Mathematics Teacher Educators Learning at the Boundary Between Classroom Practice and Educational Research

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Education departments provide support for teachers of mathematics, particularly out-of-field teachers, to improve their mathematics teaching. In this article, we explore the insights and learnings of mathematics teacher educators (MTEs) working as critical friends outside the formal structures of research or professional learning leadership. As part of the Queensland Department of Education *M in STEM* project mathematics educators from Queensland universities supported teachers in clusters of schools to address their shared problem of practice in mathematics teaching. This case study employed the Most Significant Change methodology to investigate how MTEs engaged at the boundary between classroom practice and educational research. Findings indicated that MTEs, through their roles as critical friends, had opportunities to hear teachers' stories, observe classrooms in diverse contexts, and develop new insights into teaching practices. This process also enabled the generation of new or hybrid knowledge that bridged theory and practice. Implications for initial teacher education include a strengthened capacity for MTEs to connect curriculum and pedagogy with the lived challenges of classroom practice.

Keywords • mathematics teacher educators • critical friends • mathematics teacher education research • learning-at-the-boundary

Introduction and Context

Australia has a severe shortage of qualified secondary mathematics teachers. More than 75% of Year 7 to Year 10 students are taught by teachers who are not qualified to teach mathematics for at least one of these first four years of secondary school (out-of-field teachers) and the situation is worse in rural and remote locations (Australian Mathematical Sciences Institute, 2018; Shah et al., 2020). Out-of-field mathematics teachers tend to believe that mathematics is a "set of facts, rules and skills" (Vale et al., 2021, p. 599). Also, lower achieving students are more likely than higher achieving students to be taught mathematics by an out-of-field teacher (Hill & Dalton, 2013). Vale et al. (2021) showed that with professional learning over time, out-of-field teachers can be supported to develop teaching practices that include a "stronger emphasis on understanding and problem-solving and learner-focused approaches" (p. 610).

To address the issue of out-of-field teachers the Queensland Department of Education (hereafter, referred to as the Department) established the *M in STEM* project to support clusters of schools to address problems of practice they identified with the teaching of mathematics within their schools. The Department ran professional learning to support the teachers to develop and implement a mathematics teaching improvement plan, aligned to the shared problem of practice of the cluster of schools and the Department's school improvement model, which takes an inquiry approach. Contrary to what was happening in some other Australian states where explicit instruction has been mandated, the Department was focussing on mathematical proficiency in the Australian Curriculum (Australian Curriculum, Assessment and Reporting Authority, 2014, 2026) and particularly problem solving and reasoning. The focus of the professional learning was to develop sustained change in schools. To date, 26 clusters of schools incorporating 96 schools had participated in *M in STEM*.

The project involved fourteen mathematics teacher educators (MTEs) from six universities acting as critical friends, working with clusters of schools across Queensland. The participating MTEs in the

project were in a novel position as they were neither leading the *M in STEM* project and its professional learning nor researching the project. The MTEs were assigned as critical friends by the Department to match the MTE's expertise with the needs of the cluster of schools as defined by a problem of practice identified. MTEs had conversations with key teachers from their assigned school clusters and provided resources, readings, and sometimes professional development targeted to the needs of teachers. The MTEs' role was encouraging teachers' deep engagement in professional learning associated with *M in STEM*.

The research for this article is positioned outside of *M in STEM* that is researching *M in STEM*, following three iterations of the project. In this article we examine the work of MTEs in their roles as critical friends and explore the insights generated at the boundary between classroom practice and educational research. Akkerman and Bakker's (2011) learning-at-the boundary framework was extended to illuminate how these MTEs navigated the boundary between classroom practice and educational research.

Literature

Critical Friends

Critical friends may work alongside teachers to support their change in practice. Baskerville and Goldblatt (2009) defined a "critical friend as a capable reflective practitioner (with integrity and passion for teaching and learning) who establishes safe ways of working and negotiates shared understandings to support and challenge a colleague in the de-privatisation of their practice" (p. 206). Costa and Kallick (1993) emphasised the importance of the critical friend's critique and provocative questions.

MacPhail et al. (2021) suggested that there are two broad categories of behaviours in which critical friends can engage: supportive behaviours and critical behaviours, while also recognising a range of behaviours that may overlap both categories. Support behaviours include facilitating the development of a learning community; talking, brainstorming, and encouraging; advocating for a more interactive and collaborative community; and being a sounding board. Critical behaviours include impartial feedback and asking provocative questions; challenging teacher's thinking, reasoning, and ideas; suggesting alternative ideas that might be explored; and critical feedback. There were also other behaviours that overlapped both support and critical behaviours and these include: dedicating time and energy; trusting relationship; confirming and rejecting decisions; and understanding the context. Critical friend–teacher relationships reduce professional isolation and promote learning by fostering safe, collegial dialogue that challenges assumptions and deepens pedagogical reflection (Beveridge et al., 2018; Blake & Gibson, 2021; Hostetler et al., 2014). When associated with professional learning, a critical friend's questions and critique can encourage deeper engagement with the professional learning (MacPhail et al., 2021).

A 2020 exploratory study by Fletcher and Wennergren (2021), examined their separate experiences as teacher educator critical friends with separate professional learning communities, one in Australia and one in Sweden. Over a year, they analysed collaboratively the learning conversations with the teachers as well as their collaborative research conversations. Conversations typically focussed on improving teaching and learning, with critical friends challenging assumptions and posing questions to stimulate reflection, though less attention was given to why changes and further knowledge were needed.

