Sociocultural Perspectives on the Learning and Development of Mathematics Teachers and Teacher-Educator-Researchers

Merrilyn Goos, The University of Queensland, m.goos@uq.edu.au

In this report I explore what we can learn from research that takes a sociocultural perspective on conceptualising "learning to teach". The first part of the report refers to selected studies of pre-service teacher education, the transition from prospective to beginning teacher, and professional development programs to illustrate what we might learn from the various sociocultural orientations employed. The second part further develops one sociocultural approach – an application of Valsiner's (1997) zone theory, and illustrates its use in my own research involving prospective and beginning mathematics teachers. The third part of the report examines, from a sociocultural perspective, what it means to "learn" from research in teacher education, leading to a proposal that zone theory might offer a sociocultural framework for understanding the work of mathematics teacher-educator-researchers.

Keywords
Sociocultural theories; mathematics teacher education; development of mathematics teacher educators.

The ideas presented in this report have developed from many years of my own research using sociocultural theories to investigate students' mathematics learning in secondary school classrooms and, more recently, the learning and development of mathematics teachers. In this report I look to extend these ideas to help me understand the learning of mathematics teacher educators who are also mathematics education researchers.

There is growing interest in theories that view teachers' learning as a form of participation in social and cultural practices rather than as an internal mental process. Recent reviews of research in mathematics teacher education have noted increasing attention to the social, cultural and institutional dimensions of teachers' learning as well as attempts to integrate social and individual levels of analysis (da Ponte & Chapman, 2006; Lerman, 2001; Llinares & Krainer, 2006). To explain what I mean by sociocultural approaches to mathematics teaching and learning I take the words of Stephen Lerman (1996), who defined such approaches as involving "frameworks which build on the notion that *the individual's cognition originates in social interactions* (Harré & Gillett, 1994) and therefore the role of culture, motives, values, and social and discursive practices are central, not secondary" (p. 4, emphasis added).

The report considers the following questions:

1. What can we learn from sociocultural research on learning to teach mathematics?
2. How might this research provide a framework for theorising the role of mathematics teacher-educator-researchers?

In the first part of the report I briefly survey the sociocultural landscape in mathematics teacher education by referring to representative studies that use different sociocultural approaches. In the second part I elaborate on one sociocultural approach – an application of Valsiner's (1997) zone theory, and illustrate its use in my own research involving prospective and beginning mathematics teachers. The third part of the report considers what we can learn from mathematics teacher education research using Valsiner's zone theory. The final part develops a proposal that zone theory might offer a sociocultural framework for understanding the role of mathematics teacher-educator-researchers.

1. THE SOCIOCULTURAL LANDSCAPE IN MATHEMATICS TEACHER EDUCATION

Sociocultural perspectives on learning and development grew from the work of Vygotsky in the early 20th century. Vygotsky introduced the now familiar concept of the Zone of Proximal Development (ZPD) to explain how an individual's cognition originates in social interaction. He proposed that the ZPD is created when a child's interaction with an adult or more capable peer awakens mental functions that have not yet matured and thus lie in the region between actual and potential developmental levels.

Recent socioculturally oriented research on teachers' learning has drawn on two perspectives: a *discourse* perspective and a *practice* perspective (cf Forman, 2003). The discourse perspective focuses on the dynamics of mathematical communication in classrooms, an approach exemplified by research undertaken by Blanton, Westbrook and Carter (2005). Their study examined how a prospective teacher's classroom discourse changed as her perception of teacher and student roles shifted from teacher as teller to student as mathematical participant. This change was no accident; it was deliberately planned by the university practicum supervisor (Blanton) in the conversations she had with the prospective teacher about classroom interactions she had observed and what this revealed about how students learned mathematics. Blanton calls this a "pedagogy of supervision", which she claims opens up a ZPD that can challenge a prospective teacher's models of teaching in the context of actual practice.

