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# A zone theory analysis of identity formation in mathematics teacher educators

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*Researchers in mathematics teacher education are beginning to investigate the nature and development of mathematics teacher educator (MTE) expertise. Consistent with our sociocultural perspective on learning, we conceptualise mathematics teacher educator learning as participation in social practices that develop professional identities. In this study we used Valsiner's zone theory to investigate identity formation in a pair of mathematics teacher educators – one a mathematician and the other a mathematics educator – who collaborated to develop new approaches to teacher education that integrate content and pedagogy. Analysis of interviews with the MTEs traced their identity trajectories from past to present to possible futures, highlighting their capacity for individual agency in changing their environment or seeking out professional learning opportunities.*

*Keywords: Mathematics teacher educators, identity, Valsiner's zone theory.*

## Introduction

Researchers in the field of mathematics teacher education are becoming interested in how mathematics teacher educators (MTEs) themselves learn and develop (e.g., Beswick, Chapman, Goos, & Zaslasky, 2015; Chapman, 2008). The nature of MTE expertise has most often been conceptualised in terms of content and pedagogical knowledge and their interaction (e.g., Chick & Beswick, 2018; Zazkis & Zazkis, 2011), while the process of MTE development has been explained through reflective self-studies tracing growth through practice (e.g., Tzur, 2001). Our research takes a different approach, drawing on sociocultural theories of mathematics teacher development (Lerman, 2001) to propose that MTE learning is better understood in the context of social and cultural experiences that develop their professional *identities*. We view identity as a performative process of *becoming* that addresses social interactions and institutional contexts, while acknowledging that an individual's knowledge, beliefs, and attitudes can influence their identity enactment. Our study contributes to the field by extending our previous investigations of mathematics teacher identity (Bennison, 2015; Goos, 2013) to examine identity formation in mathematics teacher educators – both mathematicians and mathematics educators who teach in initial teacher education programs.

In Australia, as in many other countries, secondary initial teacher education programs are structured so that future teachers of mathematics learn the content they will teach by taking courses taught by mathematicians in the university's mathematics department, and then quite separately they learn how to teach this content by taking content-specific pedagogy courses within the university's education department. Such arrangements offer few opportunities to interweave content and pedagogy in order to develop mathematical knowledge for teaching (see Cooper & Zaslavsky, 2017, for an example of co-teaching). Integration of content and pedagogy was the aim of the study

we report on here – the *Inspiring Mathematics and Science in Teacher Education* (IMSITE) project – which deliberately fostered collaboration between mathematicians and mathematics educators in teacher education programs. The research question that gives focus to this paper is: How does interdisciplinary collaboration between mathematicians and mathematics educators shape their identities as MTEs?

## **Theoretical framework**

Our previous research on mathematics teacher identity adapted Valsiner's (1997) zone theory of child development to study interactions between teachers and their professional environments. In this paper we elaborate on Goos's (2014) mathematics teacher zone theory framework and draw on other research on MTE development to consider influences on MTEs as learners.

Valsiner (1997) extended Vygotsky's concept of the zone of proximal development (ZPD) to incorporate the social setting and the goals and actions of human participants. Valsiner redefined the ZPD as a set of emerging possibilities for development that arise when individuals negotiate their relationships with the learning environment and the people in this environment. Thus for MTEs, the ZPD represents possibilities for development of new kinds of knowledge, beliefs, and practices related to preparing future teachers (Chick & Beswick, 2018; Cooper & Zaslavsky, 2017).

Valsiner (1997) introduced two additional zones to explain human development. The first is the zone of free movement (ZFM), representing environmental constraints that may either hinder or enable access to particular areas or resources or ways of acting with resources. For MTEs, constraints might include their perceptions of the knowledge and motivation of teacher education students; the structure of teacher education programs (e.g., extent of connection between courses on mathematics, general pedagogy, mathematics teaching methods); and university organisational structures and cultures that influence timetabling, allocation of resources, and norms of what counts as "good teaching". The second new zone is the zone of promoted action (ZPA), representing the means by which an individual's actions are promoted. For MTEs, the ZPA could represent teacher education approaches promoted via reflection on their practice, their research with teachers, participation in formal professional development or informal interaction with colleagues (Chapman, 2008; Tzur, 2001).

The ZFM and ZPA are dynamic and inter-related and form a ZFM/ZPA complex that directs development along a set of possible pathways. However, individuals still have a degree of agency in changing the environment and their relationships with people in order to achieve their emerging goals. Thus identity is shaped, but not fully determined, by participation in social practices. The possibility of exercising agency within a structured social system is key to understanding identity in terms of developmental trajectories that link past, present, and future (Wenger, 1998).