An Australian action research study by teacher educators, conceptualised the critical friend as an "academic partner" working alongside teachers in school-based research (Beveridge et al., 2018). The role was found to be complex and sometimes under-supported, yet beneficial in building mutual capacity and fostering transformative professional development. Effective partnerships require relevant expertise, a good fit between academics and schools, and clear expectations to sustain genuine, though often challenging, relationships. It is important there is a good fit between the teacher educator and the school for changes to be sustained (Beveridge et. al., 2018).

A key challenge in critical friend–teacher relationships is sustaining classroom change. Research suggests that when teachers are empowered to collaboratively explore, integrate, and reflect on innovative ideas, supported by a critical friend, they are more likely to change practice (Blake & Gibson, 2021; Fletcher & Wennergren, 2021; Marshman et al., 2024).

Problem of Practice

Reflective practitioners often struggle to reframe their practices because classroom practice is deeply entangled with their personal teaching experiences and beliefs (Schuck & Russell, 2005). This close connection can restrict their capacity to step back from established perspectives, making it difficult to question underlying assumptions or reconceptualise issues. These limitations highlight the value of external perspectives to introduce fresh insights and disrupt entrenched ways of thinking (Baskerville & Goldblatt, 2009).

Bacchi's (2012) *What's the Problem Represented to Be?* approach shifts analysis from problem-solving to problem-questioning by highlighting that every policy or proposal implicitly defines the problem (Marshman et al., 2024). These representations are never neutral, but rather, shape the way issues are understood, and which solutions are considered (Bacchi, 2012; Marshman et al., 2024). To guide the analysis, Bacchi (2012) proposed six guiding questions that examine problem representation, underlying assumptions, historical development, silenced perspectives, real-world effects, and mechanisms of maintenance. While designed for policy analysis, *What's the Problem Represented to Be?* can be applied to schools, enabling teachers to interrogate assumptions and uncover alternative explanations. Without such reflection, teachers risk identifying superficial solutions that address symptoms rather than resolve causes, thereby limiting sustainable improvement (Myran & Sutherland, 2016). Extending these ideas Fletcher and Wennergren's (2021) *What? Why? How?* framework structures professional dialogue for shared purposes (why), focal content (what), and strategies (how). Their research showed that teachers often emphasised content and methods while neglecting the purpose. Beginning with the why encourages reflection on purposes and values, clarifies causes of issues, and aligns actions with shared goals, thereby supporting agency and sustained improvement (Fletcher & Wennergren 2021). Although both frameworks offer tools for examining critically problems of practice, little is known about how they function at the boundary between the MTEs' research-based knowledge and teachers' practice-based knowledge, or how the interplay at the boundary shapes problem definition and the possibilities for sustained change.

The Different Knowledges of Mathematics Teacher Educators and Teachers of Mathematics

When MTEs and researchers work together challenges arise because teachers and education researchers are members of different but related communities with different knowledges, who share a common goal of improving mathematics teaching and learning. Teachers are focused on addressing the practical issues that they face daily in their classrooms (Wiliam, 2003). Researchers, however, are focused on creating new knowledge that helps them to understand an issue (Labaree, 2003) and to generalise the findings (Wiliam, 2003). This then creates a boundary between these two disciplinary communities. The National Council of Teachers of Mathematics Research Committee (Heid et al., 2006) called for improvement at this boundary:

> The need for improvement is bidirectional. The practice of classroom mathematics teaching needs to be better informed by an understanding of the implications of existing bodies of research, and researchers need to learn more from the insights and knowledge of practitioners. (p. 76)

Analysing 12 Dutch research and development projects for the reasons for collaboration, the division of roles and tasks, and the communication structure, Schenke et al. (2017) found four types of cross-professional collaboration, distinguished by whether schools or external experts directed the work. The

various groups were engaging in "practice-based research that seeks to contribute to school development" (Schenke et al., 2017, p. 2); however, each group had different objectives:

> Teachers' objectives are to provide good education, and their primary motive is to support students to develop as full members of society ... School leaders' objectives are generally to ensure good education. … The motive of educational researchers is knowledge development, although their objectives may be oriented more toward contributing to educational practice or to academic knowledge development (Schenke et al., 2017, p. 3)

Teacher educators involved became more practice-oriented and gained insight into educational complexities, political pressures, and the importance of school context.

Theoretical Framework: Learning at the Boundary

Boundary encounters provide insight into how meaning is negotiated across practices (Wenger, 1998). These can be one-way, such as conversations between individuals from different communities, or two-way, involving delegations from both sides. When such encounters become ongoing forums for engagement, they may develop into boundary practices that coordinate perspectives and address shared problems, leading to change (Akkerman & Bakker, 2011; Wenger, 1998).

Research has used the concepts of boundary practices and boundary crossing to examine interdisciplinary collaboration and learning (Akkerman & Bruining, 2016). In education, this work highlighted shifts in identity, such as pre-service teachers moving between student and teacher roles (Kang et al., 2013) or mathematicians working in education (Darragh, 2022). Boundaries mark sociocultural differences that create discontinuities (Akkerman & Bakker, 2011). Crossing them requires professionals to navigate unfamiliar contexts and integrate diverse practices to create hybrid solutions (Engeström et al., 1995; Suchman, 1994). Generally, MTEs in Australia were either primary or secondary mathematics teachers before becoming MTEs. These MTEs then have crossed the boundary between the two communities and have knowledge about how schools and classrooms function. Schools, however, may have evolved and may not be as the MTEs remembered.

