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Teacher Learning in Professional Communities: The Case of Technology-Enriched Pedagogy in Secondary Mathematics Education

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This paper reports on a study that is developing theoretical and practical models of innovation in integrating digital technologies into the teaching of secondary school mathematics. In the first phase of the study we are working with four teachers who are effective technology users to investigate how and under what conditions they learn to embed technology into their practice. The aim of the paper is to identify key features of the communities of practice within which the participating teachers work, using data from lesson observations, teacher surveys, and interviews with the teachers and people they identified who have significantly influenced how they teach mathematics. The findings may contribute to a better understanding of ways in which professional communities support or inhibit innovative practices.

For many years, mathematics educators have been interested in exploring the potential for digital technologies such as computer software, graphics calculators and data logging devices to transform mathematics teaching and learning in schools. These technologies offer new opportunities for students to communicate and analyse their mathematical thinking by enabling fast, accurate computation, collection and analysis of data, and exploration of the links between numerical, symbolic, and graphical representations (see Forster, Flynn, Frid, & Sparrow, 2004; Goos & Cretchley, 2004). In Australia, most state and territory curriculum documents now encourage or mandate technology use in learning and assessment tasks.

By the early 1990s, researchers were predicting that technology would become rapidly integrated into every level of education (e.g., Kaput, 1992); however, evidence accumulated over the last fifteen years indicates that integration of technology into mathematics teaching and learning has proceeded much more slowly (Cuban, Kirkpatrick, & Peck, 2001; Ruthven & Hennessy, 2002). Contributors to a recent international study of technology in mathematics education argued that access to technology resources, institutional support, and educational policies are insufficient conditions for ensuring effective integration of technology into teachers' everyday practice (Hoyles, Lagrange, Son, & Sinclair, 2006). Their findings suggest that more sophisticated theoretical frameworks are needed to understand the teacher's role in technology-integrated learning environments and the inter-relationship between factors influencing teachers' use of digital technologies. These are some of the issues we are investigating in a three year study (2006-2008) of technology-enriched teaching of secondary school mathematics. Its central purpose is to understand how and why technology-related innovation works within an education setting over time and across different contexts. We illustrate how we are investigating this question by comparing the pedagogical practices and institutional contexts of two teachers participating in our study. The analysis is grounded in a sociocultural framework for teacher learning in communities of practice.

Teacher Learning in Professional Communities

From a sociocultural perspective, learning to teach is regarded as a form of enculturation into a professional community characterised by particular values, beliefs and practices. Lerman (2001) argues that community of practice models may be fruitful for understanding how teachers' identities emerge and develop as participation in the practices of a community increases, and the notion of learning in professional communities has been widely used in studies that involve collaboration between teachers and researchers (Cobb, McClain, Lamberg & Dean, 2003). However, a group of teachers working together or with researchers on pedagogical issues is not necessarily a community of practice. Wenger (1998) describes three defining characteristics of communities of practice as mutual engagement of participants, negotiation of a joint enterprise, and development of a shared repertoire of resources for creating meaning.

In a technology-enriched professional community of mathematics teachers, the *joint enterprise* might derive from the goals teachers hold for students' mathematics learning and how these goals can be achieved through integration of digital technologies into classroom practice. *Mutual engagement* of teachers might encompass norms for justifying and enacting pedagogical decisions about using technology in their classrooms and negotiating potential contradictions between one's own knowledge and beliefs about the role of technology in mathematics education and the knowledge and beliefs of colleagues. A *shared repertoire* of resources includes ways of creating, using, and reasoning with technological tools and artefacts used in teaching mathematics. "Community" is a unit of analysis used in the present study to situate teachers' instructional practices within the institutional setting of the school.

Research Design and Methods

Participants in the first phase of the study are four secondary mathematics teachers who are acknowledged by their peers as effective and innovative users of technology. They include two beginning teachers who experienced a technology-rich pre-service program and two experienced teachers who have developed their technology-related expertise solely through professional development experiences or self-directed learning. In this paper we draw on data from one beginning teacher (Susie) and one experienced teacher (Brian)[1].