The practice perspective links classroom and professional activity structures with learning and identity. Situative and community of practice approaches typify this perspective (e.g., see Graven, 2004; Greeno, 2003; Lave & Wenger, 1991; Wenger, 1998). Peressini, Borko, Romagnano, Knuth, and Willis (2004) adapted a situative perspective on learning to develop a conceptual framework for learning to teach secondary mathematics, focusing particularly on teacher learning within multiple contexts such as university mathematics and teacher education courses, practicum experiences, and schools of employment. They noted apparent inconsistencies between the ways teachers taught in different contexts; for example, one teacher used reform-based approaches during the practicum but more traditional approaches during her first year of full-time teaching after graduation. These are not unusual or surprising observations, but Peressini et al. concluded that the inconsistencies were responses

to the different affordances and constraints of the different contexts, and hence teachers' knowledge-in-practice varies with participation in different contexts. This research is useful because it helps us understand how context makes a difference to the development of mathematics teachers and their professional identities.

Krainer has noted that teacher educators have the dual roles of "intervening and investigating … of improving and understanding" (Adler, Ball, Krainer, Lin, & Novotna, 2005, p. 371). Sociocultural studies such as those summarised above help us *understand* how teachers learn from their experiences in different contexts. But perhaps sociocultural perspectives have been used less effectively to guide research on *intervening* to improve teachers' opportunities to learn. This has left the role of the teacher educator largely untheorised. I argue that a more elaborated sociocultural theory of teaching is needed to complement existing sociocultural language and concepts used to describe learning in a community of practice or in the ZPD. My approach is based on an adaptation of Valsiner's (1997) zone theory of child development, which is outlined below.

2. VALSINER'S ZONE THEORY

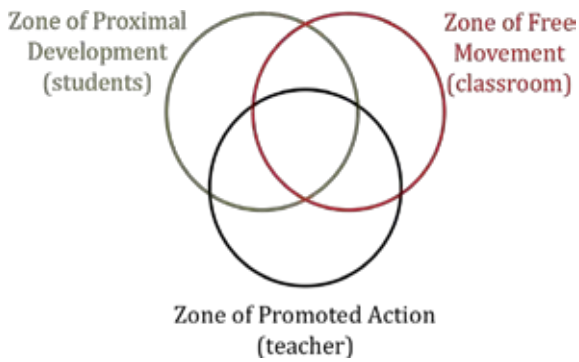
Valsiner (1997) sees the Zone of Proximal Development as a set of possibilities for development that come into being as individuals negotiate their relationship with the learning environment and the people in it. His theory proposes the existence of two additional zones, the Zone of Free Movement (ZFM) and the Zone of Promoted Action (ZPA). The ZFM structures an individual's access to different areas of the environment, the availability of different objects within an accessible area, and the ways the individual is permitted or enabled to act with accessible objects in accessible areas. The ZPA comprises activities, objects, or areas in the environment in respect of which the person's actions are promoted. The ZFM and ZPA are dynamic and inter-related, and are constantly being re-organised by adults in interactions with children.

2.1 *Adaptation of zone theory to mathematics education*

Mathematics education researchers have taken two contrasting approaches to applying this theory to teaching-learning interactions. The first defines the zones from the perspective of the teacher-as-teacher, with the ZPD "belonging" to the students as it is they who are learning. A teacher's instructional choices

about what to promote and what to allow in the classroom establish a ZFM/ZPA complex that characterises the learning opportunities experienced by students. One possible zone configuration is represented in Figure 1; others can be imagined if overlap between zones is allowed to change. This representation implies that learning takes place at the intersection of the three zones.

Figure 1. A possible zone configuration (teacher-as-teacher)



This teacher-as-teacher version of zone theory is useful for explaining apparent contradictions between the types of learning that teachers claim to promote and the learning environment they actually allow students to experience.

