Griffith UNIVERSITY

Numeracy, Equity, ICT:

Final Report

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Executive Summary

This project was funded through the Australian Research Council's Discovery grant system. The study was conducted over a period of three years in both Queensland and Victorian schools. It explored the use of Information Communication Technologies (ICTs) to support numeracy (mathematics) learning.

Aims

The aims of the project were to identify:

- How ICTs are used in maths classrooms to support numeracy learning
- The out-of-school numeracy and ICT practices of students
- Synergies/gaps between home and school numeracy and ICT practices
- Elements of best practice that will help teachers to develop practices in schools when using ICTs that will support and enhance numeracy learning for students most at risk of failure in school numeracy and/or mathematics.

Through both quantitative and qualitative methods, the project sought to identify the current state of play in schools with the use of computer technology to support mathematics learning and in that process identify quality practices with the explicit intention of using this information to develop guidelines to support quality learning for students and schools working with disadvantaged groups of students.

Approach

The primary data collection consisted of a data bank of video data collected across a diverse range of schools. These data enabled the research team to explore practices where teachers used computer technologies in mathematics classrooms. This data source was supplemented with classroom observations and interviews with teachers. Survey data were also collected so as to enable a deeper understanding of teachers' beliefs and use of computers in mathematics. Collectively these data enabled a snapshot of practice to be developed. It was also recognised that students are a key part of classroom practice so a number of schools also participated in a process that enabled the research team to explore out-of-school experiences of middle schools students in terms of their numeracy and ICT experiences. This approach employed the use of cameras and stimulated recall to elicit students' interpretations of their out-of-school experiences.

Outcomes

1) There was little use of ICTs to support numeracy learning in middle school classrooms.

   The most alarming finding from this study was that there was considerably little uptake of ICTs in middle school classrooms where the ICTS were primarily focused on numeracy or mathematics. The very small number of videos that were obtained from 10 schools over 3 years suggested to us that there was little use of ICTs in this context. This was supported by teacher interview responses where they indicated that most would not have even done the lessons provided had it not been for their participation in this study. In some cases, the school did not use computers at all in the teaching of numeracy/mathematics.

2) There tends to be a shallow teaching approach when teachers use ICTs in numeracy/mathematics classrooms

   Using the productive pedagogies framework to analyse classrooms practice, it was found that the ratings on intellectual quality were very low. Results confirmed the findings in the original QSLRS study where supportive environments were strong but quality learning (in terms of depth of knowledge) was low.

3) Teachers were able to provide rich learning environments through the use of ICTs where they radically changed their teaching from a lock-step approach to an open-ended approach.

   There was a selection of high quality learning environments identified in this study. Where teachers provided for quality learning, this was often when they deviated from the usual controlled learning environments that dominate traditional teaching approaches in mathematics.

4) Teachers need to be provided with quality professional development in order to change their practice.

   Through the survey and subsequent interviews, teachers suggested that their skill and confidence levels were impediments to the implementation of quality learning. Professional development needs to be provided to teachers if they are to move beyond the current status quo. It was suggested by teachers that such professional learning extends beyond the provision of CD-ROMs provided by authorities and other suppliers.

5) Students have varied experiences in their home numeracy and ICT experiences.

   The data supplied by students/families on the out-of-school experiences suggested that there is a wide diversity in the out-of-school experiences of middle school students. As such, it becomes critical for schooling to build the digital capital of those students for whom the out-of-school experiences may be considerably impoverished. In so doing, schooling can reduce the potential digital gap among school participants. However, this is only possible if quality learning experiences can be provided.

Recommendations

Overall, the most significant outcome of this study was the low incidence of using ICTs to support numeracy/mathematics learning. This is in contrast to the very rich case studies which document the power of technology to enhance student learning. There were instances where this occurred in this study but it was not a consistent trend. Using other data collection methods, explanations for this outcome were sought. It was clear that teachers were very busy and the potential for professional development was restricted. Teachers indicated that they needed support in the implementation of ICTs in the classroom. Support, in this case, came in two forms – professional development to enhance their own understandings of ICTS both pedagogically and knowledge based. The second case was for more human resources where specialist teachers were recommended to support teachers – this was in the case of both professional learning and/or with the hardware. As such, it was clear that more in-school support was needed.

Where teaching was observed, it predominantly aligned with traditional approaches to teaching where the teacher was in control of learning and knowledge. In part, this could be explained as reproducing approaches common to mathematics education. However, the approach is compounded by resourcing issues and pedagogical knowledge that are integral to ICT reforms.

1) There is considerable potential for ICTs to enhance the learning of numeracy when particular pedagogies are used. Such approaches encourage deep learning and engagement of the students. They move beyond the shallow teaching approaches commonly found in the teaching of both mathematics and in the teaching with ICTs.
2) There is a need for provision of quality in-school professional development to enhance teachers' understandings of ICTs as pedagogical devices that enhance student learning.
3) There is strong need for provision of opportunities for teachers working in contexts serving low SES, rural and/or Indigenous communities to develop innovative teaching approaches using ICTs. Typically, teachers in these schools are new, underqualified and/or do not have the teaching experience needed to work with the special demands of these communities.
4) There is a need for the provision of learning opportunities for teachers to move from closed, lock-step, skills-based pedagogies to more open, exploratory approaches.
5) ICTs should be enabling tools in numeracy/mathematics. Using ICTs in numeracy/mathematics needs to be an integrated process as opposed to an activity in and of itself. The power of the technology enables students to engage mathematically with ideas as opposed to the technology being an activity in which the technology is the feature of the lesson.
6) Students bring a wealth of knowledge to classrooms, including technological know-how. This needs to be recognised, utilised and built upon by teachers. Support in processes to identify student knowledge, skills and dispositions needs to be integrated into teacher professional development.