The design comprises longitudinal case studies of teachers and their institutional settings. There are four main sources of data. First, a semi-structured scoping interview invited the teachers to talk about their knowledge, beliefs, contexts, and professional learning experiences in relation to technology. Additional information about the teachers' general pedagogical beliefs was obtained via a Mathematical Beliefs Questionnaire (described in more detail in Goos & Bennison, 2002). Lesson cycles from which we generated accounts of teachers' practice (Simon & Tzur, 1999) represented the third source of data. The lesson cycles involved observation and video recording of at least three consecutive lessons in which technology was used to teach specific subject matter, together with teacher interviews at the beginning, middle, and end of each cycle. These interviews sought information about teachers' plans and rationales for the lessons and their reflections on the factors that influenced their teaching goals and methods. Finally, we used a snowballing methodology (described by Cobb, McLain, Lamberg & Dean, 2003) to

[1] Names of participants and schools are pseudonyms.

identify features of teachers' communities of practice. This involved two rounds of audio-recorded interviews. The first round asked participating teachers to identify people who significantly influence how they teach mathematics, and second round interviews were subsequently conducted with people identified via this process to determine how they attempt to influence how mathematics is taught.

The next section draws on the sources of data outlined above to delineate the communities of practice of two participating teachers, Susie (a beginning teacher) and Brian (an experienced teacher).

Communities of Practice

We organise our discussion of the teachers' communities of practice around an initial description of their professional knowledge and beliefs, a snapshot of their pedagogical practice with technology, and the influence of people within and outside their schools on how they teach mathematics.

Introducing Susie (A Beginning Teacher)

Susie graduated in 2003 and started teaching the following year at Highfields School, a co-educational independent with an enrolment of around 600 students in Years 8-12. She is still at the school and is currently Junior Mathematics Coordinator.

Susie's beliefs about mathematics teaching and learning, as revealed through the Mathematical Beliefs Questionnaire, were strongly supportive of problem solving, cooperative group work, class discussions, and use of calculators, manipulatives and real life examples. Teachers who hold such inquiry-based views about mathematics are more likely to use calculators as a means of developing students' conceptual understanding than simply as tools for checking calculations or graphs done by hand (Simmt, 1997). Susie says she wants students to develop an understanding for the mathematics rather than just learning how to do it because "being able to understand what's happening I think gets you a lot further than learning by rote". She tries to achieve this through a combination of activities and discussion. Technology plays an important role in Susie's pedagogy: she recognises that it saves time but also sees it as providing opportunities for mathematical exploration:

> You make progress so much quicker than having to do things by hand and you can just do examples like … what does this rule look like? What does this linear function look like? And they can put it into their calculator and check and have a look […] So it's just quicker to explore things.

Her original ideas of what it was to be a mathematics teacher were fairly traditional and developed during her time as a school student:

> I thought it would be great if I could just put stuff on the board and let them do their work and answer questions if they needed it and write exams, tick, cross and that's my job.

These ideas were initially challenged by her mathematics curriculum lecturer at university who opened her eyes to different approaches to teaching mathematics and introduced her to graphics calculators. However she says it was when she first started teaching at Highfields that her ideas and teaching skills really developed. At this school, students in Years 9-12 have continuous personal access to graphics calculators through the school's hire scheme, there are additional class sets of CAS calculators for senior classes, and data logging equipment compatible with the calculators is freely available. Computer software is also used for mathematics teaching; however, as is common in many secondary schools,

computer laboratories have to be booked well in advance. Susie prefers to use graphics calculators so that students can access technology in class whenever they need it.

Susie spoke enthusiastically of the support she had received from the school's administration and her colleagues since joining the staff: "Anything I think of that I would really like to do [in using technology] is really strongly supported". Nevertheless, she has noticed that some of the recently appointed teaching staff are neutral and passive in their attitudes towards technology. Although they are willing to use technology in their teaching if shown how to, they rarely ask questions or engage in discussions about improving existing tasks and technology-based teaching practices.