My own research has taken a different approach because I have applied Valsiner's theory to teacher learning and development (Galbraith & Goos, 2003; Goos, 2005a, 2005b, 2009). Here, all zones are defined from the perspective of the teacher-as-learner. When I consider how teachers learn, I view the teacher's ZPD as a set of possibilities for their development that are influenced by their knowledge and beliefs, including their disciplinary knowledge, pedagogical content knowledge, and beliefs about their discipline and how it is best taught and learned. The ZFM can then be interpreted as constraints within the teacher's professional context such as students (e.g., behaviour, socio-economic background, motivation, perceived abilities), access to resources and teaching materials, curriculum and assessment requirements, organisational structures (e.g., timetabling, room allocation, grouping of students, subject offerings) and organisational cultures (e.g., support for collaborative planning and participation in professional development). While the ZFM suggests which teaching actions are *allowed*, the ZPA represents teaching approaches that might be spe-

cifically *promoted* by pre-service teacher education, formal professional development activities, or informal interaction with colleagues in the school setting. For learning to occur, the ZPA must engage with the individual's possibilities for development (ZPD) and must promote actions that the individual believes to be feasible within a given ZFM. It is significant that prospective teachers develop under the influence of two ZPAs, one provided by the university program and the other by the supervising teacher(s) in the practicum school, which do not necessarily coincide. A possible zone configuration for teacher-as-learner is represented in Figure 2.

Figure 2. A possible zone configuration (teacher-as-learner)

2.2 *Application of zone theory: The case of Adam*

I illustrate the application of the teacher-as-learner version of zone theory by referring to a case study of one of my own students, whom I will call "Adam" (a pseudonym). Adam was a participant in a three longitudinal study in which I followed successive cohorts of my teacher education students into their early years of teaching (Goos, 2005a, 2005b). I designed and taught the mathematics methods course so that students experienced regular and intensive use of graphics calculators, computer software, and Internet applications. Thus the course offered a teaching repertoire, or ZPA, that emphasised technology as a pedagogical resource.

I developed case studies of selected participants to capture developmental snapshots of their experience at three stages: (1) during their final practice teaching session, (2) towards the end of the first year of full-time teaching, and (3) in their second or subsequent years of teaching. I selected participants to sample practicum school settings that differed in terms of the Zone of Free

Movement (professional context) and Zone of Promoted Action (supervising teacher approaches) they offered. I visited them in their practicum schools and schools of employment for lesson observations, collection of teaching materials and audio taped interviews (see Goos, 2005a for details).

Data sourced from lesson observations, surveys, questionnaires, and interviews were categorised as representing elements of participants' ZPDs, ZFMs, and ZPAs. As the zones themselves are abstractions, this analytical process focused on the particular circumstances under which zones were "filled in" with new people, actions, places and meanings. This approach enabled me to explore how personal, contextual, and instructional factors came together to shape prospective and beginning teachers' pedagogical identities.

The school where Adam completed his practice teaching sessions had recently bought resources such as graphics calculators, data logging equipment, and software. Every mathematics classroom was equipped with computers connected to the Internet, a data projector, and a TV monitor for projecting graphics calculator screen output. A hire scheme provided calculators to all students in the final two years of secondary school, and there were also sufficient class sets of calculators for use by younger classes. Some of these changes had been made in response to new mathematics syllabuses that mandated the use of computers or graphics calculators in teaching and assessment programs. Thus the school and curriculum environment offered a Zone of Free Movement that seemed to afford the integration of technology into mathematics teaching.

Adam had previously worked as a software designer and was confident in using computers and the Internet. Although he had not used a graphics calculator before starting the teacher education course, he quickly became familiar with its capabilities and with the support of his supervising teacher began to incorporate this and other technologies into his mathematics lessons. At this stage Adam was still a little concerned that students might become dependent on the technology by "just punching things into the calculator and getting the answer straight away". However, he recognised that he may have formed this view because he had only seen other teachers use graphics calculators in class as a tool for saving time or for checking work done first by hand. In theoretical terms, then, the Zone of Promoted Action organised by the supervising teacher was consistent with the ZPA I offered in my university course and also with the ZPD that defined Adam's potential for development. Thus his zone configuration at this stage resembled that shown in Figure 2.

After graduation Adam was employed by the same school where he had completed his practicum. By this time, Adam had developed more sophisticated pedagogical knowledge about how to use technology to help students learn new concepts. For example, in a lesson about families of functions, I observed him follow the students' lead when they used their graphics calculators to explore different ways of transforming an absolute value function $y = |x|$, and he coaxed generalised findings out of the students using their own language and symbols. He described his approach to this lesson as follows:

> I had a rough plan and we kind of went all over the place because we found different things. But I think that's better anyway because they're using their calculators to help them learn.