Background Literature

In providing a background to this study, there are a number of relevant themes in the literature. This review is conducted around four themes. The first is that which ties to teacher characteristics and their approaches to teaching and learning; the second relates to the literature on the power of ICTs to enhance learning; the third is classroom organisation and pedagogy; and the fourth are the synergies between home and school.

Teacher Characteristics

In this section we discuss the characteristics of teachers and teaching since these impact on the potential implementation of reforms.

Teacher Beliefs

What teachers believe about their students influences their actions and the provision of learning opportunities. The seminal work of Rosenthal showed very early on the power of teacher beliefs about learners such that if a teacher believed a student was capable or not of learning, they provided opportunities for that learning so that the expectation of the teacher became the reality for the student.

Within the context of school mathematics, the work of Jo Boaler provides an outstanding example of teacher beliefs and the provision of quality mathematics learning opportunities. What emerges clearly in her recent work in the US, Boaler (2004; also Boaler, Lerman, Zevenbergen 2004) is the nature of the commitment of the teachers to the students. The teachers in Railside were firmly committed to providing a demanding mathematics curriculum for students considered the most disadvantaged in the schooling system – poor, African-American, Latino/a and/or Asian students. Using Cohen's Complex Instruction (Boaler 2002) to structure the learning environment, Boaler has shown that the students can learn complex mathematics in deep ways. The belief that the students could learn complex mathematics and the provision of learning environments that supported such learning has met with considerable success. As Boaler showed, this school was one of the poorest performing schools in the state of California but has raised achievement levels to well above state averages. Furthermore, the students' achievements do not map onto social background in the usual ways. Believing that that the students could learn complex mathematics was critical to the success of the program. The results show that the most disadvantaged students within the Californian education were capable of success when provided with high expectations and quality learning.

Similarly, within the Australian context, Indigenous students perform very poorly on state tests. This cohort of students is consistently at the bottom of all state testing schemes, often by significant differences compared with the non-Indigenous students. Rurality and remoteness further compound differences in performance as these usually correlate with social, cultural and linguistic factors. Chris Sarra (2005), an Indigenous principal, has shown that reinforcing the belief among students and staff that Indigenous students are intelligent and strong, scores on literacy and numeracy have improved dramatically, as has attendance at school. Sarra argues that Indigenous students and communities need to believe that they are able to achieve and that schools are critical in providing a venue for this to happen. The achievements of Sarra are well documented in turning his school from an under-performing school to one achieving well above state average[1].

In an extensive study of effective literacy practices in Victorian (Australia) schools, Hill and Rowe (1998) concluded by arguing that schools did not make a difference to student performance but rather individual teachers were the key determinant in student learning. This study has been controversial in that it challenges a very strong myth that is gaining considerable momentum in Australian schools in particular, that being, that private (independent, wealthy) schools offer better learning environments for students. This has resulted in a steady movement away from state schools to the extent that there are concerns about the ghetto-isation of public schools. Hill and Rowe (1998) have shown that individual teachers can make a difference, whatever their context.

Teacher ICT Dispositions

Ertmer (2005) reported the increasing confidence of teachers to use computers in the classroom. This has increased to 85% of teachers reporting they were "somewhat well-prepared to use technology in the classroom" which was up from the 2000 figures where 58% of teachers reported the same level of confidence. This increasing confidence in capacity to teach using ICTs is encouraging as other studies have been showing similar increases in teacher knowledge, access to web resources and so on. Collectively these studies suggest that teachers are reporting greater confidence in their knowledge and capacity to use ICTs in the classroom.

In considering the impact of technology in classrooms, Cuban (2003) has shown that there has been little change to traditional instruction and learning. As Cuban argued, there is a strong push for the uptake of computers in classrooms, but they are under-utilised. In considering the use of computer technology as it pertains to mathematics education, Reynolds, Treharne and Tripp (2003) argue that teachers struggle to incorporate ICTs in their classroom, with mathematics educators being least likely to incorporate ICT into their classrooms (Williams et al, 2000).

It is recognised that state authorities are driving the agenda for implementation of ICTs in classrooms and school personnel recognise the potential of the tools,

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[1] Sarra's success with his community has been recognised through numerous awards (e.g. Queenslander of the Year 2004; Deadly Awards 2004).

however, the realisation of the reform can meet several blockers to implementation. In research from UK schools (Goodison, 2002), it was suggested that these include the management processes adopted within the school; the role and expertise of those coordinating the change process; the amount and expectations of change expected (??); and the emotional energy of the teachers to cope with change. Other common barriers to the uptake and use of technology in the classroom include limited access to technology (Reynolds et al 2003); not enough training and professional development in the area of ICT (Ruthven and Hennessey 2002); and the pedagogical beliefs of the teacher (Robertson, 2002; Lederman & Niess, 2000; Ertmer & Hruskocy, 1999). Mathematics educators in particular struggle with the implementation and appropriateness of ICTs in the classroom (Lederman & Niess, 2000).

At the level of ideology, there is some sense that there is resistance to change, that is, a resistance to the uptake of ICTs in classrooms based on the ideological position that educators hold towards ICTs. There is also a sense that reform in and of itself can create barriers to change. In studying the resistance to change among preservice teachers Zakis (1999) reported that there was a need to explore the modes of teacher learning that encourages teachers to change practice. In a study working with teachers and their use of technology (Hughes & Ooms, 2004), it was reported that teachers need to have a catalyst for changing their dispositions towards technology – an outsider to the group – whose role is to provoke change, so that they will move beyond their current modes of thinking about ICTs.

Teacher Preparation and Professional Development

While governments have been spending considerable resources on the hardware and wiring for the installation of computers in schools, the commitment to teacher professional development has been substantially reduced.

> *"Teachers not receiving the support they need in order to be able to support young people and provide them with a relevant, post-modern education that embraces technology in order to improve actual teaching and learning rather than the aesthetic delivery of it"* (Beastall, 2006, p.99).