## **Research design and methods**

The IMSITE project was undertaken over three years in six Australian universities and involved a team of 23 university academics who were either education specialists (mathematics and science educators) or discipline specialists (mathematicians and scientists). Its purpose was to improve the quality of teacher education by encouraging collaboration between Faculties and Schools of

science, mathematics and education on course design and delivery. Within each university, these interdisciplinary teams developed and implemented approaches targeting recruitment and retention strategies that promote teaching careers to undergraduate mathematics and science students, innovative curriculum arrangements that combine content and pedagogy, and continuing professional learning that builds long-term relationships with teacher education graduates.

This paper is concerned with the collaboration between a mathematician (Leonard) and a mathematics educator (Joanne) at one of the participating universities. We selected this pair as the focus for the paper because a zone theory analysis of their interdisciplinary collaboration reveals interesting insights into the productive tensions that shape MTE identities.

Leonard and Joanne were interviewed together by the first author at the end of the first year of the IMSITE project, and separately by the second author midway through the project's third year. They were asked to describe their prior history of collaboration, the extent of collaboration between mathematicians and mathematics educators in their university, barriers to and enablers of such collaborations, and activities that they considered to be successful in bringing together mathematicians and mathematics educators. Interviews lasted for 20 to 40 minutes and were transcribed in full.

To analyse the interview transcripts we used the approach developed in our previous research with teachers to trace identity trajectories from past to present to possible future (Goos, 2013), which allowed us to capture the temporal character of identity as a process of becoming (Wenger, 1998). We began by annotating interview transcripts to identify responses that provided information about the MTEs' past, present, and future ZPDs, ZFM, and ZPA, which we interpreted in terms of the theoretical framework outlined above. We then constructed a table for each interview with columns for the ZPD, ZFM, and ZPA and rows for past, present, and future influences. The annotated interview excerpts linking the MTEs' responses to both zonal and temporal dimensions were then electronically copied and pasted into relevant table cells, and a single summary table was produced. We inspected the table horizontally, across columns, to identify alignments and misalignments between the zones within a given time period. We inspected the table vertically, across rows, to identify events that triggered a change in alignment between ZPD and ZFM/ZPA from past to present or that could anticipate a change from present to future. This analysis aims to reveal productive tensions arising from a misalignment within the zone system that led MTEs to change their environment or seek new learning opportunities. The findings are discussed in the next section and summarized in Table 1. Interview excerpts are labelled with the relevant analytical category (ZPD, ZFM, ZPA) to illustrate the relationship between data and theory.

## **Findings**

The analysis begins in the temporal dimension of the *past*, and looks across the zonal dimensions of the ZPD, ZFM, and ZPA. Because the two academics had not yet begun to collaborate their identity trajectories are analysed separately here. Leonard was an applied mathematician working in the School of Mathematics and Statistics. He held a PhD in physics and also a Diploma in Education (an initial teacher education qualification for secondary school teachers) that he completed several years ago to better understand how teachers were prepared. Joanne was an experienced teacher of

secondary school mathematics with a PhD in mathematics education, who worked in the School of Education in a different Faculty from Leonard. Leonard taught large undergraduate mathematics classes with students from different degree programs, while Joanne taught mathematics pedagogy subjects to future secondary school teachers: thus both MTEs had well-developed mathematics content knowledge and pedagogical knowledge appropriate to their teaching assignments. Before the IMSITE project started they had met each other in various professional contexts. For example, Joanne had been President of the national mathematics teacher association and Leonard was involved in a mathematical enrichment program for secondary school students. Their *past ZPDs*, before joining the IMSITE project, therefore offered possibilities for development of shared knowledge and collaborative teacher education practices.

However, both MTEs reported barriers to collaboration in the form of institutional structures and cultures that defined their zones of free movement. The structure of the initial teacher education programs at this university created disciplinary “silos” that separated content from pedagogy: there was no coordination between the School of Education and the School of Mathematics and Statistics when it came to preparing future teachers. Leonard also claimed that the mathematics department was not interested in educational research.

Leonard: Educational research is always viewed as a kind of second tier research activity compared to discipline research, and compared to, say, industrial linkage research. (Interview 2; ZFM)

At the same time, Joanne found it difficult to raise the visibility of mathematics education in the university, and even within her own School and Faculty.