One might expect Adam to experience a seamless transition from prospective to beginning teacher; yet I found this was not the case when I visited him near the end of his first year of teaching. By this time he had discovered that many of the other mathematics teachers were unenthusiastic about using technology and favoured teaching approaches that he claimed were based on their faulty belief that learning is linear and teacher-directed rather than richly connected and student-led. He described these beliefs and teaching approaches as follows:

> You do an example from a textbook, start at Question 1(a) and then off you go. And if you didn't get it – it's because you're dumb, it's not because I didn't explain it in a way that reached you.

Because he disagreed with this approach, Adam deliberately ignored the worksheet provided for the families of functions lesson by the teacher who coordinated this subject. The worksheet led students through a sequence of exercises where they were to construct tables of values, plot graphs by hand, and answer questions about the effects of each constant in turn. Only then was it suggested that students might use their graphics calculators to check their work. Conflicting pedagogical beliefs were a source of friction in the staffroom, and this was often played out in arguments where the teacher in question accused Adam of not teaching in the "right" way. Compared with his earlier experience as a prospective teacher, Adam now found himself in a more complex situation that required him to defend his instructional decisions while negotiating a

harmonious relationship with several colleagues who did not share his beliefs about learning. Adam explained:

> [Now I'm willing] to stand up and say "This is how I am comfortable teaching". I just walk away now because we've had it over and over and the kids are responding to the way I'm teaching them. So I'm going to keep going that way.

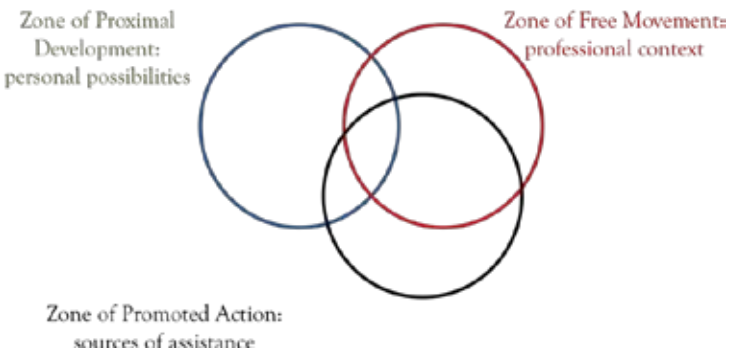
In terms of Valsiner's zone framework, Adam became aware of conflicts between his technology-rich ZFM, a ZPA that promoted, at best, fairly mundane uses of technology in his teaching, and his personal ZPD. This zone configuration is depicted in Figure 3. He responded by paying attention only to those aspects of the Mathematics Department's ZPA that were consistent with his own beliefs and goals (his ZPD) and also with the ZPA offered by the university teacher education course. This, it seemed to me, was how he was able to reconcile his pedagogical beliefs (a part of his ZPD) with the ZFM/ZPA complex within his teaching environment.

Figure 3. Adam's zone configuration for first year of teaching

The next year Adam was transferred to a different school that had fewer resources and a more difficult teaching environment. For example, there was only one class set of graphics calculators in the whole school, and most students were from low socio-economic backgrounds and could not afford to buy their own calculators. The learning environment was disruptive and poorly managed, and teachers felt frustrated at a perceived lack of support from the school's

leadership team. Adam found no colleagues in the mathematics department who shared his pedagogical beliefs or enthusiasm for using technology to help students learn. This school promoted teaching approaches (Zone of Promoted Action) that were consistent with the technology-poor environment (Zone of Free Movement), but not with Adam's beliefs and aspirations as a beginning teacher (his Zone of Proximal Development). I have represented his zone configuration at this school in Figure 4.