Susie is actively involved in her state mathematics teachers' professional association and participates in formal professional development activities. She sees value in the latter when "you take things [activities, ideas, concepts] away from it feeling excited to try them". However in evaluating technology-related professional development she has found that most was not helpful "for where I am". She explained: "because we use it [technology] so much already, to introduce something else we'd have to have a really strong basis for changing what's already here".

Snapshot of Susie's Practice

Susie's technology-enriched pedagogy is illustrated by a series of lessons in which she introduced her Year 11 Mathematics class to differential calculus. She started by considering rates of change, drawing a graph on the whiteboard and asking students to describe the physical activity that could produce such a graph if it was measuring heart rate, flow rate or speed. Each situation was discussed and in the last case a student suggested that the graph could be produced by a person walking in front of a motion detector (i.e., walking away from it, stopping, and walking back towards it). On inspecting the graph one student suggested that the person was moving backwards at 4 m/s, which prompted Susie to ask how this could be read from the graph and provided an opportunity to revise gradients of linear functions and functional notation.

In subsequent lessons students were given scenarios and asked to draw graphs of displacement versus time, velocity versus time, distance versus time, and speed versus time. There was much discussion about the slope of graphs, such as the need to be steeper or shallower, the need for flat sections and how sections of the graphs should be joined. Susie started these lessons with questions but was happy to step back and allow students to conduct the discussion. These lessons concluded with students working out the average rate of change of distance with respect to time (i.e., velocity) for the following scenario: Susie walked 50 m at 1 m/s and then ran another 50 m at 5m/s.

Susie began the next lesson by having students draw the graph of $f(x) = -x^2 + 20x$ for $0 \le x \le 20$ (Figure 1). She suggested that they use their graphics calculators to assist them. Susie displayed the graph using a Viewsceen and asked students to interpret its meaning if it was a displacement versus time graph. She used questioning to assist them, leading to the culminating question: "At 7 seconds, how fast is that person running?" This question is significant in developing the concept of derivative because it requires students to estimate the instantaneous rate of change of displacement with respect to time (i.e., velocity) at $t = 7$ seconds. The initial response from a student was to calculate the average gradient (representing average velocity) between $t = 0$ and $t = 7$, prompting Susie to ask about the accuracy of this result and whether or not it could be improved. Another student suggested finding the average gradient between $t = 7$ and $t = 10$ (as shown in Figure 1).

Students suggested that this calculation was more accurate because the points were closer together on the graph. Students continued to refine this process by selecting points closer and closer to $t = 7$, eventually leading to calculation of the average gradient between $t = 7$ and $t = 7.1$.