In relation to the literature on teacher professional development, there have been considerable criticisms of particular models. Keller (2005) draws on these literatures to challenge current models as not providing the forms of professional development needed to change the status quo in the use of ICTs in classrooms. In an earlier paper, this author (J. B. Keller & Bichelmeyer, 2004) proposed that the current instrumentalist approach of authorities with regard to the uptake and implementation of ICTs may "actually work against more imaginative and adventurous pedagogy often associated with technology integration and innovation efforts" (Keller, 2005, p 331). Keller (2005) reported that for significant learning and change to occur, teachers needed opportunities to engage with sustained and well supported models of professional development, such as those afforded by action research approaches. More explicitly, (Lou, 2004) argues that teacher learning with technology can be enhanced when teachers are provided opportunities to work in small groups as opposed to individual work. The provision of sustained support in terms of mentors to work with teachers has similarly met with success (Holahan, Jurkat, & Friedman, 2000). It would appear that success in the integration of computers into classrooms requires a sustained period of teacher professional development where teachers are provided with opportunities to learn rather than the quick fixes offered by one-off or short courses.

Using Schulman's categories of teaching knowing, Koehler and Mishra (2005) developed a professional development course for teachers where they undertook designing technological interventions. They reported that "learning by design appears to be an effective instructional technique to develop deeper understandings of the complex web of relationships between content, pedagogy and technology and the contexts in which they function" (p. 131).

Technology Support

Many teachers may have access in the home but lack the confidence to use them in the classroom (Wood, Mueller, Willoughby, Specht, & Deyoung 2005). In identifying the environmental issues on the implementation of ICTs in the classroom, these authors suggest that support for the use of ICTs is seen by teachers to be an important aid to their work. This support can be in the form of computer technicians who are able to provide advice when there are malfunctions with ICTs; compatibility between platforms and software; and the provision of advice for the quick changes that occur in both hardware and software. Support may also be required for the internet and other connections.

Provision of Services

In this section, we review the literature that focuses on the provision of services to schools and education providers. This literature addresses the provision of services by authorities (such as state departments) as well as other services provided by a range of hosts.

Software

The software purchased by a school can pre-empt the practices to be adopted (Goodison, 2002). By purchasing particular software packages, the school is buying into particular approaches. For example, in considering the reforms in the mathematics curriculum in Queensland at the time of writing this report, we note that there are a number of companies marketing software packages that purport to support mathematics learning. We note that one package adopts a lock-step, algorithmic approach to mathematical concepts. The software package claims to reinforce student understandings but this is through a behaviourist approach and not one which encourages deep learning. In Goodison's study (2002), it was reported that teachers moved away from the purchase of software and moved towards the use of on-line, web-based resources, in part, due to the frustration of software packages.

In studying the design of software packages, Pinkard (2005) reported that there are specific features of such designs that have been built in ways that can interest and motivate genders differently. For example in a study of a particular software package that featured Afro-American girls, Pinkard reported that this software engaged and supported this cohort of learners. She concluded that explicitly targeting groups of students, in this case Afro-American girls, through the use of software design, may be useful in bridging gaps between genders, socio-economic and cultural groups.

Integration of Computers

(Kozma) reported on the research in computer use internationally and found that computers were being used across most curriculum areas.

Interactive Whiteboards

An emerging technology in Australian classrooms is that of interactive whiteboards. To date, the review has focused on the use of computers in the classroom. However, the extension of the computer through the use of interactive whiteboards creates new opportunities and obstacles to learning. To be competent with the use of IWBs, it was recommended that teachers need daily access to such tools (Armstrong et al., 2005) so that teachers are able to develop their repertoire of skills and to integrate them into practice (Glover & Miller, 2001) In studying the use of IWBs in English classrooms, it was reported that

"IWB can facilitate and initiate learning and impact on preferred approaches to learning. The pupils describe how different elements of software and hardware can motivate, aid concentration, and keep their attention. On the negative side, pupils candidly describe their frustration when there are technical difficulties, their desire to use the board themselves and their perceptions of teacher and pupil effects (Wall, Higgins, & Smith, 2005 p. 851).

(Greiffenhagen, 2000) states that the availability of interactive whiteboards as a teaching aid is only of value where it becomes part of the regular pattern of classroom life.

They also need to have access to a wide range of software and applications that are subject specific (Armstrong et al., 2005) and that on-going training with the use of IWBs helps teachers develop their skills and knowledges with regard to the affordances of these tools.

ICTs and Learning Spaces

Potential of ICTs in Mathematics

Using Technology to Support Mathematics Learning

(Wall, Higgins, & Smith, 2005)

In this section we discuss two key issues related to the use of technologies in mathematics. In the first section we discuss various forms of technology and how they can be used to support mathematical learning. In the second section we discuss the implications of the differential uptake and use of technologies in schools and beyond with particular reference to the digital divide.

Within the mathematics education research literature, there are many ways in which technologies have been documented so as to show their potential in enhancing learning. This has been from the early childhood years through to senior secondary years. For example, in the early years, the work of Yelland (2002) has been powerful in showing how young preschool students can use LOGO to develop and enhance many spatial and other mathematical concepts. At more advanced levels, other studies of Logo (Smith & Olkun, 2005) have shown its power to enhance geometric thinking. This has been documented in other countries as well, particularly through the work of Clements (1990).

The power of hand-held technologies has been explored along a number of fronts. For example, in the senior years of schooling, the work of Goos et al (2003) and Geiger (2002) has impacted significantly on awareness of the power of hand held tools to enhance understandings of functions and graphing. Their work with graphing calculators has illustrated the power of the tool in facilitating student learning and engagement. The use of graphing calculators has been powerful in enhancing students understandings of functions for students as well as providing new opportunities for teachers in terms of pedagogy (Cavanagh & Mitchelmore, 2003). However, the technologies need not always be high-end types. For example, the work of Groves (1995) with calculators showed the possibilities of number learning through the open-ended use of very available resources. Recent innovations in technology include the use of palm held computers. These relatively new tools(ICTs) are being developed as tools to be used in the classroom. While their application is still new, they have been found to increase motivation and help gain a sense of responsibility among students (Savill-Smith, 2005).

