Towards a Sociocultural Framework for Understanding the Work of Mathematics Teacher-Educator-Researchers

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Within the mathematics education research community there is growing interest in theories that view teachers' learning as a form of participation in social and cultural practices. This paper explores what we can learn from research that takes a sociocultural perspective on learning to teach, and how such research might provide a framework for understanding the work of mathematics teacher-educator-researchers. These questions are addressed with particular reference to Valsiner's zone theory, drawing on studies that take contrasting approaches to its application.

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). Lerman (1996) defined sociocultural approaches to mathematics teaching and learning 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). In the light of these theoretical developments, this paper considers two questions:

1. What can we learn from research that takes a sociocultural perspective on learning to teach mathematics?
2. How might socioculturally oriented research provide a framework for theorising the role of mathematics teacher educators who conduct research with prospective and practising teachers?

Following a brief review of some of the main themes in socioculturally oriented research in mathematics teacher education, these questions are addressed with particular reference to Valsiner's (1997) zone theory as a potentially useful framework.

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's theoretical approach refers to the social origins of higher mental functions, and the mediation of these functions by tools and signs, such as language, writing, systems for counting and calculating, algebraic symbol systems, diagrams, and so on. Vygotsky also introduced the concept of the Zone of Proximal Development (ZPD) to explain how social phenomena are transformed into psychological phenomena. Since the 1970s, education researchers have applied Vygotsky's ideas to the study of social interactions in classroom and institutional contexts. Contemporary sociocultural theory proposes that learning involves increasing participation in socially organised practices, and the notion of a situated learning in a community of practice composed of experts and novices (Lave & Wenger, 1991; Wenger, 1998) has been fruitfully applied to education settings.

Recent socioculturally oriented research on teachers' learning has drawn on both *discourse* and *practice* perspectives. The discourse perspective focuses on the dynamics of mathematical communication in classrooms, where interest centres on the role of semiotic mediation. Representative of this approach is research by Blanton, Berenson, and Norwood (2001a, 2001b), who used Vygotsky's concept of language as a mediating tool in an individual's development to investigate the discourse of prospective teachers and their university supervisors. The pedagogy of supervision that emerged from this research was claimed to open up a Zone of Proximal Development where the nexus between theory and practice could be explored.

The practice perspective in sociocultural research links activity structures with learning and identity. Here, the notion of learning in a community of practice has been invoked in research on teacher learning via professional collaboration (e.g., Graven, 2004) and in studies of the effects of participating in different communities on the development of beginning teachers. For example, Bohl and Van Zoest (2003) analysed discontinuities between a beginning teacher's facility in talking about reform based mathematics teaching during her teacher education program and her difficulty in translating her knowledge and beliefs into classroom practice.

Similarly, situative approaches have helped researchers understand how context makes a difference to the development of mathematics teachers and their professional identities (e.g., Peressini, Borko, Romagnano, Knuth, & Willis, 2004).

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). Studies of the type referred to above demonstrate that sociocultural research can enhance our *understanding* of how teachers learn from their experiences in different contexts, such as the university pre-service course, the practicum, and the school of employment. Sociocultural perspectives have perhaps been used less effectively to inform research on *improving* teachers' opportunities to learn, and this has left the role of the teacher educator largely untheorised. A more elaborated sociocultural theory of teaching is therefore needed to complement sociocultural language and concepts used to describe learning in a community of practice or in the ZPD. In this regard, some researchers have turned to Valsiner's (1997) zone theory – which re-interprets and extends Vygotsky's concept of the Zone of Proximal Development to incorporate the social setting and the goals and actions of participants – to develop stronger sociocultural frameworks for teacher education research. Use of zone theory in this research is illustrated in the next section.

Using Valsiner's Zone Theory to Understand and Improve Mathematics Teachers' Learning

In his theory of child development, Valsiner's (1997) sees the ZPD as a set of possibilities for development that are in the process of becoming actualised as individuals negotiate their relationship with the learning environment and the people in it. He then proposes 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. Valsiner explains that the ZFM and ZPA are dynamic and inter-related, and are constantly being re-organised by the adult in learning interactions with the child. Mathematics teacher educators have taken two contrasting approaches to applying this theory in their research, one of which defines the zones from the perspective of the teacher-as-teacher and the other from the perspective of the teacher-as-learner.