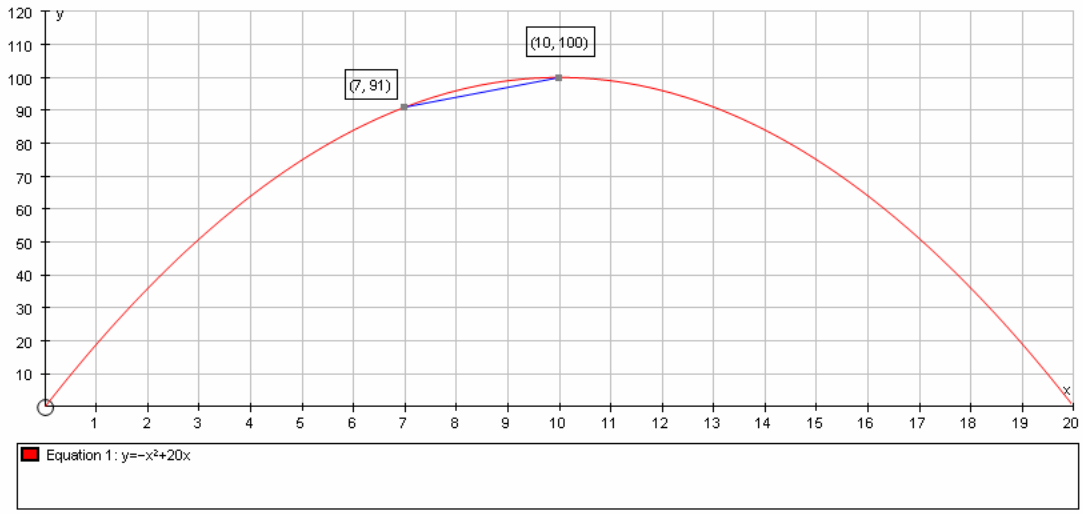

Figure 1. Graph of $f(x) = -x^2 + 20x$

Susie showed students how to find the instantaneous rate of change, $\frac{dy}{dx}$, using their graphics calculators and asked them to do this for various times and record these values in a table. Students were able to recognise that certain gradients on either side of the turning point at $x = 10$ had the same magnitude, but for values of $x < 10$ the gradients were positive, for values of $x > 10$ the gradients were negative, and at $x = 10$ the gradient was zero. She asked students to produce a scatterplot of the values for instantaneous rate of change against corresponding values of x, describe the graph, and find its equation using either algebraic methods ($y = mx + c$) or the regression facility on their graphics calculator. Students found that the equation of the gradient function was $\frac{dy}{dx} = -2x + 20$ and noted that it was a linear function. Their homework was to find the gradient function of another quadratic function by following the same procedure.

In the following lesson Susie gave students a third quadratic function to investigate. When student had the three functions and their gradient functions, she asked if it was possible to find the gradient function from the original function without using the graph or graphics calculator. Students were able to suggest a rule of the form "If the function is px^n then the gradient function will be npx^{n-1}". They checked that the rule worked for their three quadratic functions and moved on to investigate cubic functions.

Susie's approach to introducing differential calculus contrasts with the more traditional approach found in mathematics textbooks. Whereas the textbook approach is purely abstract and relies on the difficult concept of a limit to symbolically define the instantaneous rate of change, Susie gave meaning to these concepts by using a real life context (motion, expressed as distance versus time) and an inductive, technology-enriched

approach that helped the students to collaboratively work out for themselves the rule for finding a gradient function.

Influences on Susie's Teaching of Mathematics

Susie identified three people who significantly influenced how she taught mathematics, all of whom had worked or continued to work in the school. The first source of influence was Victor, the former Head of the Mathematics Department, who had developed a culture where mathematics was taught as much as possible in *context*, students worked *collaboratively* and available *technologies* were used extensively. Victor was the driving force behind the introduction of technology to the school during the 1990s, before state syllabuses had made the use of technology mandatory. He believes he was able to achieve this cultural change because the school administration supported his teaching philosophy provided funds for resources. Victor developed technology based activities and provided teachers with a lot of professional development, but claims that "left as an option there wasn't a huge uptake". To overcome this inertia he introduced technology into assessment tasks:

> You actually had to design activities that you ask all teachers to do or you build it into assessment and teachers will tend to engage a bit more because they always want their students to do the best they can. And it took a long time before it got to the point where it is now where people just pick it up and use it and there are still people that resist anything that's new, even in that culture.

When Susie arrived at Highfields she was, according to Victor, "given some guidance and direction along the way" because "we were certainly trying to do those three things" (foster collaboration, teach mathematics in context and use available technologies). She was assigned to share an office with Victor "so she could get as much assistance that she needed when she wanted it".

Thus Susie started her teaching career in a school where there was a very strong culture within the mathematics department that determined the way mathematics was taught, resulting in an expectation that she would teach in the same way. Although Susie described the approach at Highfields as "this is what we do here", she wasn't opposed to this approach to teaching mathematics or to using technology. This approach made sense to her, and she "learnt so much in the first year about [her] personal understandings of maths let alone to do with the teaching of it but also the different approach to it".

The second source of influence on Susie's development as a teacher is Mark, the new Head of Department. He started teaching at Highfields 12 years ago and acknowledges the role that Victor played in establishing the culture of the mathematics department. He has maintained this culture and has ensured that new staff members, if not already familiar with the use of technology in mathematics teaching, are willing to take it on board. He believes that his role is to provide direction based on discussion with other members of the mathematics department and encourages input from them. This collegial approach is facilitated at Highfields as the five teachers in the mathematics department all teach only mathematics and share a common staffroom.