The computer environment has also been found to create new learning potential. In their study of secondary students working in pairs at a computer, Hoyles, Sutherland and Healy (1995) reported that the computer environment "provokes any cognitive conflict necessary for the individual conceptual development" (p.175). They found that when working in pairs and with tasks that were challenging, students engaged in complex dialogue that enabled them to move forward in their development of conceptual understandings. Similarly, Clements (2002) claimed that there was a large increase in interactions when early childhood children were working in pairs at a computer than when playing with puzzles on the floor. He noted the amount and quality of interactions and found them to be substantially enhanced when students worked at computers – in pairs. Similarly, the work of Galbraith and Haines (1998) showed that the learning environment provided by computers can enhance students feeling towards mathematics.

While there is an increasing use of technology in schools, Ertmer (2005) found that "using technology for numerous low-level tasks (word processing, Internet research) [was more common and that] higher level uses are still very much in the minority" (p.399). She concluded that "uninspired technology use is especially prevalent in urban schools" (p. 397).

Given the richness of the potential of computer technologies to enhance learning, both social and cognitive, the concern raised by Clements (1994) about the approaches used by teachers needs to be considered. Despite considerable public money being invested in computer technologies in education, systems are asking why there is not the uptake by teachers in terms of quantity of use as well as quality.

Technology and a Digital Divide

In this section, we consider the impact of digital technologies in both homes and schools and the potential for creating divisions between those who have access and those who do not. The digital divide can exist at many levels. For example, there is divide between urban and rural access where, in a study of Canadian access to computers, it was reported that 53% of rural households have access to the Internet, compared to 68% of urban households (Harding, 2002). Similarly, the access that was available in country areas can often be restricted in terms of broadband access thus limiting the functionality of the internet. In terms of access according to age, Downes, Arthur and Beecher (2001) cite figures from 1998 where "48% of Australian homes where the oldest child is in the age range 0-4 years have computers. This proportion increases to 54% for homes where the oldest child is in the age range 5-9 years, and 71% where the oldest child is in the age range 10-14 years" (p. 141). However having access to a computer does not mean 'access' in terms of potential for learning. As Angus, Synder and Sutherland-Smith (2003) argue from their study of home computer use, there are quite different ways of using such technologies which may or may not align with the practices of schools, thus creating differential opportunities for children of those families. Angus et al's study focused on the access of economically disadvantaged families and found that their access and use of the internet was not aligned with the practices of school, thus even though they had access, it was still disadvantaging them in terms of creating digital capital.

In studying the use of computers in schools, Downes, Arthur and Beecher (2001) claim that there is an increasing uptake of computers as students progress through school, that is there are fewer computers in the lower years with more in the upper years of primary. They also contend there are few, if any, in many birth to three settings. One could contend that this increasing uptake in classes as students progress through school may be misplaced in terms of addressing a digital divide. Students whose home environments are digitally impoverished may be better served by experiencing greater access to technologies in their early years of schooling where there is potential to add digital capital earlier in their years and thus bridge the divide early in their schooling instead of when the gap is much wider.

In considering students' perceptions of access and familiarity with computers in schools, a large survey of Australian schools (Meredyth, Russell, Blackwood, Thomas, & Wise, 1999) noted that students from independent and boys-only schools reported greater familiarity with the more advanced computer skills and demands than their peers in state or girls-only and co-educational schools. This suggests that there are differences in both gender and school-type perceptions of competences. Within the Australian system, the differences noted by Independent schools and boys-only could be interpreted to be indicative of class differences as well since many independent schools are attended by students from higher SES backgrounds due to the fiscal demands of these schools.

In the studies on gender differences, the work of Vale and Leder (2004) showed that while students see the value of ICTs in schools and mathematics, the girls viewed computer-learning environments less favourably than boys. They also reported differences in the value that boys and girls placed on computer-learning environments. This study reinforced gender differences noted in many earlier studies suggesting that such differences are enduring despite attempts to reduce gendered digital differences.

Researchers (Grabill, 2003; Clarke and Gorski, 2002) contend that lower income families acquire home computers at significantly lower rates than higher income families, a trend equivalent comparable to the acquisition of computers and internet access in schools. This pervasive uneven acquisition of ICT's means that children of low income families not only have less access to computers and the internet at school, but also in their homes, and leads to a greater divide based on socioeconomic status. Research conducted on the positive influence of a connection between home and school use of ICT's needs to consider the impact this would have on students who have limited to no access to technology in their homes. If technology is to be integrated fully into the classroom, all students would require access to technology in their homes, otherwise those students of higher socioeconomic advantage meaning those more likely to have access in their homes, are more likely to succeed in the classroom.

While access rates are lower for socioeconomically disadvantaged students, their attitudes towards technology are strongly influenced by their environment. Clarke and Gorski (2002) argued that students of higher socioeconomic status were educated to see ICT as a highly useful resource, and to take full advantage of it, while those of low SES were educated to see ICT as little more than a calculator and use it for rudimentary tasks if at all. Furthermore, Clarke and Gorski (2002) reported that teachers at lower income schools were less likely to be computer literate and incorporate ICT's into their lessons, and where they did incorporate ICT's, is was in far less sophisticated ways. Therefore, even if students of low SES have access to technology, they are likely not to appreciate or utilise ICT's to their full potential, thus ensuring the divide intensifies.

According to Clarke and Gorski (2002), there is a lack of relevant information online for socioeconomically disadvantaged people, with most information available on the internet being directed at the middle and upper classes. According to researchers (ref), this lack of relevance means that when socioeconomically disadvantaged do have access to the Internet, they are less likely to see the usefulness of the Internet, and therefore, less likely to utilise and become familiar with it. With ICT literacy becoming a powerful literacy in today's economy (Sutherland-Smith, Snyder and Angus, 2003), technoliteracy is also an important consideration in the digital divide. If young people don't have equal access to technology, a class of techno-illiterate people is likely to develop, and is more likely to be comprised of socioeconomically disadvantaged youth.