Figure 4. Adam's zone configuration for second year of teaching



3. WHAT CAN BE LEARNED FROM SOCIOCULTURAL RESEARCH USING VALSINER'S ZONE THEORY

Earlier I wrote that teacher education research aims to *understand* how teachers learn and to *intervene* so as to improve teachers' opportunities to learn. Let me take up these themes once more to consider how using zone theory has helped me to understand and intervene in teachers' learning and development.

In my work with prospective and beginning teachers, I now have a better understanding of the scope and limitations of my role as a mathematics teacher educator. For example, for many years I addressed separately some of the key factors known to influence technology integration. I had my students carry out an annual technology audit of their practicum schools so that on their return to the university they could report on and debate the significance of access to resources and technical support and the effect of curriculum and assessment requirements on technology usage. In these post-practicum sessions I also structured small group discussion tasks in which students compared their

own pedagogical beliefs about the role of technology in mathematics education with the technology-related practices demonstrated (or not) by their supervising teachers. These coursework activities have not changed in their classroom enactment. What has changed is the way I now integrate these and other elements of my course into a single zone-theoretical framework that suggests to me how and where I might intervene in the development of prospective and beginning teachers' identities as users of technology.

The question of intervention is more difficult, since I am but one of many influences on the learning and development of a beginning teacher. In Adam's case, I decided to try to change the way he viewed his context (ZFM) and the influence of other teachers (ZPA) in his second school to bring these zones into alignment with his ZPD. I encouraged him to view the single class set of graphics calculators as an opportunity he could exploit, because he was the only teacher who wanted to use them. I also supported him in increasing his involvement in the local mathematics teacher professional association where I hoped he would find a ZPA external to the school that would nurture his potential for further development. Through these quite modest interventions I aimed to help Adam change the way he interpreted his circumstances and gain a sense of agency in his own development.

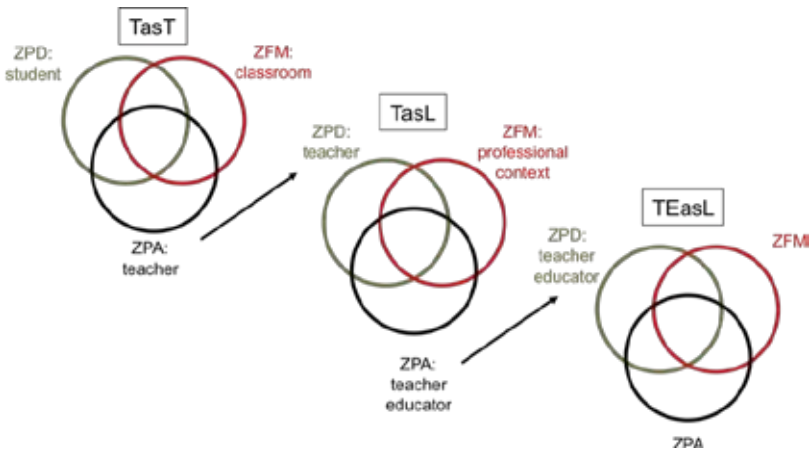
I have also used Valsiner's zone theory to better understand the issues facing experienced teachers who are unfamiliar with new teaching or assessment approaches or with new technologies. I use this theory to deliberately design professional development interventions that take into account not only teachers' knowledge and beliefs, but also with what they believe to be feasible in their professional contexts (e.g., see Goos, Dole & Makar, 2007). Again, my aim is to create a sense of agency in teachers by helping them see how they could view their circumstances differently and recognise elements of their professional context that they can change.

4. USING VALSINER'S ZONE THEORY TO UNDERSTAND THE ROLE OF MATHEMATICS TEACHER-EDUCATOR-RESEARCHERS

Zone theory is useful because it brings teaching, learning and context into the same discussion. The work outlined above shows it can be applied in two connected layers: (i) the teacher-as-teacher (TasT in Figure 5) creating classroom Zones of Free Movement and Promoted Action that structure student learning;

and (ii) the teacher-as-learner (TasL in Figure 5) negotiating the ZFM/ZPAs that structure their own professional learning. At the latter layer the teacher-educator-as-teacher comes into the picture, providing the ZPA. Now let us imagine a third layer, with teacher-educator-as-learner (TEasL in Figure 5). This theoretical extension of the zone model opens up the possibility for investigation of how mathematics teacher educators' knowledge and beliefs define a set of possibilities for their continuing development (ZPD), how their professional contexts constrain their actions (ZFM), and how they experience and benefit from different opportunities to learn (ZPA).