Approach #1: Focus on Teacher-as-Teacher

Applying Valsiner's ideas to classrooms, the teacher's instructional choices about what to promote and what to allow establish a ZFM/ZPA complex that characterises the learning opportunities experienced by students. This is the approach taken by Blanton, Westbrook, and Carter (2005), who used Valsiner's theory to interpret novice teachers' ZPDs. They compared the ZFM/ZPA complexes organised by three mathematics and science teachers in their respective classrooms as a means of revealing these teachers' understanding of student-centred inquiry and hence establishing the potential for development within their own ZPDs. Two of the teachers created the appearance of promoting discussion and reasoning when their teaching actions did not actually allow students to experience these, and the researchers explained this apparent contradiction by theorising the existence of an illusionary Zone of Promoted Action (IZ). For one of these teachers, the IZ appeared to signal a transitory state as she eventually changed her practice to both promote and allow student interaction. Thus existence of an IZ may indicate that inquiry based teaching practices are within the teacher's ZPD but have not yet been enacted in the way intended or perceived by that individual. Nevertheless, Blanton et al. note there is no guarantee that this transition will occur and they acknowledge the need for further research on external factors, such as the role of teacher educators, that contribute to teachers' development.

Approach #2: Focus on Teacher-as-Learner

My own approach to the use of zone theory (see Galbraith & Goos, 2003; Goos, 2005a, 2005b, 2005c) differs from that of Blanton and colleagues in that 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

(behaviour, socio-economic background, motivation, perceived abilities), access to resources and teaching materials, curriculum and assessment requirements, and organisational structures and cultures. While the ZFM suggests which teaching actions are *allowed*, the ZPA represents teaching approaches that might be specifically *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.

The vignettes in Figures 1 and 2 illustrate how I applied this theory to mathematics teacher learning in two studies involving prospective and practising teachers, both of which involved integration of digital technologies into secondary mathematics teaching (for details of these studies see Galbraith & Goos, 2003, and Goos, 2005b).

Pre-service teaching. Adam completed practice teaching in a school with substantial technology resources (graphics calculators, data logging equipment, software, internet). 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. *(ZFM afforded technology integration).* 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. *(ZPA organised by Supervising Teacher was consistent with ZPA I offered in my university course and also with Adam's ZPD defining his potential for development.)*

Beginning teaching. After graduation Adam was employed by the same school where he had completed his practicum. *(Same ZFM, ostensibly affording technology integration)* He now discovered many of the other mathematics teachers were unenthusiastic about using technology and favoured teaching approaches he claimed were based on their faulty belief that learning is linear and teacher-directed rather than richly connected and student-led. Conflicting pedagogical beliefs were a source of friction in the staffroom, and this was often played out in arguments where other teachers 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. *(Conflicts between technology-rich ZFM, school ZPA that promoted technology-poor teaching, and Adam's ZPD.)* He responded by paying attention only to those elements of the Mathematics Department's teaching culture *(school ZPA)* that were consistent with his own beliefs and goals *(his ZPD)* and also with what he had learned in the university teacher education course *(university ZPA)*. This was how he was able to reconcile his pedagogical beliefs *(a part of his ZPD)* with his teaching environment *(ZFM/ZPA complex).*

Figure 1. *From pre-service to beginning teaching: The case of Adam. (Goos, 2005b).*

Early professional development workshops. Lisa was an experienced teacher but a relative novice in the use of technology *(mixed ZPD: strong pedagogical content knowledge but not in relation to technology integration)*. As Head of her school's Mathematics Department she had considerable autonomy in obtaining desired resources and in managing curriculum and assessment programs *(ZFM afforded technology integration)*. She described the early professional development workshops she attended to learn how to use graphics calculators as "off-putting", because the emphasis was on procedural aspects of operating the calculators and the mathematics presented was too difficult for participants to engage meaningfully with the technology. *(early ZPA inconsistent with ZPD)* After several more workshops she felt confident enough to use graphics calculators in her teaching, but only as a replacement for pen and paper.

Research-based professional development program. Lisa's participation in a research-based professional development program was a turning point for her as it emphasised pedagogy rather than "pushing buttons" *(research-based ZPA consistent with her ZPD, i.e., her need to understand pedagogical rather than procedural aspects of using technology)*. Until this time she only saw graphics calculators as a tool to draw graphs and analyse statistics. Now she "started to see different ways of using it that I hadn't thought of before", such as in data collection and analysis, mathematical modelling, and collaborative group work. She began to see how technology could be used to build mathematical understanding rather than just to improve speed and accuracy of calculations.