Considering that ICT is increasingly incorporated into educational, social, financial and employment opportunities, with those who are lacking access to ICT's increasingly falling behind (Carvin, 2000), the digital divide reinforces the inferior position of those belonging to the lower classes, propelling them further behind. If, as Tiene (2002) proposed, the world's most serious problem is the growing gap between the wealthy and the underprivileged, then the digital divide needs to be addressed in order to accomplish what technology in education is purported to achieve – social inclusion in education.

Pedagogy: Implications of Teaching Approaches

In this section we consider the literature on the approaches used in the teaching of mathematics generally against the literature on computer use. The literature suggests that the approaches used in classrooms may align with those traditionally used in the teaching of mathematics. We then consider the literature on productive pedagogies which is an approach now becoming a part of the teaching discourses in Queensland and Australian schools.

Shallow Teaching vs Deep Learning

Current approaches in reform teaching advocate for pedagogies that develop deep learning in students. This movement represents a significant change from the lock-step, individualistic approaches that have dominated much of mathematics teaching and learning. There is considerable literature that explores the teaching approaches of mathematics and identifies common themes in teaching – these are teacher directed, whole class teaching, the use of textbooks, and the encouragement of algorithmic thinking. This is despite considerable research and policy initiatives that seek to adopt more open, flexible and substantive approaches to the teaching of school mathematics.

In reviewing the literature on the use of the computer in mathematics classrooms, there has been mixed successes. In some cases, there have been reported cases of innovations. In these studies, the authors seek to document innovations where there has been considerable input from an external authority. However in documenting the current state of play, Samuelsson (2006) reported that in Sweden at least, that there has been little overall change. He concluded that:

"Teaching of mathematics seems to have such a strong tradition that the computer as a change-agent is relatively weak. The fact is that the computer is assimilated into an old tradition of methods and contents. A great deal of the computer-aided lessons give attention to drilling pupils with different types of drill-program where they can learn mathematical procedures. In some lessons laborative work is pursued with the intention that the pupils computer-aided learn mathematical concepts" (Samuelsson, 2006, p.71).

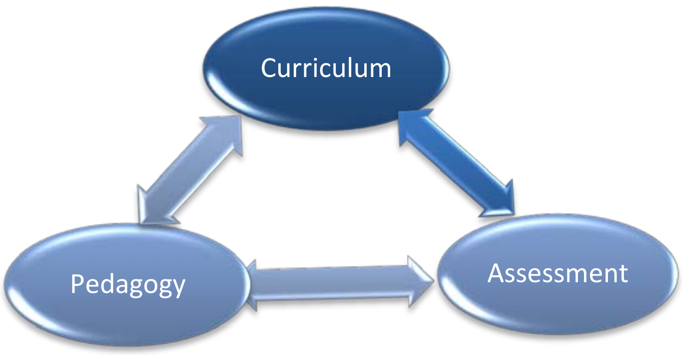
Rather than consider the digital divide as a block to access and success for some students, we propose that teachers can make a difference to student learning through the provision of learning environments. As Boaler's and Sarra's work show, believing that students can learn complex ideas through providing appropriate learning environments suggests to us that it becomes important to document both practice and teacher beliefs about how it may be possible to provide for quality learning. Twelve years ago, in the early days of suitable software and powerful machines for classroom learning of mathematics Morgan (1994) argued that, whilst ICTs offer potentially rich learning environments, what matters is pedagogy. Unless they are integrated into suitable forms of pedagogy, they may well make no difference to learning.

Productive Pedagogies: Fostering Deep Learning

Recognising that there are critical issues facing schools and education, many education authorities see it as vital that reforms are enacted that will keep students in schools longer and prepare them for the changing world and workplace. As part of its goal to reform schools so as to make them more relevant and engaging for young people, Education Queensland has sought to develop a reform that embraces new forms of learning, curriculum and assessment that meet the needs of Australian society. As part of the process to inform such reform, the Education Department of Queensland undertook a major review of Queensland schools. Known as the Queensland Schools Longitudinal Reform Study (QSLRS) (1999), the project was undertaken over a period of three years with over 1000 classrooms being observed. All curriculum areas were considered. The brief of the review had been informed by the quality learning project emanating from the United States and lead by Newmann and colleagues (1996). Using a framework developed by Newmann and expanded by a team at the University of Queensland, it was found that that whilst teachers are very good at providing nice, friendly classrooms the intellectual quality was very low (QSLRS, 1999). In this framing, what is outstanding from the study is that mathematics was consistently ranked as one of the poorest taught areas in the curriculum. As a consequence of these findings, the government instigated wide changes which were lead by Prof Allan Luke who was seconded to the Department of Education to oversee the introduction of these reforms in 2000. Known as the New Basics the reform was, at first, restricted to 20 trial schools across the state with more coming on line the following year. However, many schools are now implementing the approach as it is a novel and engaging reform that appeals to teachers. Furthermore, most states in Australia have now taken up the reform in some guise or another. Due to the autonomy of each state in Australia, they have modified the reform to make it unique to that particular state but the general premises of the reform can be seen in each state's protocols.

The New Basics are built on tripartite model which is based on Bernstein's theoretical framework of curriculum, pedagogy and assessment (Education Queensland, 2006). The New Basics has "New Basics" as its basis to curriculum, "Productive Pedagogies" as the basis to pedagogy and "Rich Tasks" as the assessment tools.

Figure 1:
The Structure of the New Basics Reform



It can be somewhat confusing for those not inducted into the reform since the overall reform is referred to as New Basics while the curriculum (knowledge) integral to the reform is also known as New Basics. This slippage in terminology is a reflection of the ideology underpinning the reform, where there is a strong push for the reform to move away from (old) Basics to embrace new forms of knowing that are synonymous with "New Times".