*Figure 5. Three lay*ers of application of zone theory: students, teachers, and teacher educators.



Let me sketch out what such an analysis might look like by applying zone theory to my own practice in the dual roles of researcher and teacher educator. As a researcher, my Zone of Proximal Development is influenced by my growing knowledge of theories and methodologies within my discipline (mathematics education) and the sub-fields in which I work (sociocultural approaches to mathematics learning and teaching). Disciplinary epistemologies and beliefs shape my ZPD as a teacher educator in much the same way. In many respects, the knowledge needed by mathematics teacher educators is similar to that required of mathematics teachers. According to Jaworski (2008), this includes:

> … knowledge of mathematics, pedagogy related to mathematics, mathematical didactics in transforming mathematics into activity for learners in classrooms, elements of educational systems in which teachers work including curriculum and assessment, and social systems and cultural settings with respect to which education is located (p. 1).

However, mathematics teacher educators also need to know how new teaching practices are learned and the pitfalls associated with promoting this learning. This includes knowledge of how to design teacher education activities, especially activities that connect prospective teachers' learning in the university and practicum contexts (Bergsten & Grevholm, 2008).

Mathematics teacher beliefs have been extensively researched, but the beliefs of mathematics teacher educators have received little attention in studies published to date. As an element of the ZPD, mathematics teacher educator beliefs about teaching and learning are likely to be influenced by theoretical studies and research (Bergsten & Grevholm, 2008), which suggests a need to identify the theoretical and philosophical positions (e.g., constructivist, sociocultural, post-structuralist) that inform mathematics teacher educators' practice.

As a researcher, my Zone of Free Movement is constrained by academic structures and cultures within and beyond my university. These include:

guidelines for career development, identifying activities that are formally recognised and rewarded; mechanisms for managing academic workloads that seek to balance teaching and research; government programs for assessing the quality and impact of university research; competitive research grant schemes; the process of peer review of articles submitted for publication in scholarly journals.

Closely inter-related with these elements of my professional context is the Zone of Promoted Action represented by my initial research training (doctoral studies, early experiences as a research assistant), participation in research conferences and other activities of educational research associations, and formal or informal mentoring by more experienced colleagues. This ZFM/ZPA complex helps shape possibilities for my development as a researcher (ZPD) by defining what is allowed and what is promoted. The learning opportunities that arise in this way are well charted and form part of the enculturation of novice researchers into academic life.

As a mathematics teacher educator, I must negotiate a different zone configuration. Here, my practice is constrained by a Zone of Free Movement comprising the following elements: student characteristics, such as their mathematical knowledge and their beliefs about mathematics teaching and learning; curriculum and assessment requirements that are governed by external teacher registration authorities as well as university course accreditation processes; limited access to technology resources in the university; reduction of the hours allocated to teaching methods courses in the pre-service teacher education program; difficulties in finding suitable practicum placements for prospective teachers; perceptions amongst colleagues that teacher education is low status work.

My ZPA as a teacher educator is less clearly defined in that it is difficult to identify people or activities that explicitly promote my development in this role, and thus difficult to describe the ZFM/ZPA complex that shapes my teacher education practice. Llinares and Krainer (2006) point out that the growth of mathematics teacher educators as learners is a new field of study, and research in this area has so far drawn on notions of reflective practice rather than sociocultural theories that take into account the settings in which practice develops. From a sociocultural perspective, I could say that my own research in teacher education acts as a ZPA that informs my practice as a mathematics teacher educator. My research using zone theory has also influenced how I work with prospective teachers – my own teacher education students – to help them analyse tensions between the learning experiences offered by the university course and the practicum. While this approach helps give coherence to my dual roles as researcher and teacher educator, further elaboration of Valsiner's zone theory is necessary to create a conceptual framework that better explains how mathematics teacher educators learn from research into teacher education.

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