While boundaries offer learning potential (Engeström, 1987; Wenger, 1998), there is limited research on the types of learning that occur (Akkerman & Bakker, 2011). Learning can involve new understandings, identity shifts, changes in practice, and institutional development. Akkerman and Bakker (2011) identified four dialogical mechanisms through which learning happens: identification, coordination, reflection, and transformation. *Identification* involves recognising the distinct practices of different communities and re-evaluating one's own without necessarily crossing boundaries. *Coordination* enables collaboration and knowledge exchange, aiming to make boundaries more permeable. *Reflection* involves viewing each community's practices from the other's perspective, enriching personal identity. *Transformation* arises when communities address collaboratively issues, creating new or hybrid practices. These mechanisms can operate at institutional, interpersonal, and intrapersonal levels (Akkerman & Bruining, 2016). Schenke et al. (2017) showed that crossing boundaries between school classrooms and educational research led to teachers, school leaders, and researchers learning via different mechanisms during Dutch research and development projects.

Goos (2014) examined the differing ways in which teachers and researchers construct knowledge and proposed a framework for analysing their partnerships: focusing on how the partnership is initiated, the roles assumed by participants, and the purposes of the research. In the present study, the critical friends acted as translators of research, supporting teachers to engage with research insights in order to address practice-based challenges. This role can be understood as boundary crossing (Akkerman & Bakker, 2011; Wenger, 1998), where participants navigate sociocultural differences to negotiate meaning and combine diverse forms of expertise. Importantly, the work of the critical friends extended beyond translation. It developed into a boundary practice, an ongoing and structured way of connecting communities. In this capacity, critical friends operated as *knowledge brokers* who not only made research accessible to teachers but also carried practice-based insights back into research discourses. This reciprocal exchange helped to align professional learning with the lived realities of

classroom teaching while also shaping the direction of research to better reflect teachers' concerns. By sustaining this two-way flow of knowledge, critical friends fostered professional agency, deepened inquiry into practice, and generated hybrid understandings that contributed to both immediate classroom improvement and longer-term educational change (e.g., Blake & Gibson, 2021; Fletcher & Wennergren, 2021; Marshman et al., 2024).

Knowledge brokers mediate between communities of practice, going beyond simple translation by negotiating meaning, coordinating perspectives, and exchanging insights in both directions (Akkerman & Bakker, 2011). By bridging sociocultural boundaries, they make ideas meaningful across contexts and can establish boundary practices where teachers and researchers co-construct hybrid knowledge that addresses classroom challenges and may inform research. In this study, critical friends functioned as knowledge brokers, facilitating reciprocal exchange and ongoing professional learning. The research question explored here is:

> *What were the learning and insights generated by MTEs at the boundary between classroom practice and educational research?*

Research Design

This case study is part of a broader project examining factors that supported or hindered the effectiveness of *M in STEM*, particularly enhancing support for out-of-field teachers of mathematics. The project was initially framed using most significant change methodology, a participatory evaluation approach that collects narratives of significant change to reveal values, foster critical reflection, and support adaptive practice (Dart & Davies, 2003; Davies & Dart, 2005). Due to challenges convening focus groups, individual interviews with participants were conducted. The case study approach was used to develop a rich, contextualised understanding of the phenomenon under investigation (Stake, 2006). This case study only considers the MTE's (both the university-based MTEs and the Departmental project leads) perspectives.

Context

Ninety-six schools in twenty-six clusters over a three-year period voluntarily joined *M in STEM*, each identifying a specific problem of practice. MTEs from various universities were matched to school clusters based on the alignment of their expertise and the schools' needs. MTEs were not conducting research whilst working with their clusters of schools. The project ran for a school year, with some participating twice. The initial departmental professional development session and project induction allowed time for teachers and critical friends to establish working relationships and contextual understanding. Teachers sought practical support for mathematics teaching; researchers aimed to apply research in classroom contexts. The project had no formal research component, and MTEs supported schools in addressing their problems of practice, highlighting the asymmetry between teachers' need for actionable strategies and researchers' focus on knowledge application. This research sits outside *M in STEM*.

MTEs reported engaging in the project through a variety of approaches. Online interactions included emails, virtual meetings, and PD sessions, while those able to visit schools also conducted classroom observations, modelled inquiry-based learning, and/or delivered PD workshops. MTEs provided accessible academic readings, adapted teaching resources, and supported survey and assessment tool refinement or development. Engagement frequently involved collaborative discussions with teachers from school clusters, fostering the co-construction of pedagogical approaches, shared terminology, and context-specific solutions. Contact was initiated by either the MTE or the cluster leader, with closer proximity enabling more frequent or sustained engagement.

Participants

All MTEs who worked on the *M in STEM* project were invited to participate in an interview or focus group. Eight university-based mathematics educators (Ava, Claire, Kerrie, Kylie, Maisie, Molly, Tara, and Troy) from five Queensland universities participated in online semi-structured interviews. None of these MTEs were researching with the cluster(s) of schools to which they were assigned. The two project leads (Lilly and Penny) from the Queensland Department of Education completed a focus group interview online. Penny also completed a follow up interview one year later.