While each of these areas are important and integrally connected to each other, a description is beyond the scope of this paper. Of interest in this paper is the productive pedagogies component. This aspect of the reform was designed to provide a framework upon which to consider aspects of quality teaching practice. A brief overview of the framework is provided in *Table 1*.

	Productive Pedagogy	Key question
Intellectual quality	Higher order thinking	Are higher order thinking and critical analysis occurring?
	Deep knowledge	Does the lesson cover operational fields in any depth detail or level of specificity?
	Deep understanding	Do the work and response of the students provide evident of understanding concepts and ideas?
	Substantive conversation	Does the classroom talk break out of the initiation/response/evaluation pattern and lead to sustained dialogue between students, and between students and teachers?
	Knowledge as problematic	Are students critiquing and second guessing texts, ideas, and knowledge?
	Metalanguage	Are aspects of language, grammar and technical vocabulary being foregrounded?
Relevance	Knowledge integration	Does the lesson range across diverse fields, disciplines and paradigms?
	Background knowledge	Is there an attempt to connect with students' background knowledge?
	Connectedness to the world	Do lessons and assigned work have any resemblance or connection to real life contexts?
	Problem based curriculum	Is there a focus on identifying and solving intellectual and/or real world problems?
Supportive School Environment	Student control	Do students have any say in the pace, direction or outcome of the lesson?
	Social support	Is the classroom a socially supportive, positive environment?
	Engagement	Are students engaged and on-task
	Explicit Criteria	Are criteria for student performance made explicit?
	Self regulation	Is the direction of students' behaviour implicit and self-regulatory?
Recognition of difference	Cultural knowledges	Are diverse knowledges brought into play?
	Inclusivity	Are deliberate attempts made to increase participation of all students from different backgrounds?
	Narrative	Is the teaching principally narrative or expository?
	Group Identity	Does teaching build a sense of community and identity?
	Citizenship	Are attempts made to foster active citizenship?

Table 1: Productive Pedagogy Dimensions, Items and Key Questions (from Gore, Griffiths & Ladwig, 2006)

Gore et al (2006) argue that the productive pedagogies framework is most useful as a tool for reflecting on practice. In this project we were seeking to identify a method through which we could examine the teaching practices of teachers as they used ICTs to support numeracy learning. To this end, we have employed the productive pedagogies framework to analyse a series of lessons conducted by a range of teachers across various sites in Queensland.

Classroom Organisation

Sequential, drill, open ended practices

In their study of spreadsheet use, Clarke and colleagues reported on the sequencing of delivery of mathematical content versus technological content. They concluded that it was better to teach spreadsheet skills prior to teaching mathematics than to teach them concurrently when working with novice spreadsheet learners.

As noted earlier in this paper, there is a tendency for teachers to hold on to the practices of the past. In mathematics, there is a valuing of drill and practice. This approach has been used and adopted in many of the software programs available for use in mathematics classrooms. Samuelsson (2006) concludes that such approaches encourage the use of fast handling of procedures but fail to encourage the development of reflection and abstraction.

Small Groups vs Individual Teaching

Many schools lack the resources for students to have access to individual computers. Where this may be seen as impoverished resourcing, the literature poses a challenge to the need for individual workstations. Lou (2004) argues that student learning with technology can be enhanced when teachers provide opportunities for the students to work in small groups as opposed to individual work. This author studied the richness in interactions and knowledge creation offered by small groups when working with computers and concluded that the shared environment was offered more affordances for learning than individual work. Lou, Abrami, and d'Apollonia (2001) reviewed a large number of studies (122) relating to the use of small group and individual work in computer teaching to conclude that small group teaching environments were significantly more positive when compared with individual learning. In his review of research using computers, Kozma found that 83% of the studies explored the use of computers in shared learning situations.. This does not necessarily translate to classroom practice only that his findings report on research being conducted. It does, however, suggest that there is a strong leaning towards the use of computers in shared learning situations.

In studying the interactions in paired work in a geometry classroom, Sinclair (2005) reported many features of quality classroom talk as students engaged with the task. Recognising that the task format is critical to fostering quality learning opportunities, Sinclair argued that the opportunities afforded by sharing in pairs enriched the experiences of students in ways that may not be possible with teacher interventions.

The evidence indicates that student interactions involved more than a sharing of information; students intervened with their partner to correct, inform, cut off conversation, initiate play, and communicate their vision. We know that teacher interventions can provide motivation for the consideration of new ideas, and help uncover misunderstandings that may interfere with student progress (Sinclair, 2005, p.106)

Learning Communities

Many researchers are now arguing for learning spaces that support communities of learning. In her work with secondary school teachers and students, Goos (2006) argues that this environment has considerable learning opportunites for both teachers and students.

While in distance education, communities of learning were encouraged through the use of on-line forums where students could chat with each other. However, this form of community does not seem to foster the elements of a face-to-face community (McPherson & Nunes, 2004).

Synergies between Home and School

Angus and colleagues(year) reported on the differences between home and school use of computers. They found that for their cohort, there was little synergy between the home practices of students, particularly those from disadvantaged families. Similarly, other studies have shown that there is little linkage between the home activities and those used in school. For example, in their study of software packages used in the home, Kerrawalla? and Crook (year) reported that the intentions of parents when purchasing software for their children was to ensure a continuum between home and school. However they reported that “Although parents had strong aspirations that household computers should support their child’s learning and although parents’ main software purchase s were educationally oriented, children spent most of their time on games of a sort not typically found in their classrooms” (p.751). “two-thirds of time is spent on the kind of games that would not be found in a school context. (p.768) Kerawalla & Crook (2002). Mumtaz (2001) argues that students are more positive about their home experiences with ICTs than with their school activities. This may, in part, be due to the fact that homes have more up-to-date technologies than schools. These more contemporary technologies enable students to engage in more complex and innovative practices than what would be possible on the older school technologies (Sefton-Green & Buckingham, 1998; Comber et al. 2002). In her detailed study of students’ in school and home use of computers, Lewin (2004) reported considerable differences in the use and approaches to computer usage between the two contexts. She reported that home use was more engaging, richer, and more authentic than the school-based work which tended to focus on skill development (which the students often had).