Susie describes Mark as an "inspirational teacher" who is very experienced and values the use of technology. He sees the benefits of technology covering a wide spectrum from providing students with a "feeling of initial success to then making our learning experiences quite rich and challenging". He says that it has exposed teachers to different approaches to teaching mathematics by providing immediate answers and visual representations that can then be developed, such as by investigating the graphs of quadratic

functions using a graphics calculator before attempting an algebraic analysis. However he also feels that there is a danger that students may not develop understandings of some concepts, such as "that a graph is a visual representation of a set of points" if technology is used exclusively. So he believes that a balance is necessary and he describes achieving this balance as "part of the joys and challenges of teaching mathematics".

The third source of influence is Pamela, a teacher with more that 30 years experience. Pamela is more reserved than other Highfields teachers in her approach to technology. She is willing to use technology but sees it more as a computational tool rather than as a means by which students can explore mathematical concepts. She is willing to use existing activities but does not develop new ones. She expresses concerns that sometimes technology can be used just because it's there and cites as an example the use of dynamic geometry software in junior secondary classes at the expense of using concrete materials: "I think it's good to draw things and measure things". Pamela is willing to speak her mind and question the value of using technology in certain circumstances and Susie appreciates this frankness when she seeks feedback from Pamela on new ideas she would like to try in the classroom. Susie says that Pamela has "shaped me in how I interpret things with technology" and made her discerning in its use for teaching.

Features of Susie's Community of Practice

The evidence summarised above suggests that the mathematics teachers at Highfields School are engaged in the joint enterprise of building students' understanding through challenging learning experiences. Their mutual relationships are characterised by collegiality and a common identity as specialist teachers of mathematics. Over time they have created a shared repertoire for reasoning about resources and pedagogical approaches based on the principles of teaching mathematics in context, via student collaboration, and with appropriate use of technology – as Susie put it, "This is what we do here". However, some teachers have different opinions on the role that technology should play in helping students learn mathematics, and these differences are evident in the ways they justify their pedagogical decisions and select resources for teaching. Susie's professional learning is observable in her engagement in and contribution to the practices of this community, and especially in her awareness that reconciling her colleagues' diverse views about technology can lead her to a better understanding of its usefulness as an educational resource.

Introducing Brian (An Experienced Teacher)

Brian completed a Graduate Diploma in Education in 1982 and since then has taught mathematics in government high schools in various parts of Queensland. For much of this time he was Head of the Mathematics Department at Matlock State High, a school located on the outer suburban fringe of Brisbane serving a socio-economically disadvantaged community. In the late 1990s he recognised that the traditional classroom settings and teaching approaches the students were experiencing did not help them learn mathematics. He pioneered a change in philosophy that led to the adoption of a social constructivist pedagogy in all mathematics classes at the school. This new philosophy, expressed through problem solving situations and the use of technology, concrete materials and real life contexts, produced significant improvement in mathematics learning outcomes across all year levels. At the start of 2006 Brian moved to a new position as Head of the Mathematics Department at Bancroft State Secondary College, also situated in a low socio-economic

area close to Brisbane. There are around 800 students enrolled at the school, including a significant proportion from Indigenous and Pacific Island backgrounds. Only a little more than half of students who begin Year 8 go on to complete Year 12.

Brian describes his general approach to teaching as being within "a constructivist paradigm". He tries to introduce each new topic "with an overarching question or thought or activity that encompasses some sort of big picture" and uses technology and hands on activities to assist students to develop an understanding of the concepts. He sees the role of technology as providing opportunities for students to see the connections between algebraic and graphical solutions, giving meaning to the former. He says that many students are not given opportunities to see these links until they study further mathematics, but that being able to graphically solve equations to confirm algebraic solutions makes the mathematics meaningful and gives students a feeling of confidence and success. They are able to see for themselves that they are correct rather than "the algebraic solution being an end to itself because it agrees with the answer in the back of the book".

Brian emphasises that his reason for learning to use technology stemmed from his changed beliefs about how students learn mathematics:

> When my philosophy changed, it became a question of – what can I put in front of my kids to allow them to access the concepts? So then it didn't really matter what it was, the outcome that I was after was them accessing the concept. So it became obvious over time that technology was a way that many students do access concepts that they couldn't, wouldn't normally access.

