Beginning Teachers and Technology: Developing Identities as Teachers

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This paper reports on a study that investigated the pedagogical practices and beliefs of pre-service and beginning teachers in integrating technology into the teaching of secondary school mathematics. A case study documents how one teacher's modes of working with technology changed over time and across different school contexts, and identifies relationships between a range of personal and contextual factors that influenced the development of his identity as a teacher. This analysis views teachers' learning as increasing participation in sociocultural practices.

Much of the existing research on the role of technology in mathematics education has been concerned with effects on curriculum content or student learning (Penglase & Arnold, 1996). However, less attention has been given to the relationship between technology use and issues of pedagogy, in particular the impact on teachers' professional learning in the context of specific classroom and school environments. This paper reports on the preliminary stages of a study that aims to address this gap in current knowledge. The study is situated at the interface between pre-service education and initial professional experience of secondary mathematics teachers, in order to investigate the pedagogical practices and beliefs of beginning teachers who have graduated from a technology enriched teacher education program.

From a theoretical perspective, this research extends earlier work which applied sociocultural perspectives on learning to develop models of technology enriched mathematics learning (Goos, Galbraith, Renshaw, & Geiger, 2000), and models of mentoring in pre-service teacher education (Goos, 1999a). The aims of this preliminary study are to identify modes of working with technology adopted by pre-service and beginning teachers, and to explore the influence of a range of personal and contextual factors on the pedagogical identities they construct.

Sociocultural Perspectives on Teacher Learning and Development

Learning to Teach

Although research on mathematics teacher education has grown rapidly in the past 10 to 20 years, influential voices have argued that teacher education is an under-theorised field of inquiry, lacking coherent conceptual frameworks that address the complexity of individuals acting in social situations (e.g., Cooney, 1994; Lerman, 2001). Particularly relevant to the present study is research on teacher socialisation, the goal of which is to explain how teachers acquire the beliefs, values and attitudes of their professional culture. Studies of teacher socialisation from a functionalist perspective typically identify influences such as the beliefs that students bring to the pre-service course from their own schooling, and the classroom practices they observe and experience as novice teachers (Brown & Borko, 1992). Such approaches view teachers as being passively moulded by

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external forces to fit the existing culture of schools – thus producing the common explanation for why beginning teachers are unable to implement innovative approaches (e.g. those involving use of educational technologies) that they may have experienced during their pre-service courses (e.g., Loughran, Mitchell, Neale, & Toussaint, 2001). However, Lerman (2001) claims that the study of teacher beliefs, and of apparent mismatches between espoused and enacted beliefs, is often too static and decontextualised to adequately describe these (dis)connections between theory and practice. As an alternative, he points to the work of Vygotsky (1978) and followers in proposing that teachers' learning is better understood as increasing participation in sociocultural practices that develop their identities as teachers.

There are yet few studies that have applied sociocultural theories to teacher learning, particularly in pre-service teacher education. Some of these have adopted a neo-Vygotskian approach, extending the well known concept of the Zone of Proximal Development to additionally incorporate the social setting and the goals and actions of the participants (e.g., Blanton, Westbrook, & Carter, 2001; Goos, Evans & Galbraith, 1994). In a teacher education context, the ZPD can be thought of as the novice teacher's emerging skills that have not yet developed fully, but which are taking shape under the guidance of other people. However, this gap between present and potential ability is not the only factor influencing future development. Valsiner (1987) has described two additional zones of interaction, the Zone of Free Movement (ZFM) and Zone of Promoted Action (ZPA), that can account for the contextual constraints and affordances of the teaching environment and the teaching actions specifically promoted.

According to Valsiner (1987), the ZFM represents environmental constraints that limit freedom of action and thought. For pre-service or beginning teachers, elements of the ZFM might include:

1. their students, whose (perceived) abilities and behaviours may constrain teaching actions;
2. curriculum and assessment requirements, which influence choice of topics, teaching methods, and the time available to teach required content;
3. resources, in the form of teaching materials, computers or calculators, or specially equipped rooms, whose availability has a bearing on teachers' planning decisions;
4. the relationship between pre-service or beginning teacher and supervising teacher or more experienced colleagues, and the extent to which their beliefs about teaching and learning coincide.