Data Collection and Analysis

Following ethical approval from the university ethics review committee (Approval number A231920) and the Queensland Department of Education (Approval number 550/27/2771) interviews were conducted via Teams or Zoom and audio recorded. Early interviews were transcribed by Zoom and later ones via otter.ai, an AI powered transcription and meeting-notetaking platform. Participants were invited to review a copy of their transcribed data, but all declined. All participants gave informed consent to participate in the research and for their data to be used for research purposes.

The interviews lasted between 21 and 52 minutes and the focus group 36 minutes. Participants were asked about how they became involved in the project, and then following the most significant change methodology, participants were invited to share: what they thought was the most significant change from their participation in the project; why this change was significant; and the changes in practice ensuing from the project. Later participants were asked about the different knowledges of teachers and MTEs. A focus group with two Departmental project leads discussed similar questions but were also asked about their role and the MTEs' role in achieving change.

Braun and Clarke's (2022) six phases of thematic analysis: familiarising with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and reporting findings were used to analyse the data inductively. Each author analysed the data identifying codes and possible themes for each MTE. The authors then collaboratively generated an agreed upon set of themes and together assigned codes and potential quotations from MTEs to the themes. To maintain anonymity and confidentiality, all participants were assigned pseudonyms for reporting purposes.

Findings

Results are presented under the four dialogical mechanisms through which learning may happen at the boundary between communities: identification, coordination, reflection, and transformation (Akkerman & Bakker, 2011). These align with themes within the inductive reflective thematic analysis: fit between MTE and teachers, school's problem of practice, teachers' expectations of how MTEs would solve their problem, the different knowledges of MTEs and teachers, MTE perspectives of teacher needs, and barriers to enacting change.

Identification

School's problem of practice

MTEs recognised that each school's problem of practice is distinct to the school and its context, and wanted to help the school to re-evaluate its context. When applying to participate in *M in STEM,* clusters of schools or individual schools were invited to identify their problem of practice. MTEs observed, however, that schools often struggled to articulate clearly their problem of practice, or framed their concerns in terms of broad, overarching issues. Claire described "wondering what problem we were trying to solve by implementing those strategies … sometimes they haven't articulated what their problem really is." In many cases, these initial problems were either too ambitions or insufficiently focused, requiring substantial refinement. This lack of clarity created ambiguity both in terms of the schools' intended goals and their understanding of the processes needed to achieve them.

The Departmental project leads valued the input of the critical friends as they described how the MTEs helped teachers to refine their problem of practice:

> Critical friends certainly helped them refine their problems of practice, because they were all way too big, and then they did a great job on getting them to get moving on that problem of practice. (Lilly)

> I think the critical friend was essential for them to be able to take whatever the problem practice that they started with, and they thought they were coming in to help them actually recognise what it was. [Penny]

MTEs described their focus as identifying the underpinning reasons for the problems of practice raised by the teachers. Troy said that he was "trying to find the root cause of the problem."

Sometimes teachers thought that other initiatives, for example, *Building Thinking Classrooms* (*BTC*) (Liljedahl, 2020), would solve their problem of practice. As Claire explained "teachers are being led to believe that they can just pick a thing from this research and implement it in their classrooms to solve any given issue." Whilst Penny, from the Department described how MTEs challenged teachers to consider why they wanted to implement *Building Thinking Classrooms*.

> Having the critical friend there was really great to get those teachers to sort of take that step back and say, yeah, it might be really fun and great to do this thing. But why are we doing this thing? Like, what are you actually addressing? What is it in what you're thinking? Because implementing *BTC* is not a problem of practice. That's a strategy to address the problem of practice. So, the critical friend was really great in being able to go, hold on a sec that is shiny and bright, let's just put our blinkers up for a second and think about why we're attracted to that shiny thing. And I think that was a powerful role for the critical friend. [Penny]

The challenge was compounded when schools within a cluster did not share the same problem of practice, intention, or level of engagement. Because MTEs were not embedded in the day-to-day work of the schools, they were unable to fully diagnose the underlying issues. identifying these issues required the contextual knowledge and insights of the teachers. This limitation constrained the extent of the support the MTEs could provide.

> It was really up to them to try and work out how they wanted me to help them… it's really up to them to work out what they want, and bring me in in whatever way it might be useful, and I think they found that difficult" [Molly]

But the challenge was how to support the teachers to determine their problem of practice as Molly and Maisie discussed:

> Trying to get the teachers to work out what their problem is, rather than having the Department tell them, you know, here's the goal or have us tell them. But I think it's working that out that is in itself a real challenge. [Molly]

> And that, that's probably at the crux of it isn't that? Really what we've got to do is to help teachers find out what their problems are, and to articulate their problem. [Maisie]

In the initial planning days MTEs began identifying underlying issues and co-designed the shape of the critical friend-teacher relationship, for example, negotiating regular contact between MTEs and cluster leads, potential resources, and the possibility of in-person visits to schools.

