also important as they allow hybridisation, the emergence of new practice as they discuss their responses to students' ideas:

When we discuss and analyse a case for example ... this dialogue becomes their own, so that when something unexpected happens they will have developed another way of thinking. The dialogue going through their heads and the questions they will ask the student will be different ... because they had a dialogue with others about that. ... And then they can use it in their teaching.

Both MTEs value being two in the classroom. For Daniel, it allows identification as decisions and dilemmas become visible in a dialogue between the MTEs where they query each other's choices. Silje elaborates in the follow-up interview that the spontaneity of dialogue is key:

I love the dynamic [...] from Daniel [interrupting me to clarify] - so much fun! [...], to my saying to him "I completely disagree with you and here's why", to someone suddenly jumping in because what I said made them think of something that fits perfectly. But spontaneously! [...] We need to stand together and be in dialogue and talk to each other and talk to the audience.

Discussion: partnering in change

In this paper, we have drawn on the concepts from Wenger's (1998) *Communities of Practice* to understand two MTEs' justification for their practice as they co-teach a course for teachers. Conceptualising the MTEs' roles as brokers (Star, 2010; Wenger, 1998) for teachers' boundary learning, analysis of their written theory of change allowed us to identify three key boundary objects: 'gatherings', research-based course literature, and missions. Interview data showed that the two positioned themselves as members of both communities of practice (mathematics teachers and MTEs) as they shifted between justifying the theory of change from the perspective of practitioners or academics, with Silje foregrounding the first and Daniel the second. Akkerman and Bakker's (2011) framework for boundary learning enabled a distinction between Silje's holistic manner of justifying the theory of change (an aspiration to radical change, to transform the practices of the teachers) and Daniel's more analytical approach picking out specific items from the theory of change (e.g. teacher questioning, Table 1) and unpacking these. The next layer of analysis identified similar contrasts in their accounts of enactment: Silje tended to initiate accounts of pursuing identification and transformation through the three boundary objects, while Daniel concentrated on coordination between practices. This characterisation of the complementary roles they take on as brokers supports

their sense that their collaboration is fruitful. To return to our research question, and the issue of Silje and Daniels' justification for their overall goals of the course, these complementary roles and aims perhaps provide some indication of ways forward for understanding mathematics teacher educators' evolving practice in more detail, and the nature and extent of their role in teacher change and development.

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