Brian's knowledge and beliefs were the driving force that led him to integrate technology into his inquiry-based approach to teaching mathematics. When graphics calculators became available in the mid-1990s he attended several professional development workshops presented by teachers in other schools who had already developed some expertise in this area, but initially he saw technology as being "interesting but not essential". As a result of his work at Matlock SHS he won a state government scholarship to travel overseas and participate in conferences that introduced him to other types of technology resources and to international experts in this field. Apart from these instances Brian has rarely sought out formal professional development, preferring instead to "sit down and just work through it myself".

Snapshot of Brian's Practice

Some of the lessons we observed dealt with solving trigonometric equations. Brian's method for teaching this topic exemplified his general philosophy in that he initially used a graphical approach to help students develop understanding of the central concepts so they might then see the need for analytical methods involving algebra. He justified this by saying:

> The options are to give them heaps of algebra and watch them fail or try to get them to understand the concepts. If they're confident about what they're doing then I find the algebra's not such a task for them because there's a lot more meaning or reasoning behind it.

A vignette from a Year 11 lesson illustrates this approach. Brian used graphing technologies and probing questions to help students develop a general method for solving trigonometric equations, starting with a straightforward example, $2\sin x + \sqrt{3} = 0$ for $0 \le x \le 2\pi$. He emphasised the critical importance of attending to the domain, as this tells us how many solutions there are. Using his laptop computer and portable data projector,

Brian launched the *Autograph* program and displayed the graph of $y = 2\sin x + \sqrt{3}$ shown in Figure 2.

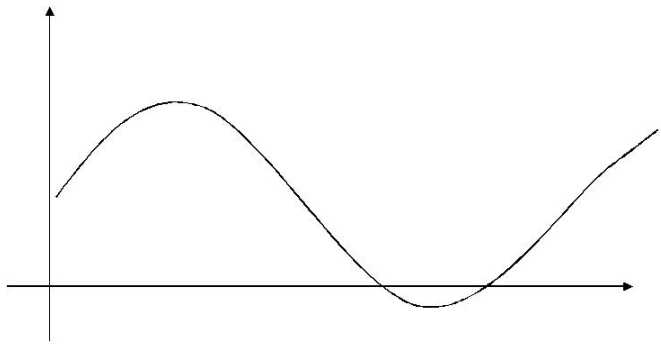

Figure 2. Graph of $y = 2\sin x + \sqrt{3}$

The students also drew the graph using their graphics calculators, and observed that there are two roots. Brian then announced that they needed to "go into the algebra world", and through careful questioning he led the class through the algebraic process of "unwrapping" the equation. Upon reaching the conclusion that $\sin x = -\frac{\sqrt{3}}{2}$, the students were reminded that they needed instantly to recognise the exact trigonometric ratios for certain angles, in this case 60° or $\frac{\pi}{3}$ radians. Brian explained that "the negative sign tells us a story too", and he guided the students through sketching the unit circle and locating the relevant angles in the third and fourth quadrants as $\frac{4\pi}{3}$ and $\frac{5\pi}{3}$ respectively. The students then used the graphics calculator TRACE function to give meaning to the solutions by entering them as *x*-values and observing that the corresponding *y*-values were zero in both cases: in other words, they had found the points where the curve cut the *x*-axis.

Influences on Brian's Teaching of Mathematics

The person who has most significantly influenced Brian's teaching of mathematics is Lawrence, formerly his university mathematics curriculum lecturer. However, this was an influence that took effect long after Brian completed his pre-service teacher education course and it led to a fundamental transformation of his practice.

Brian was taught and learned mathematics in a traditional manner and he believed that this was how everyone learned mathematics. He described his teaching in the first stage of his career as follows:

> I would present the mathematics as cogently and articulately and clearly as I could. I guess what I expected kids to do was learn what I'd done on the board, copy what I did and give it back to me on a test. Those that could were good at maths and those that couldn't weren't good at maths.