Teachers' expectations of how the MTE would solve their problem

Sometimes teachers did not want to reevaluate their own practices and had expectations of how the MTE would solve their problem. Some MTEs perceived this disconnect between what MTEs intended to provide and what teachers wanted. MTEs expected to provide support, theoretical frameworks, readings, resources and guidance. Molly described the expectation gap clearly as she was asked, "But are you going to tell us?" Troy suggested, "Time poor teachers just wanted to be told which technique is best for their classroom" and a Departmental project lead reported, "I feel like teachers want specifics. They want step one, step two, step three." [Lilly]

Sometimes the school knew what they wanted, for example Kerrie was asked, "to model how to teach inquiry in the maths classroom." Another cluster wanted Maisie to tell them how to implement problem-solving in Years 7-10 in preparation for the Problem Solving and Modelling Task (Queensland Curriculum and Assessment Authority [QCAA], 2019): a mandated assessment task in senior secondary. Providing the theoretical framework in a professional development for the six cluster leads, Maisie encouraged the teachers to embed this in their school's pedagogical framework.

> Some of the school's use Polya, "see, plan, do, check". … but then you have the formal *Approach to problem solving and modelling* [(QCAA, 2019, p. 14)] in senior, you know, formulate, solve, evaluate and verify, and communicate. They couldn't see how to get them to work together. … I basically gave them a blank *Approach to problem solving and modelling* and then said, Okay, here's that. Here's Polya, how are you going to map the two? And they're looking at me, and I'm going well, each of your contexts is different. and I don't know how you work. You can do these with your staff. And they actually liked it. Well, according to …, the *M in STEM* team. … and they didn't respond to another email after that. They got what they needed. They were happy. [Maisie]

Teachers often sought practical solutions to fix a problem in their classroom. Kerrie described this as "driven by time constraints to improve outcomes and they [teachers] don't see it immediately; it doesn't lend itself to change."

Coordination

Fit between the mathematics teacher educators and teachers

A good fit between the MTE and teachers enabled the collaboration and knowledge exchange that made the boundary more permeable. The success of MTE-schools partnerships appeared to depend on a committed individual or "champion" within the school/cluster. The champion often acted as a conduit between the MTE and the school communities. Tara explained, "It was achieved by having a champion or an advocate in the school." The champion ensured more consistent communication, greater staff buy-in within schools, and ultimately, more successful project outcomes because as Ava described, it was "better to have enthusiastic, motivated people that are going to find the time and the resources to actually engage with the program."

Engagement levels varied across clusters and schools due to the pressures on teachers' workloads, school contexts, cluster proximity, and the availability of the MTE to connect with all staff on the project. Schools where principals, deputy principals, or heads of departments (HoDs) actively supported or engaged in the project were consistently described as having higher engagement levels. Maisie described the Mathematics HoD at one school as "enthusiastic and able to bring the teachers on the journey, … she had good leadership skills … she also knew how to get help." Some leaders encouraged broader staff participation and helped sustain momentum for longer-term change. Tara explained that projects worked best for teachers who were "reform orientated" and willing to push forward with innovative practices and change within their school.

> That was really quite powerful, because they used some of the strategies or trialled some of the strategies and found them to be really effective, and then were really motivated to keep trialling different ones and to bring other people on board. And then gradually it increased through the school. [Tara]

Conversely, MTEs reported schools with limited buy-in were less connected to the project and sometimes disappeared completely from communications, thereby not allowing collaboration at the boundary. These reasons included: a vague definition of their problem of practice, schools seeking a quick-fix, lack of time for teachers to work on the project, or to network with other cluster schools, limited teacher engagement, the diverse needs of the teachers in the project—different year levels, and teachers feeling like they are bothering the MTE. Kerrie explained that schools were "driven by time constraints to improve outcomes and if they don't see it immediately, it doesn't lend itself to change." MTEs also described the challenge of working with remote schools. "The remote ones are difficult,

because again, there's no opportunity really to go and visit or to maintain relationships … [though] not impossible." [Kylie] Some MTEs described attending meetings and delivering PD online.

MTEs described the importance of building authentic and reciprocal relationships between researchers and schools.

> I think the relationship between schools and a researcher is really valuable … connecting schools with researchers and having authentic relationships that are built on what their [teachers] needs are can really enhance teaching and learning. [Kerrie]

Understanding the school context was essential and Ava considered there could be a disconnect or "gulf between what researchers think teachers need and what teachers actually need." Ava attributed this divide to the vastly different focus of the MTEs and the teachers, which again did not allow for collaboration at the boundary. Tara emphasised the importance of the MTE understanding the school context as key to achieving success:

> If you're going to really bring about changes in teachers' practice, you have to sort of situate it in the classrooms, and you probably have to be involved in what they're doing in the classroom, get a feel for what they're doing in the classroom. [Tara]

Reflection

The different knowledges between mathematics teacher educators and teachers

MTEs described the boundary between themselves and the teachers in terms of the different knowledges and environments in which they and teachers generally worked and how viewing the practices of the other community provided an opportunity for their learning. Ava described, "There is a divide, created partly by the very different environments in which teachers and researchers work." whilst Molly said, "[It] can be a barrier between those worlds." MTEs described their primary focus as the creation of new knowledge, which can potentially extend beyond individual classrooms.

> Researchers can only publish new knowledge, and it has to be generalisable and significant to make a difference. So, researchers generally are wanting to make a difference and to get ideas that are going to appeal or to support lots of teachers, not just one. [Maisie]

Claire and Ava both emphasised MTEs' central aim "to create new knowledge" and that the emphasis on generalisable findings was often reflected in methodological approaches. Troy also indicated, "When the problem is solved, [we] want to generalise it." Kylie, however, said that sometime research was exploratory and therefore not generalisable:

> Confirmatory research seeks to be generalised. But exploratory research isn't. That's not the aim of it. So that's my only thing. Because I do mostly exploratory research, so I don't try to make claims that that the work I do is generalisable. It's more illustrative, I guess. [Kylie]

To ensure relevance, MTEs described the importance of situating new knowledge in broader contexts rather than isolated, non-generalisable classrooms.