Although these elements clearly have an external existence, teachers may also construct personal ZFMs within which constraints – or affordances – exist as a result of their interpretation of the external environment.

While the ZFM suggests which teaching actions are *possible*, the Zone of Promoted Action (ZPA) represents the efforts of a teacher educator, supervising teacher, or more experienced teaching colleague to *promote* particular teaching skills or approaches. It is important that the ZPA be within the novice teacher's ZFM, and is also consistent with their ZPD – that is, the actions promoted must be within the novice's reach if development of their identity as a teacher is to occur. Additionally, pre-service teachers develop under the influence of two ZPAs – one provided by their university program, the other by their supervising teacher(s) during the practicum – which do not necessarily coincide. Unlike functionalist approaches, this sociocultural model facilitates an analysis of teacher learning

and socialisation that considers the person-in-practice, and examines how identities develop as involvement in practice increases (Lerman, 2001).

Teaching with Technology

Research on technology use by mathematics teachers has identified a range of factors influencing uptake and implementation, including: previous experience in using technology; time and opportunities to learn (pre-service education, professional development); access to hardware (computers and calculators), software, and computer laboratories; availability of appropriate teaching materials; technical support; support from colleagues and school administration; knowledge of how to integrate technology into mathematics teaching; and beliefs about mathematics and how it is learned (Fine & Fleener, 1994; Manoucherhri, 1999; Simmt, 1997; Simonsen & Dick, 1997). In terms of the concepts introduced in the previous section, studies such as these have catalogued elements of a teacher's Zone of Free Movement without necessarily considering possible relationships between the setting, actions, and beliefs, and how these relationships might change over time or across different classroom or school contexts.

From a sociocultural perspective, technologies such as computers and graphics calculators can be viewed as cultural tools that not only re-organise cognitive processes but also transform classroom social practices. In an earlier study (Goos, Galbraith, Renshaw, & Geiger, 2000), metaphors were developed to describe how such technologies can provide a vehicle for incorporating new teaching roles. Teachers can see technology as a *master* if their knowledge and competence are limited to a narrow range of operations, especially in situations where external pressures force implementation. Technology is a *servant* if used by students or teachers as a fast, reliable replacement for pen and paper calculations – that is, in reproducing rather than transforming existing teaching and learning arrangements. However, when teachers develop an affinity for technology as a *partner*, there is potential for students to achieve more power over their own learning, for example, by using a screen projection unit interactively to construct a mathematical argument in whole class discussion. Technology becomes an *extension of self* when seamlessly incorporated into a teacher's pedagogical and mathematical repertoire, such as through the integration of a variety of technology resources into course planning and the everyday practices of the mathematics classroom. These categories elaborate different ways in which teachers may appropriate technology as a cultural tool, and also provide a means of tracing trajectories of professional growth as teachers construct new pedagogical identities.

The Study

Background

This study represents the preliminary stages of a three year project that spans the transition from pre-service to beginning teaching of secondary school mathematics. In the pilot phase reported here, participants comprised all Bachelor of Education students enrolled in the mathematics curriculum studies class of 2000 (n = 18) at The University of Queensland. The BEd program is available to undergraduates as a four year dual degree or to graduates as a single degree taken in four semesters over eighteen months. Students undertake mathematics curriculum studies as a single class group in a one year course that corresponds to the fourth year of the Dual Degree and the first two semesters of the

Graduate Entry program. All students complete two, seven week blocks of practice teaching during this year.

BEd mathematics curriculum students experience a technology-enriched pre-service course (taught by the author) that features regular and intensive use of graphics calculators, computer software, and internet applications (see Goos, 1999b). Integration of technology into mathematics education is emphasised through continuous personal access to a graphics calculator for the duration of the course (including the practicum), assignment tasks that ask students to prepare technology related classroom activities, and encouragement for students to contribute to the professional community through publication of resources they have produced and presentation of student workshops at professional association seminars and conferences. The course thus offers a teaching repertoire, or Zone of Promoted Action, that privileges technology as a pedagogical resource.