During the 1990s, it became obvious to Brian that the students he taught were not really learning mathematics. Some students were able to pass a test but six to twelve months later were unable to remember particular skills that they had previously demonstrated. He also realised that many students who struggled with mathematics were not unintelligent. In addition he found that many very capable students were not choosing to study

mathematics, partly because of the range of options that were becoming available, but also because of the way mathematics was taught. He began to feel that his teaching was ineffective and he "needed to rethink what mathematics education was about or get out". He obtained a week's leave from school and visited Lawrence, who was still teaching pre-service courses at the university. Lawrence remembers Brian as being "lively and interesting" during the pre-service program and describes him as being someone who enhanced the group because of his "willingness to participate" and contribute. After Brian graduated they had no further contact with each other until Brian approached Lawrence.

Lawrence suggested that Brian read some books about current thinking in mathematics education, and the one that Brian found to be most influential was by Paul Ernest on constructivism. Lawrence chose to direct Brian to the work of Ernest because "there was quite a lot going on in the mathematics education fraternity at that stage and he succinctly brought together a few points which … appealed to me in a reasonably coherent way". Lawrence had some discussions with Brian about these ideas but sees his main role as providing Brian with "directed reading", an approach that is best summed up in comments he made about his role in the pre-service program:

> All you would ever ask from anyone in the Dip Ed program was to seriously consider all the things that are presented. The extent to which anyone does or doesn't do that [implement the ideas] is really their decision.

Lawrence directed Brian towards readily available resources but did not provide "an easy road that you just follow the dots and you'll get to where you need to be". Brian took the initiative for his continuing development as he involved himself in Internet discussion groups and further reading. This led Brian to embark on a radical change to his teaching approach. As he read about constructivism and had contact with the mathematics education community he developed ideas and tried them in the classroom, and his students' responses gave him impetus to explore this approach further.

The extent of Lawrence's influence is evident in Brian's efforts to lead pedagogical change in the mathematics departments of the schools where he has since worked. As Head of Department at Matlock, Brian saw a need to introduce his new philosophy to the mathematics teaching staff there. He had the support of the Principal who was positive about the approach and able to provide some financial support to buy resources. He began by developing units of work for Year 8 that started with two to three weeks of hands on mathematical activities, during which time there would be no formal, teacher-led lessons. Following these introductory activities the role of the teacher would be to work with students' understanding of the new concepts by orchestrating whole class discussion and providing individual assistance where needed. He designed and delivered workshops for his staff to prepare them for implementation of the new Year 8 curriculum the following year. However, he encountered considerable resistance, with only two of the twenty teachers supporting him and the rest being either neutral or quite hostile. Brian interpreted this resistance as arising from teachers' discomfort at having to think more carefully about what they were doing in the classroom, and their belief that use of manipulatives led to a "dumbing down" of the mathematics curriculum. He overcame some of the resistance by inviting his staff to observe him teaching demonstration lessons to Year 8 classes. Those who were not initially convinced of the benefits shifted their position when they found that students whom they had previously dismissed as incapable of learning mathematics were able to achieve success under this different approach.

When Brian was appointed to his new position at Bancroft State Secondary College at the beginning of 2006 he found many challenges:

> I was confronted by not only traditional thinking in mathematics education but pretty ordinary … pretty terrible organisation and resources.

Brian diplomatically described the organisational culture as "old fashioned", not only in the mathematics department but also across the school. Many of the staff have been at the school for more than twenty years and an atmosphere of lethargy seems pervasive. Although unsaid, Brian implied that many of the teachers believe their job is to survive the day and that the students are deliberately disruptive, do not want to learn, and are only filling in time until they leave school. When Brian arrived at the school he found little in the way of mathematics teaching resources:

> There was a lot of stuff here but it was just in cupboards and broken and not used, and not coherent, not in some coherent program.

In the mathematics department there was no filing system or record of students' previous results. Different textbook series were used from one year level to the next and there was no common assessment program across any year level. Only one outdated class set of graphics calculators was available, and it was rare for mathematics classes to use the school's computer laboratories.