> Researchers are trying to not only find out what it is, but try and explain why, and look for ways to overcome it and to get it out there, to help other researchers and teachers, but also to map it onto education theory, because as researchers, you've got to base your research on theory. [Maisie]

Some MTEs described the need to bridge the gap between theory and practice to support teachers to change their practice. This project provided MTEs access to classrooms to apply their theoretical knowledge in real-world contexts. In translating existing theoretical knowledge for application in the classroom MTEs can cross this theory-practice boundary, supporting learning of both communities. This may be translating published professional articles into classroom-based activities that can be immediately used by a teacher.

Despite this overarching focus, MTEs also reported attempting to provide teachers with agency and ownership of the project in their own classroom. Others noted that giving teachers agency in the project, empowered them to make a change in their classrooms. This strengthened the fit between MTE

and cluster/school strengthening engagement of teachers and potentially students. This approach, "gave the teachers some agency and ownership that worked well." [Molly]

Mathematics teacher educator perspectives of teacher needs

When looking at the teachers' practices MTEs consistently reported that teachers required practical support that could be directly applied in their classrooms.

> Teachers are really only concerned about what's happening in their classroom, and when they go to PD, they want something they can take away and implement in their classroom ... read the research literature if it's short, easy to interpret and relevant, but they want something that they can do in their classroom [Maisie]

Teachers sought professional learning from the MTE that offered specific examples to deal with the problems in their classrooms. Tara described, "Typically teachers want help with the problems that are in their classroom." Molly emphasised that as MTEs the support given needed to be "accessible and directly applicable knowledge." MTEs recognised that while teachers needed practical strategies, they also needed to be able to adapt and contextualise theoretical approaches to their classroom realities. Even if teachers have time and can access professional journals, they may find decoding, access to strategies, and translating the substance of journal articles to their classrooms challenging. Penny from the Department described this challenge as barriers: "I think there's a lot of barriers in the place between, here is what's written in a journal and here's what I'm doing in my classroom."

MTEs also spoke about that the teacher's focus was appropriately situated in the classroom because as Claire explained, "That's their job." Ava also described this as part of teachers' dedication to their students: "Teachers are time-poor and dedicated to their students so it is understandable that their focus is (rightly) on the best ways to solve the practical issues they face." Penny from the Department described this as, "They want to make it better for the kids that are in front of them right now."

MTEs recognised that teachers focus was pragmatic and student-centred, emphasising real-time problem-solving tailored to the specific content. They understood why teachers were seeking an immediate fix to their solutions. The work from this project was highly context-specific because "classrooms and schools are 'messy' environments and researchers need to recognise this fact." This highlighted a potential tension between the broader research goals of the MTE and the needs of the classroom teachers because teachers made immediate, context specific decisions based on the needs of their students in that moment. Actionable solutions needed to fit within the constraints of the classroom and school environment. In other cases, however, teachers just needed some support to begin.

> It might just take one little spark of an idea. But also, I think what's powerful …, if they realise that they have, are being given permission to exercise their own professional judgement. … there's a lot of frameworks and sort of, you know, accountability things, and I think they're losing confidence in, you know, exercising that judgement for themselves. [Molly]

Transformation

The different knowledges between mathematics teacher educators and teachers

Having established strong connections with champions within the cluster/schools, MTEs were then able to collaborate with teachers to clarify and address their specific problem of practice. Molly acknowledged that as critical friends their role was to bring the two types of knowledge together.

> I think a role as a critical friend, can be a way to bring those two kinds of knowledge together in a whole range of ways. …, one way is to provide teachers with articles that are published in professional journals. So even writing in a professional journal is a way of bridging between those two worlds, now bringing the world of research and presenting it in a way that can be used immediately by a teacher. [Molly]

Molly did not believe "as a researcher, you need to go and teach in the classroom, otherwise, you can never understand the particularities; or if you're a teacher, you need to become a researcher" but believed there were other ways to move between the two worlds.

> There are ways of sort of moving backwards and forwards between those worlds or finding a meeting place in the middle. And I think a lot of the work that, you know, that we do as education researchers is finding the middle, finding meeting places where you can have a meeting of minds with teachers that allows for mutual respect of each other's specialist knowledge. [Molly]

Molly believed that together MTEs and teachers can create new knowledge.

> We can kind of see into each other's minds a little bit, and, you know, and create, you know, some new kind of knowledge that sort of merges the theoretical and the practical. [Molly]

Claire described the process saying, "I tried to bridge the gap between the research and the theory, or between the research and the practice."