Research Design

The research design for this pilot study had two components: (a) a cohort study of pre-service students' practicum experiences in technology integration; and (b) individual case studies of selected students that allowed snapshots of experience to be captured at two developmental stages, during the second block of practice teaching (August 2000) and towards the end of the first year of full-time teaching (November 2001). For the cohort study all students completed a Technology Survey of their practicum schools to record information on the availability and accessibility of technology resources (computers and graphics calculators), and the frequency and mode of technology use during lessons they observed or taught, and in assessment tasks. Survey findings were discussed and compared in an audiotaped whole class interview when students returned from the first block of practice teaching.

Four students were also selected for individual case studies to represent a range of initial school placements (government vs independent schools, capital city vs regional location) and program formats (Dual Degree vs Graduate Entry). These students were visited in their schools during the second practicum session and again after graduation as described above. The school visits involved lesson observations, collection of teaching materials, and audiotaped interviews. Observations focused on teachers' modes of working with technology, using categories developed in an earlier study and described in the previous section of this paper. A Post-lesson Interview assisted participants to reflect on pedagogical beliefs that influenced lesson goals and methods (as in Goos, 1999a), while a more general Technology Interview sought perceptions of constraints and opportunities affecting technology integration, and the influence of technology on mathematics curricula, learning, teaching, and assessment. The purpose of these interviews was to gain insights into factors shaping the formation of beginning teachers' professional identities.

This paper draws on the Technology Survey, lesson observations, teaching materials, and interviews from one case study participant (Geoff) to compare his modes of working with technology over time and in different school settings, and to examine how changing relationships between his Zones of Proximal Development, Free Movement, and Promoted Action generated an environment for development of his identity as a teacher.

Geoff's Practice as a Pre-Service Teacher

Geoff's practicum placement was in a co-educational government school in a low SES Brisbane suburb. The student population of 430 was ethnically diverse, with many students having recently arrived in Australia on refugee visas. Geoff was assigned to teach a Year 10 Mathematics class and a Year 11 Numeracy class, the latter being the focus for observation and interview for the purposes of this study. Geoff explained that Numeracy was a low status, school based subject, regarded by students as "a repository for misbehaving students", or for "druggos and dropouts". Yet he was determined to challenge this perception by designing interesting activities that demonstrated how mathematics is used in real life situations. He commented that students' negative attitudes towards mathematics often come from "ingrained mathematical practices from Years 1 to Years 10 and Years 12 that maths is some kind of remote thing. It's some kind of island that you visit and then you go back to your other lessons". Geoff's goals for these students were concerned as much with building their self-respect and encouraging their engagement with their futures beyond school as with teaching mathematical content.

Geoff was an experienced computer user and spoke enthusiastically of his desire to integrate technology into his teaching, mentioning in particular the potential for technology to speed up calculations and "make things easier to understand because ... it's dynamic and not static". Nevertheless, after almost fourteen weeks of practice teaching, he had only had one opportunity to use technology in a mathematics lesson. This involved creating an internet research activity for the Numeracy class that required them to use the Australian Bureau of Statistics website to produce a fact sheet on a health issue of their choice, such as alcohol or drug use. The fact sheet was to include a graph (e.g. Excel chart) that compared how this health issue affected different age groups, genders, or countries.

Constraints and Affordances in Teaching with Technology

At the time of this study, mathematics syllabuses in Queensland only encouraged, rather than mandated, the use of technologies such as computers and graphics calculators. Geoff's school was poorly resourced in this area, with no graphics calculators and only two computer laboratories that were almost continually booked out to Information Technology or Business Studies classes. Geoff felt that teachers in this school did not regard mathematics as a subject worthy of computer use. In the Technology Survey of his school Geoff noted that no technology was used in any of the mathematics classes he had observed. He commented that the mathematics staff seemed to be generally uninterested in learning about technology and unconvinced of its benefits for mathematics learning, especially for low status mathematics subjects such as Numeracy. Each of these elements of Geoff's Zone of Free Movement could be interpreted as constraints that might limit his teaching actions. Furthermore, while Geoff's supervising teacher allowed him to take the initiative in planning and delivering Numeracy lessons, the Zone of Promoted Action offered by this supervision excluded technology, and thus was not well matched with the ZPD that defined the direction in which Geoff hoped his teaching would develop. In this respect, neither did the supervisory ZPA coincide with that offered by the pre-service course.