Over the last two years Brian has begun to restructure the Bancroft mathematics department and to change its culture. He has developed a set of about 60 activities for junior classes similar to those that were used at Matlock, redesigned the assessment program to include tasks other than tests, delivered professional development sessions for staff on the use of technology, acquired a set of graphics calculators and some data projectors, and managed to gain access to computer laboratories for mathematics classes. Nevertheless he still faces resistance from teachers who are unwilling to participate in discussions about constructivist approaches to teaching and learning. He has found he needs to take a different approach from the one he used at Matlock because the teachers at his new school are part of a more entrenched culture. Also significant is the fact that he came to the school with his constructivist reputation already established, whereas at Matlock his colleagues witnessed his transformation from teacher-centred to learner-centred practitioner. Teachers may be more willing to change their own practice if they experience leadership that demonstrates pedagogical change is possible as well as beneficial for students.

Features of Brian's Community/ies of Practice

Wenger (1998) points out that we all belong to many communities of practice, some of which are central to our identities while others are more peripheral. It seems that Lawrence's influence has drawn Brian into a research-based professional teaching community where pedagogical approaches are justified by reference to theories of learning and philosophies of mathematics education. Membership of this community extends beyond the boundaries of the school to include researchers who publish scholarly articles and books. In his day-to-day practice, however, Brian is also a member of the community of mathematics teachers in his school. The evidence we have gathered suggests that these two communities have different visions of mathematics teaching and learning.

For the professional teaching community, the joint enterprise might be expressed as building student understanding of significant mathematical concepts; members engage in

mutual relationships that value students' construction of mathematical knowledge; and their repertoire for reasoning about teaching involves discussing, designing and choosing tasks that allow all students to access the curriculum. This is a community that participates in the discourse of constructivism, and role of technology is to help students to access concepts. In contrast, the community of mathematics teachers at Bancroft State Secondary College appears to participate in an enterprise of pedagogical indifference and survival. Engagement of members has developed norms of avoidance of any discussion of pedagogy and lack of accountability to each other for students' learning. Their repertoire of ways of reasoning is based on deficit views of students, and there was no common "way of doing things" as evidenced by lack of coherence in resources, planning, documentation, and assessment.

In his previous position at Matlock SHS, Brian was able to align his membership of the professional teaching community and the community of mathematics teachers in the school by acting as a *broker* who transfers "some element of one practice into another" (Wenger, 1998, p. 109). His efforts to change the teaching culture in his new school can also be considered as brokering activities that aim to coordinate the perspectives on mathematics teaching and learning of the two communities.

Conclusion

In this paper we have provided a discussion of conditions that support or inhibit technology-related innovation in mathematics teaching by comparing the experiences of two teachers, one in the early stages of her career and the other an established Head of Department. We used Wenger's (1998) concept of a community of practice to locate the teachers' pedagogical practices within their institutional contexts (Cobb et al., 2003) and to identify other influences on their professional learning.

We noted many similarities between the pedagogical practices of Susie and Brian. In both cases they emphasise building understanding rather than rushing to "cover the content", and they use careful questioning to assist students to discover concepts. Their use of technology facilitates understanding by allowing students to graphically explore tasks before attempting an algebraic solution. Both also had their original ideas about teaching challenged, although this took effect at different times in their careers.

There are clearly differences between Susie's and Brian's institutional contexts, but consideration of context alone does not provide a convincing explanation for the ways in which these teachers integrate digital technologies into their practice. Instead we attempted to examine the "person-in-practice-in-person" (Lerman, 2000, p. 28), a unit of analysis that allowed us to shift our focus between the individual and the context. This analysis highlighted the significance of *alignment* within and between communities as a potential trigger for learning and change. In Susie's case, lack of alignment between beliefs about the role of technology held by some of her colleagues led her to a more critical evaluation of its usefulness. For Brian, the quest for alignment between his two primary communities of practice – the professional teaching community beyond the school and the mathematics teacher community within his school – drives his efforts to bring about pedagogical reform. As our project proceeds we will continue to develop and test these ideas about innovation in integrating technology into secondary school mathematics.

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