Barriers to Enacting Change

The final theme from the inductive analysis was barriers to change, those things that constrained opportunities for learning. MTEs faced multiple challenges in effecting long-term change, including unclear school/cluster foci, diverse teacher needs across year levels, limited release time, especially in remote schools, leadership and team member changes, institutional resistance, and teacher workload. Distance further hindered collaboration. Funding for the project was tied to the Queensland Department of Education School Improvement agenda and data had to be collected to measure any change, which Kerrie described as, "The education system, more generally, is looking for measurable outputs." Teachers tended to think about this in terms of student outcomes, which was improvement in their students' results in terms of A-E grades. Schools were, however, completing shorter inquiry cycles, and student outcomes data takes time to show improvement. Drawn by the large-scale quantitative studies where effect sizes were quoted and cited in the media, teachers believed that data needed to be quantitative. Ava described this as "a focus on quantitative data is the predominant paradigm used in universities, education systems, and government." MTES were therefore encouraging teachers to consider data about teachers' perceptions of changes in their practice or changes in student engagement, as well as encouraging teachers to collect qualitative data about the issues.

The MTEs identified several restrictions that limited the teachers' ability to enact long term change in their schools. Many constraints stemmed from systemic structure, with principals playing a critical role in driving project support. Limited time was a recurring barrier. This included release time to connect with the MTE. Kerrie explained this identifying that "state schools don't have much money, and they might not budget for these kinds of relationships with academic researchers." Teachers also needed time to trial and evaluate new strategies. Sometimes there was a lack of support from the school community and a lack of release time to trial and evaluate new strategies, which also influenced project sustainability. Tara described, "I worked with one motivated teacher who tried activities, but after four weeks had returned to original 'tried and true practices' due to school based pressures."

Even when initial enthusiasm was strong, some projects stalled: "Sometimes it's hard to get the schools to connect, like they start the project, and then it all gets too much, and they get lost," [Maisie] or stopped responding to emails. [Kerrie] Staffing changes further disrupted continuity:

> Some of them would get started and not finish. Someone would leave. That would be the end of it. I mean, you know, someone gets transferred, someone goes on maternity leave. If they didn't have their champion, they didn't really continue very well. ... They would revert back to what they were doing before, or they just get too busy and stop, stop meeting" [Maisie]

Some teachers in the cluster hesitated to seek help from the MTE, positing themselves as not worthy of the support.

> And this is something actually, I think, over the period of time has improved as well, is that they didn't want to reach out to their critical friend. They were really like, "Oh, we're just merely teachers, and we don't want to, we don't want to make take up the researchers' time," and so, you know, they didn't want to make contact because they didn't feel like they were almost deserving of it. [Participant name]

Departmental Perspectives of the Changes

The Departmental project leads reported that *M in STEM* showed improvements in school results:

> I think because it proved that clusters of schools working with leading academic researchers can move what's happening in student engagement and assessment results. So, it proved that, and I think that's a really, that's probably the most significant thing in my mind, from the *M and STEM* project. [Lilly]

Departmental project leads also reported that *M in STEM* Increased teachers' confidence and capability.

> I think the critical friends' role was really confidence building … the teachers that they feel valued, because there was a really hard dichotomy that has sort of been overcome when the teachers were first working with their critical friends. … I think this project was really great because it said to the teachers, no, you are deserving, and we're giving you this time, and we want you to make the most of those contacts. [Penny]

> Investing in the capability of that teacher, and then that teacher has the confidence and the capability to perhaps do it again by themselves. So, it's not something that we're just doing once off. It's something that that teacher is taking with them throughout their career and perhaps being able to replicate in their career and maybe even share with others. … this is what I did, and this is what I found, and give others, those the permission and the skills to do so just kind of going to lift the system [Penny]

Discussion

Within *M in STEM*, the MTEs were not conducting research or extended professional learning programs. As critical friends, MTEs' focus was on fostering reflective practice and posing challenging questions (Baskerville & Goldblatt, 2009; Costa & Kallick, 1993; MacPhail et al., 2021). A key tension the MTEs negotiated was the different orientations of teachers and researchers: teachers sought practical solutions to classroom challenges (Wiliam, 2003), while researchers pursued broader theoretical insights (Labaree, 2003). This boundary positioned MTEs as translators of research, making scholarly knowledge accessible to help teachers address problems of practice.

Identification

Identification (Akkerman & Bakker, 2011) occurred when without crossing boundaries MTEs recognised teachers' practices, were context-specific and reflected on how to situate change within the classroom practice. As Tara explained, "If you're going to really bring about changes in teachers' practice, you have to situate it [the new strategy/pedagogy …] in the classrooms," acknowledging the pressures teachers face. These understandings allowed MTEs to challenge assumptions and foster deeper pedagogical reflection, identified as central to critical friendship (Beveridge et al., 2018; Blake & Gibson, 2021; Hostetler et al., 2014).

Coordination

MTEs highlighted the importance of having a school champion who would drive the project, act as a conduit between the teachers and the MTE, and secure school leadership support. Consistent with Beveridge et. al. (2018), this champion was seen as vital for sustaining momentum to ensure longer-term change. Therefore, MTEs viewed supporting this person as an important part of their role.

For MTEs, establishing critical friendships required building rapport with school project leads and developing "authentic relationships," echoing Baskerville and Goldblatt's (2009) findings that trust is essential for safe collaboration. Without trust, teachers are unlikely to share reflections or engage with "provocative questions" (Costa & Kallick, 1993).

When reciprocal and authentic relationships were established, MTEs were able to go beyond merely translating research knowledge to actively brokering it, particularly when ideas were co-constructed with teachers. Tara highlighted the value of situating herself in the classroom to support

this process. Such *coordination* fosters collaboration and knowledge exchange, helping to make boundaries between teachers' practice and research more permeable (Akkerman & Bakker, 2011).