Despite these many hindrances, Geoff did design and implement a technology-based activity with his Numeracy class. In theoretical terms, he achieved this by re-interpreting aspects of his teaching environment, or ZFM, so as to *afford* at least some use of

technology in ways that were consistent with the actions promoted by the university course. First, he found there was little direct opposition towards introducing technology activities into the Numeracy class "because basically it's a class that nobody cares about". Also, he was aware of the general expectation within the practicum environment that student teachers would be adventurous in trying out new ideas, including those involving technology. Thus he was able to construct his practice as a pre-service teacher of low status mathematics students to further develop his emerging identity as a teacher for whom technology was an important pedagogical resource. However, at this stage his teaching experience had included technology only in the role of a *servant*, to facilitate his students' information searching or production of accurate graphs.

Geoff's Practice as a Beginning Teacher

After graduation Geoff found employment at an academically oriented, independent girls' school with an enrolment of over 1000 students. Geoff taught two senior secondary Mathematics classes, and also a Year 8 class which was observed during a visit to the school near the end of his first year of teaching. In the previous lesson with this class, Geoff had presented a graphing task that introduced students to use of a motion detector in conjunction with a graphics calculator and viewscreen. The aim of the activity was for individuals to walk towards, or away from, the motion detector so as to match a pre-selected distance-time graph displayed on the calculator screen. Students conducted "walking contests" within their working groups, followed by a hotly contested "walk off" to determine the most accurate walker in the class. In discussing his rationale for this task, Geoff referred to the motivational benefits of having students physically involved in creating a graph of their own movement, the capacity for the technology to provide instant feedback to walkers so they could adjust their movement to better match the target graph, and the thoughtful interaction this facilitated between walkers and observers. He also pointed out the mathematical skills required to make an accurate match, such as scale reading, estimation, and knowledge of the meaning of slope. At the beginning of the following (observed) lesson, Geoff reinforced these skills through a simulated graph matching activity, where a student volunteer "walked" the graph he had drawn on the whiteboard as he moved his pen along the x-axis to represent the passage of time. In these lessons, he worked with technology as a *partner* that entered into the mathematical practices and collective memory of the classroom.

Constraints and Affordances in Teaching with Technology

The teaching environment within this school contrasts significantly with that experienced by Geoff during his practicum. As a newly graduated teacher, Geoff came to an apparently well resourced school with an explicit policy of emphasising technology use across all subject areas. All students from Year 9 upwards were required to buy their own graphics calculator, and peripherals such as data loggers and viewscreens were readily available, as was school based professional development on the use of this equipment. Thus Geoff's Zone of Free Movement appeared to afford teaching actions consistent with his beliefs about mathematics learning and teaching, as expressed in his justification for the graph matching activity. Furthermore, the Zone of Promoted Action offered by his teaching colleagues seemed to be consistent with both his development as a teacher (i.e. his ZPD) and the ZPA offered by his pre-service course, in that new graduates teaching at the school

were actively supported in integrating technology into their practice. For example, as part of a move to include at least one technology-based assessment task per semester in every mathematics subject, at each year level, Geoff had designed a Year 8 assignment on tessellations that involved students in web-based research, and using Microsoft Paint to create their own tessellations. As Geoff commented, "I have basically been given a brief to go ahead and ... try whatever I like, and do anything I like with technology".