With respect to the zones of promoted action experienced in the past, Leonard reported having been positively influenced by two mathematician colleagues whose research had been in mathematics pedagogy. Because pedagogical research was not considered a mainstream activity in his discipline, “meeting the right human beings at the right points in time” (Interview 2; ZPA) was important for his development. He was encouraged by these colleagues to attend mathematics education conferences, where he was able to spend more time with Joanne, a regular participant. For Joanne, conferences, research with teachers and reflection on her own teacher education practice were key elements of her ZPA as a MTE.

Summarising *past* zone configurations: Leonard’s and Joanne’s MTE identities developed along mostly separate trajectories. Leonard’s past ZFM did not allow or value his development as a MTE because of established cultural norms in his department. However, he did not see this as a serious barrier.

Leonard: Given that I actually love the educational side of things, it wasn’t a problem for me. (Interview 2; ZPD)

Leonard’s past zone configuration was characterised by productive tension between his desired direction for development (part of his ZPD) and the university’s ZFM/ZPA complex, which did not seem to allow, and did not promote, a trajectory towards pedagogical research. He had attempted to

resolve this tension by seeking out an external ZPA in the form of mathematics education conferences. No such tensions were evident within Joanne’s past zone configuration.

We move now to the temporal dimension of the *present*, encompassing the IMSITE project and the collaboration between Joanne and Leonard. Thus the unit of analysis is now the pair of academics. At the time the IMSITE project began, Leonard said that his position as a relatively senior academic made it possible for him to pursue educational research collaborations that might pose a career risk for younger mathematics academics. Yet he admitted not fully understanding the disciplinary norms of educational research.

Leonard: I don’t really know how it works inside an education department – each kind of discipline is like a different country with its own rules and social norms. (Interview 2; ZFM)

	ZPD	ZFM	ZPA
Past	<p>Joanne:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Experienced secondary school mathematics teacher</li> <li><input type="checkbox"/> PhD in mathematics education</li> </ul> <p>Leonard:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Applied mathematician with secondary mathematics teaching qualifications</li> <li><input type="checkbox"/> Interested in teacher education</li> </ul> <p style="text-align: center;"><b>Leonard</b></p> <p style="text-align: center;">TENSION: Interest in education discouraged by institutional structures and cultures.</p>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Teacher education programs separate content (taught in School of Mathematics and Statistics) from pedagogy (taught in School of Education)</li> <li><input type="checkbox"/> School of Mathematics and Statistics indifferent to educational research</li> <li><input type="checkbox"/> School/Faculty of Education indifferent to mathematics education</li> </ul>	<p>Joanne:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Research with teachers</li> <li><input type="checkbox"/> Reflection on MTE practice</li> <li><input type="checkbox"/> Conferences</li> </ul> <p>Leonard:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> University mathematicians who conducted pedagogical research</li> </ul> <p><b>Leonard seeks external ZPA:</b></p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Attended mathematics education research conferences</li> </ul>
Present (IMSITE project)	<ul style="list-style-type: none"> <li><input type="checkbox"/> Both academics have credibility in mathematics and education communities</li> </ul> <p style="text-align: center;">TENSION: Interest in collaboration discouraged by institutional structures and cultures.</p>	<ul style="list-style-type: none"> <li><input type="checkbox"/> Perceptions of students (risk of attrition)</li> </ul> <p><b>Change the ZFM :</b></p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Social networking</li> <li><input type="checkbox"/> Tutorial timetabling</li> <li><input type="checkbox"/> Alumni conference</li> </ul>	<p>IMSITE project:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Promotes interdisciplinary collaboration</li> <li><input type="checkbox"/> Provides funding, time, resources</li> </ul>
Future	<p>TENSION: Maintaining MTE identity trajectory after project funding ends</p>		

**Table 1: Zone theory analysis of Leonard's and Joanne's MTE identity trajectory**

Joanne described a parallel experience where she worked hard to establish her academic credibility with the mathematicians she encountered in her role as President of the national mathematics teacher association. Thus at the start of the IMSITE project Leonard and Joanne were developing the kinds of knowledge, beliefs, and goals that would be encouraged by the project – that is, their emerging *present ZPDs* were conducive to interdisciplinary collaboration.

Nevertheless, neither Leonard nor Joanne believed that institutional factors involving, for example, teacher education program structures, academic workloads and budgets, could be overcome, even though IMSITE participants in other universities had managed to do so.