MTEs observed that schools often struggled to clearly articulate their problem of practice, or framed their concerns in terms of broad, overarching issues. In many cases, these initial problems were either too ambitions or insufficiently focused, requiring substantial refinement. This lack of clarity created ambiguity both in terms of the schools' intended goals and their understanding of the processes needed to achieve them. Through the collaboration and knowledge exchange of coordination (Akkerman & Bakker, 2011), MTEs supported the teachers to question their problem and consider any underlying assumptions, policy impacts, or cultural influences (Bacchi, 2012: Marshman et al., 2024; Fletcher & Wennergren, 2021) also giving MTEs insight and understandings into the classroom practices. Such challenges occur in professional learning initiatives, where participants define issues in terms of aspirational goals rather than practical starting points (Brehmer & Ryve, 2024; Marshman et al., 2024). A key role of the MTEs, therefore, was through collaboration and knowledge exchange, support schools to refine and reframe their problems of practice into focused, achievable directions, providing a foundation for meaningful change.

MTEs also described how teachers sometimes wanted to implement new pedagogies such as *Building Thinking Classrooms* (Liljedahl, 2020) to solve their problem of practice without considering what their problem was. MTEs then needed to support the teachers to go through a process such as Bacchi (2012) or Fletcher and Wennergren's (2021) to help teachers to reflect on their teaching practice and consider their assumptions and data rather than just focussing on the "shiny and bright" teaching strategy. The *coordination* (Akkerman & Bakker, 2011) led by MTEs made the boundary more permeable and helped MTEs and teachers learn from the collaboration and knowledge exchange.

Reflection

MTEs emphasised the importance of allowing "the teachers to work out what their problem is, rather than having the Department tell them." [Molly] Some teachers, however, resisted this approach preferring the MTE to just tell them how to "fix" their problem of practice. As Troy observed, "Time poor teachers just wanted to be told which technique is best for their classroom," and Lilly from the Department noted that some teachers wanted to be told what to do rather than engage in reflective practice (Timperley, 2024). In their role as critical friends, MTEs did not define the problem for teachers; instead, they posed questions to provoke reflection. Being unfamiliar with the school context, MTEs could not prescribe the problem themselves but could mentor the teachers thereby providing support in their context (Kitchen, 2025; Munson, 2025). MTEs also wanted to empower the teachers so that they could identify their problems in the future, building their professional identity.

Opportunities for *reflection* sometimes arose when teachers and MTEs could view each other's practices from the other's perspective. For example, Kerrie modelled an inquiry mathematics lesson, experiencing the school context with students who were unfamiliar with both her and inquiry-based learning. The teachers had an opportunity to observe Kerrie's research-based understanding of inquiry teaching.

At other times teachers needed only a "spark of an idea" and "permission to exercise their own professional judgement" as Molly explained, because they were "losing confidence in … exercising that judgement for themselves" due to the media and political blaming (e.g., Hunter et al., 2025). Another instance involved providing teachers with a blank senior secondary *Approach to Problem Solving and Modelling* template and inviting them to map their existing junior secondary processes, including their school pedagogical framework, to support students' transition to senior secondary mandated assessment (QCAA, 2019).

Transformation

The significance of *M in STEM* is the opportunity for transformation. Molly described how the critical friend role enabled "ways to bring [teachers' and MTEs'] the two kinds of knowledge (Heid et al., 2006;

Labaree, 2003; Schenke et al., 2017; Wiliam, 2003) together." Beyond writing for journals or presenting at conferences, she highlighted the transformative potential when MTEs and teachers collaboratively address issues, creating hybrid practices by "moving backwards and forwards between those worlds or finding a meeting place in the middle." This, she explained, as a "meeting of minds" that fostered mutual respect and generated new knowledge that "merges the theoretical and the practical."

Conclusion

In this article, we explored the learning of MTEs acting as critical friends for teachers in clusters of schools. This research is significant because MTEs rarely take on the critical friend role outside of formal research projects or leading professional learning programs. Findings indicated that the benefits extended beyond teachers to the MTEs themselves. They had opportunities to hear teachers' stories and observe classrooms in diverse contexts and developed insights into teaching practices. The role also enabled the generation of new or hybrid knowledge that bridged theory and practice at the boundary between classroom practice and educational research.

This study highlighted the value of MTEs working as critical friends outside the structures of research or formal professional learning. Acting in this role created space for reciprocal learning: teachers benefited from reflective dialogue and research-informed perspectives, while MTEs gained deeper insights into classroom realities across diverse contexts. At the boundary between classroom practice and education research, new hybrid forms of knowledge emerged that blended theory with practice.

The contribution of this paper is the extension of Akkerman and Bakker's (2011) learning-at-the boundary framework to illuminate how these MTEs navigate the boundary between classroom practice and educational research. MTEs gained contextual insight into classroom realities, while teachers developed reflective capacity and confidence. The mutual learning sometimes generated hybrid knowledge that merged research with classroom practice.

For teacher education, these findings point to the importance of integrating such boundary work into the preparation of future teachers. By engaging as critical friends, MTEs are better positioned to connect curriculum and pedagogy with the lived challenges of classroom practice. This not only enriches preservice teacher learning but also strengthens the ongoing dialogue between schools and universities, supporting more responsive and contextually grounded mathematics education.

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Competing interests

The authors declare there are no competing interests.

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