However, other, less obvious, elements of the school context constrained Geoff's practice in more subtle ways. For example, some classrooms were designated as technology centres and specially fitted with equipment such as computers, internet and intranet connections, and data projectors. However, the timetabling of classes into these special rooms was neither transparent nor flexible, with the result that some teachers and classes regularly allocated these rooms rarely used the available technology while others who wished to use these resources were unable to gain access. Apart from these classrooms the school had only three dedicated computer laboratories which, according to Geoff, were almost always fully booked to non-mathematics classes. These components of Geoff's ZFM tended to undermine his goal of infusing technology as a *partner* in assessment tasks as well as learning activities. In particular, his original plan to include oral presentations and computer demonstrations of the tessellation assignment mentioned above had to be modified when it proved impossible to arrange access to the specially equipped technology centres for all Year 8 classes.

At the end of his first year of teaching, Geoff was looking for further challenges in exploring what technology could do:

> I know what things the graphics calculator can do, and I have a pretty good knowledge of Excel, but really now that teachers know how to include this in their pedagogy, I suppose the emphasis would be now on getting the most out of it. Instead of just knowing what to do, how to really take this technology and explore it to its fullest extent and use all of the resources that [it] has to offer instead of taking bits and pieces that might be good. I suppose unlocking the potential ... of what this technology has to offer. [...] I have been sort of nominated by the Maths faculty to go out and delve into the world of Microsoft PowerPoint because I believe there is a lot more to PowerPoint than what meets the eye in terms of the teaching tool ... how you can use animations to explain mathematical concepts, how you can integrate the whole thing into [your teaching] and have it available on line for every teacher. PowerPoint is not just something you can put bullet points up on the screen with ... There is [no inservice] for teaching with PowerPoint because everyone just takes it for granted as a display [tool]. I might get myself a book or two on it and maybe try to do an inservice of my own and try to get my head around how useful it can be.

Here he maps out the landscape of his ZPD in a way that suggests he is moving towards using technology as an *extension of self*, and anticipates seeking out – or perhaps even generating – a ZPA that will further develop his identity as a teacher.

Discussion

This study addresses one of the major themes in current debates on educational reform – the need for teachers to become more effective, confident, and creative users of technology in their teaching – by examining how beginning teachers of secondary school mathematics integrate technologies such as computers, graphics calculators, and the internet into their practice. Rather than analysing teacher beliefs about technology and its role in mathematics education, and possible connections (or conflicts) between beliefs, the teaching repertoire offered by the pre-service course, and practicum experiences, the study applied sociocultural perspectives on learning to focus on beginning teachers' identities

and the settings in which those can change (as proposed by Lerman, 2001). A case study of one teacher's early professional experiences demonstrated how he developed that part of his pedagogical identity concerned with technology use, by negotiating changing relationships between his teaching environment, actions, and beliefs.

Clearly, it is not possible to explain Geoff's appropriation of technology as being determined solely by the material and human resources available to him in technology-poor and technology-rich school settings. Nor is it meaningful to describe his initial socialisation into teaching practice in functionalist terms that separate theory from practice. Instead, the sociocultural analysis presented here revealed how Geoff was an active agent in his own development as a teacher, not simply reproducing the practices he observed nor yielding to environmental constraints, but instead re-interpreting these social conditions in the light of his own professional goals and beliefs. Reading this as interactions between Zones of Proximal Development, Free Movement, and Promoted Action provides a dynamic way of theorising teacher learning as identity formation.

In contrast with research that suggests beginning teachers are unlikely to implement innovative approaches promoted by their pre-service courses, this study documented different ways in which Geoff was able to work with technology in quite different school settings. In addition, it appears that this aspect of his teaching identity developed to the extent that his modes of working became more varied and sophisticated over time, as indicated by the metaphors of technology being used first as *servant*, then later as a *partner* and *extension of self*. Thus these categories appear useful not only for describing different models of teaching and learning with technology, but also for anticipating a trajectory of development. In this regard, there is potential for technologically knowledgeable beginning teachers to act as catalysts for technology integration in schools, as Geoff's experience in his first year of teaching demonstrates. This observation raises interesting questions for further research on how novice teachers might develop their pedagogical identities by sharing their technology-related expertise with more experienced colleagues.

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