Theoretical Framing of Practice

The study of teaching is beset by the methodological dilemma of how to frame research on ‘good practice’. One is faced with choices: determining a priori, based inevitably on the researchers’ beliefs, values and ideology, what constitutes good teaching and then engaging with the empirical field in order to identify the effects of such practice and study; determining a posterior, having focused on a teacher or some teachers either through selecting a criterion, such as pupils’ achievements, by which to identify those teachers, or by choosing teachers identified as such by their colleagues, through a grounded approach identifying those teaching methods that have led to good practice that may be common among those teachers. An alternative approach, taken by Ball, Bass and colleagues (2003) is to study in detail a range of lessons of one teacher, enabling an analysis of strategies that lead to good learning, defined by the team, and those that do not. The approach we take here is to adopt a framework from sociological theory that is impartial with respect to the form of pedagogy. This model provides a framework for analysis that furthermore enables the possibility of modifying strategies that will potentially bring about different outcomes. We will work in this model.

The focus of our analysis is therefore on the process of teaching, for which we require a theoretical framework and a language with which to classify systematically the effects of what we describe. For this, we will draw on the work of the sociologist of education, Basil Bernstein. For Bernstein the dominant communicative principle in the classroom is the interactional which regulates ‘the selection, organisation, sequencing, criteria and pacing of communication (oral, written, visual) together with the position, posture and dress of communicants’ (Bernstein, 1990: p 34). The communicative principle offers recognition and realisation rules which need to be acquired by communicants in order to achieve ‘competence’.

In this paper we have chosen to examine the practices of one teacher who is deemed to be successful[2]. We make no judgement however, choosing to analyse his teaching because we are aware of his drawing on an interesting mixture of strategies; what might be classified as some explicit approaches within a largely progressive mode of pedagogy. Drawing on Bernstein’s analysis we will characterise the interactions in Christian’s classroom in terms of these parameters (e.g. Bernstein, 2004, pp. 198/199) in an attempt first to provide a framework for a rigorous analysis of teaching and, second, to offer some insights from that analysis for what might constitute successful teaching in the context of the use of ICTs in mathematics for equitable outcomes.

[2] Christian (not his real name) has been earmarked as an excellent teacher for many years - he was seconded to his local university at one stage; he has been involved in a number of submissions for awards for the schools (they won the national numeracy award in 2005; commonwealth ICT award in 2004; and the state literacy award in 2005). He has represented the school on numerous events; was asked by the AAMT to present his work at the middle years conference - an invitation only conference at which leading teachers across the nation were invited to present on their work.

The framing of the pedagogic interactions can range from strong to weak. In the latter case the pedagogy is what Bernstein calls invisible, that is, means of gaining the approved discourse and being able to demonstrate the acquisition of that knowledge are hidden from the students. Middle-class children, however, have generally acquired these rules from their home life and are therefore not disadvantaged by the weak framing, whereas working class children have not and therefore find themselves in a position where they cannot demonstrate their knowledge. Research (e.g. Cooper and Dunne, 2000) shows that mathematics questions set in everyday contexts are a form of invisible pedagogy in that pupils who have not acquired the appropriate way to read such questions may find themselves responding in everyday mode and not the 'esoteric' school mathematics mode that is required. As teachers we tend to assume that pupils have picked up the correct reading in informal ways, and we are rarely explicit about those recognition and realisation rules. Publication of this phenomenon is sometimes interpreted as calling for a return to traditional teaching, since here the framing is strong and the rules visible. We know, however, that such classrooms fail most students for a range of reasons. In particular, if children cannot meet the requirements of reading, coping with the pacing of school discourse, and so on, at the early stage of their entry into schooling they are likely to find themselves in a unending spiral of remedial situations, through which they are publicly identified and because of which they fall further and further behind (Bernstein, 2004, pp. 204/5).

Research shows that working within a progressive paradigm, that is, where the pedagogy is invisible, but mitigating the weak framing through strengthening some of the features of the pedagogy can make a substantial difference to the success of disadvantaged students (e.g. Morais, Fontinhas & Neves, 1992). These are the kinds of analyses and research strategies that are enabled by the richly descriptive framework of Bernstein (and other sociologists of education).

Understanding Practice: Method

The Project - Numeracy, Equity and ICTs

This was initially proposed as a three-year study but was extended for one further year. The project explored the ways in which middle school teachers used ICTs to support mathematical learning. The overall study aimed to investigate:

- How ICTs are used in maths classrooms to support numeracy learning
- The out-of-school numeracy and ICT practices of students
- Synergies/gaps between home and school numeracy and ICT practices
- Elements of best practice that will help teachers to develop practices in schools when using ICTs that will support and enhance numeracy learning for students most at-risk of failure in school numeracy and/or mathematics.

The Method

Over a period of the study we worked with a range of schools, with a focus on the middle years of schooling. The schools were selected so that they represented the diversity of Australian communities including social status, geographical location, and sector status. Classrooms were also included that were both straight-age or multi-age. Schools from Queensland and Victoria were included. As the project evolved, some schools dropped out and others commenced. In this paper report? we are presenting the data from the initial schools that commenced the project. At the commencement of the project, schools were surveyed, with most teachers responding, on their computer usage, with a particular emphasis on how technologies were being used to support and enhance numeracy learning.

Data Collection Methods

A number of tools were used in the project. A survey was initially implemented to gain insights into the schools, their technology use, and the levels of confidence/skills among the teachers. All schools were provided with a video camera to use to capture their teaching when using ICTs. This method was adopted so that it would cater for the flexibility that is needed when undertaking classroom-based work, particularly in this study where schools were often considerable distances from the research team. In some cases, teachers were able to video their classes, in other cases, the method was too intrusive and the research team would go out and video lessons. Observations were also conducted of the lessons. Interviews were conducted with teachers.