Joanne: I dismissed that idea fairly early on, even though I heard them [other IMSITE participants] talking about it. I couldn't see how it would work in my context. (Interview 2; ZFM)

Despite these difficulties, another element of Leonard's and Joanne's zone of free movement, related to their joint perception of the students they taught, gave rise to a further productive tension between their interest in collaborating and the barriers that stood in their way. Leonard taught mathematics courses and Joanne mathematics pedagogy courses in a 5-year Bachelor of Science/Bachelor of Education degree. In this program students took mathematics content subjects in the first two years, and did not experience mathematics pedagogy subjects until the third year, by which time many had dropped out of the program. This was a common program structure in Australian universities, with mathematics and mathematics education academics based in different Schools and teaching into the program but seldom interacting with, or even knowing, each other. Joanne recounted a crucial development that occurred when the IMSITE project brought her into closer contact with Leonard and they realised they were teaching the same students.

Joanne: I said to you, you know what? You teach the students maths and I teach them education. We should at least be sharing what we know about the students; starting to compare, contrast, talk about issues, like retention. We started talking about the fact that we would lose some of them. (Interview 1; ZFM)

Accepting what they could not alter about their institutional context (ZFM), Leonard and Joanne set about making small changes to build a sense of community and collective identity as future mathematics teachers amongst their students. To do so they developed three initiatives. The first involved social networking events that brought together beginning students who were studying mathematics, but not yet any education subjects, in the first year of their degree, and later years students who were studying mathematics pedagogy and had been on school placements. Leonard led the second initiative, which rearranged tutorials in his large first year mathematics subject so that they were timetabled and streamed to allocate all future teachers to the same tutorial class, thus helping them to identify with peers who were aspiring to a teaching career. The final initiative, organised by Joanne, was an annual mathematics education alumni conference that connected her current students with recent graduates, experienced secondary school mathematics teachers, mathematicians, and mathematics educators.

Each of these initiatives required some modification of the institutional ZFM (e.g., altering the tutorial timetable and allocation of tutors and rooms; finding times and university venues for social networking events) to bring the institutional environment into alignment with the MTEs' trajectory of identity development. The initiatives were made possible by the IMSITE project, which offered a ZPA that promoted collaboration and provided the necessary resources (e.g., funding for a project officer). The project supported the growing academic credibility of mathematicians who were developing a non-traditional identity in educational research.

Leonard: The impact of the project is measured in a more tangible way than just counting up the number of publications and citations. So I'm very happy that I'm part of a project that's got visible positive tangible impacts. (Interview 2; ZPD)

Summarising *present* zone configurations: the IMSITE project appears to have created a modified ZFM/ZPA complex for Leonard and Joanne that offered possibilities for these MTEs to develop new knowledge and practices for teacher education, thereby expanding their ZPDs. To the extent to which this occurred, we could say that the project developed their identities as MTEs, which now seem to be on interconnected trajectories.

Anticipating the *future* zone configurations of these MTEs raises the question of sustainability once IMSITE project funding ended. While both Leonard and Joanne were comfortable with being recognised as "champions" of a collaborative approach between their disciplines, they wished to share their experience with other mathematics educators and mathematicians, both within and outside their own university, so that their ideas could be taken up and adapted to different contexts. There was a sense, then, that their future identity trajectories would be oriented towards seeking further opportunities for collaboration.

## Discussion

In this paper we have begun to explore how interdisciplinary collaboration between mathematicians and mathematics educators can shape their identities as MTEs. Using the theoretical lens provided by Valsiner's (1997) zone theory, we have shown how individuals can exercise agency by changing their professional environment or at least their interpretation of the constraints it imposes (zone of free movement), as well as seeking out opportunities for professional learning outside their immediate environment (zone of promoted action). In addition, incorporating the idea of *productive tensions* into zone theory creates a theory of goal-directed change that can be used to understand MTEs' identity development. For example, Leonard's and Joanne's new goal of cohort building in the teacher education program motivated them to work around institutional constraints to connect mathematics content with mathematics pedagogy. We would also highlight that individuals can experience multiple and fluid identities because of their membership of different communities: Leonard and Joanne saw themselves as mathematics teacher educators who were crossing boundaries between their respective disciplines. The ways in which MTEs negotiate multiple identities, and the extent to which they can inspire others to cross disciplinary boundaries while preparing future teachers, deserves further investigation to enhance our understanding of their professional learning and development. Boundary crossing and identity formation of MTEs also



needs to be studied in other cultural contexts that present different, or fewer, challenges to interdisciplinary collaboration.

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