Figure 2. *A professional development intervention: The case of Lisa. (Galbraith & Goos, 2003).*

What Can We Learn from Teacher Education Research Using Valsiner's Zone Theory?

The elaboration of Valsiner's zone theory outlined above is helpful for analysing relationships between teachers' pedagogical knowledge and beliefs and the teaching repertoire offered by courses for prospective teachers, practicum and initial professional experiences, and professional development programs in order to understand how they learn in multiple contexts. One such configuration is represented in Figure 3; others can be imagined if we allow the overlap between zones to change. This representation implies that learning takes place at the intersection of the three zones.

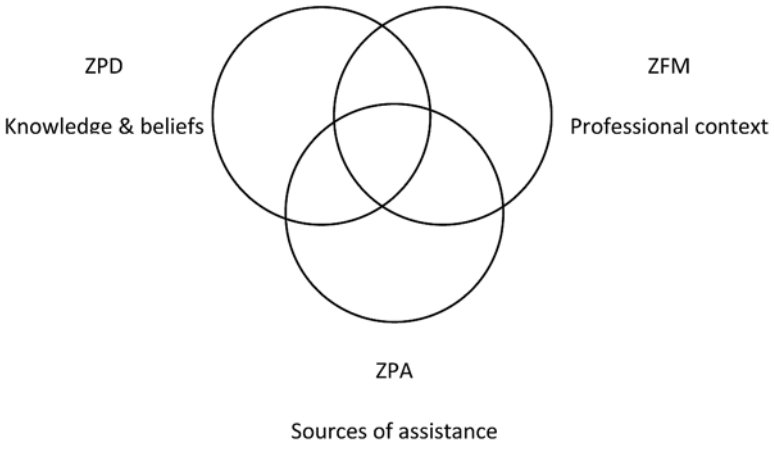

Figure 3. Representation of relationships between ZPD, ZFM, ZPA.

Analysis of Adam's case and the experiences of other prospective and beginning teachers who participated in this study gave me a better understanding of the scope and limitations of my role as a mathematics teacher educator as I pondered the question of how I could help novice teachers implement the technology enhanced

approaches I promoted in my teacher education course. For many years I dealt with this question by addressing separately some of the key factors known to influence technology integration. For example, 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 case of Lisa illuminated for me some of the issues facing experienced teachers who are unfamiliar with new technologies such as graphics calculators. While her ZFM presented few constraints, she had to search for professional development (ZPA) that would extend and challenge, rather than accommodate, her existing ideas about teaching with technology (her ZPD). As a result of this work with Lisa and other teachers I began to use Valsiner's zone theory to design professional development interventions that give careful attention to discovering the participating teachers' epistemological and pedagogical beliefs, understanding their institutional contexts, and identifying how all these factors interact to potentially influence their learning and development (see Goos, Dole, & Makar, in press). Only by analysing this initial zone configuration do I feel able to engage with their possibilities for development (ZPD) and promote actions they believe to be feasible in their school environments (ZFM).

From a broader perspective, zone theory could be used by teacher educators to improve teachers' opportunities to learn at three stages of development:

- Pre-service education: helping prospective teachers to analyse their practicum experiences (ZFM), the pedagogical models these offer (school ZPA), and how these experiences align with or contradict the knowledge gained in the university-based program (university ZPA);
- Transition to the early years of teaching: creating induction and mentoring programs that promote a sense of individual agency within the boundaries of the school environment (ZPD within ZFM);
- Professional development: designing professional learning programs for more experienced teachers (ZPA to stretch ZPD).

How Can Valsiner's Zone Theory Help Us Understand the Role of Mathematics Teacher-Educator-Researchers?

This paper has shown how Valsiner's zone theory brings teaching, learning, and context into the same discussion, and how the theory can be applied in two connected layers – to the teacher-as-teacher orchestrating classroom ZFM/ZPAs for students (Blanton, Westbrook, & Carter, 2005) as well as the teacher-as-learner negotiating the ZFM/ZPAs offered by the professional environment (Goos, 2005a). At the latter layer the teacher-educator-as-teacher comes on the scene, providing the ZPA. What if we imagine a third layer, with teacher-educator-as-learner? How does our professional context constrain our actions in culturally expected ways (ZFM), and what are our opportunities to learn (ZPA)? Could we describe a set of possibilities for our own development in the near future (ZPD)? In other words, how might zone theory help us analyse our own roles as mathematics teacher educators conducting research with prospective and practising teachers?

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 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 increasingly 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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