To ascertain the background of students in terms of their numeracy and technology skills/usage, a method was employed where students took cameras home to photograph their out-of-school practices. Using a stimulated recall approach, interviews were conducted with the students once they had completed their photographs so as to identify their out-of-school practices.

Process

At the commencement of the project, a two-day workshop was conducted with the teachers to induct them into the project. Teachers were asked to distribute surveys to their peers. Each school was provided with a digital video camera and a supply of tapes to use for videoing lessons. Lessons were video taped, sent to the research team, downloaded on to DVD and then analysed. Running records were made of the tapes, and excerpts transcribed for detail analysis. Over the participation period, some schools participated in the collection of photographs in the out-of-school contexts.

Throughout the project, other workshops were conducted. These subsequent meetings were to monitor progress in the project but also to provide inservice/professional development opportunities for the teachers. Teachers working in the middle years of schooling, that is the upper primary/lower secondary, were invited to participate in the study. An initial full-day workshop was conducted at which participants were provided with an overview of the project and professional development to support their use of ICTs in mathematics lessons. At a follow-up workshop in the following year, schools were provided with resources to use in the classroom as well as sharing time in which participants shared their learning from the project and the activities they had been undertaking in their classrooms.

Survey

At the commencement of the project, schools were surveyed, with most teachers responding, on their computer usage, with a particular emphasis on how technologies were being used to support and enhance numeracy learning. A survey was developed and piloted with a small group of teachers separate from the study. This was to ascertain the clarity of the questions and to seek feedback as to whether or not other information should be sought. The final survey was distributed to all teachers in the participating schools. The responses to some of the questions will be the focus of subsequent sections of this paper. They have been selected as they indicate the extent to which computers are being used in the project schools; how they are being used to support numeracy learning; and teachers' backgrounds in relation to ICT use and implementation. These data are collated around the schools so that a sense of the differential use across the schools was observed. In terms of this project, this provided us with information that subsequently enabled us to make sense of classroom observations and other analysis we undertook. It also allowed us to consider the outcomes of the overall project.

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Video Data

As this was a project that sought to identify the ways in which ICTs were being used in the classroom, and where the focus was on the teaching practices being adopted, we used a range of tools to explore the phenomenon. Of particular interest to us was classroom practice. As such, video data were collected as the teachers undertook lessons. Over a period of 3 years, with a total of 10 schools ultimately participating in the study, we had a data bank of less than 40 lessons. In some schools, no video data were collected, whereas in two schools, the majority of lessons were video-taped. At the conclusion of the study, we sought to identify the reasons for this paucity of data, despite considerable attempts throughout the project to collect such data. While the threat posed by data collection through video was identified by some teachers as a reason, they did not see it as problematic. What was identified as the most significant factor was that they rarely used ICTs in their mathematics teaching. Indeed, as a number of teachers indicated, had it not been for this project where they were compelled to use ICTs, they would not have otherwise used them.

Data were collected through the use of video cameras. Each school was provided with a camera, tripod and digital videos. In part this method was selected so as to enable considerable data to be collected and subjected to multiple analyses within the context that many of the schools were considerable distances from the University. In one case, the school was over 2000 kms from the University, the next most distant school was approximately 450 kms. As such, a method was needed that would enable some consistency in data collection. However, the method was not easy for teachers to implement. Consequently throughout the project, the research team would visit schools with the intention of supporting data collection. This was met with mixed success. In some cases, it was possible to video lessons, in other cases, despite the distance travelled by the research team the possibility to collect video data was hindered by the lack of lessons that used ICTs being undertaken in the schools. In one case, despite many attempts to liaise with a school to support teachers with videoing classrooms, the camera was returned to the project unused.

Summary of the Overall Project

As a project that sought to identify the ways in which ICTs were being used in the classroom, and where the focus was on the teaching practices being adopted, we used a range of tools to explore the phenomenon. Of particular interest to us was classroom practice. As such, video data were collected as the teachers undertook lessons. Over a period of 3 years, with a total of 10 schools ultimately participating in the study, we had a data bank of less than 40 lessons. In some schools, no video data were collected, whereas in two schools, the majority of lessons were video-taped. At the conclusion of the study, we sought to identify the reasons for this paucity of data, despite considerable attempts throughout the project to collect such data. While the threat posed by data collection through video was identified by some teachers as a potential hinderance, they did not see it as problematic. What was identified as the most significant factor was that they rarely used ICTs in their mathematics teaching. Indeed, as a number of teachers indicated, had it not been for this project where they were compelled to use ICTs, they would not have otherwise used them.

The Schools

In total, nine schools participated to varying degrees over the four years of the study. Pseudonyms have been used for the schools and all participants in line with ethics protocols.

School	Description
Banksia	Metro school, low SES, outskirts of a major city, had been recognised nationally for it excellence in web-based learning
Snow Gum	Small, rural school located in a farming district; low to mid SES
Melaleuca Hills	Inner city, low SES
Huon Pine	Remote, mining town, large proportion indigenous students
Bottlebrush Plains	Mid SES; high technology use, multi-age, urban
Ash Gums	Mid –high SES; independent; high technology use
Weeping Willow	Regional rural school, low SES, considerable transience
Nettlewood	City, low SES, high proportion Indigenous urban students
Upper Cottonwood	Large P-12 college, new, ability grouping from Year 1.

Table 2: Brief descriptions of the Schools

Over the three years that data were collected in schools, a total of 9 schools participated in data collection. The schools were carefully selected using purposive sampling techniques. For the study, we were cognizant of representing the diversity in Australian schools. The schools were identified to represent the diversity of schools (government, independent); social demographics; geographic location, and cultural diversity that is across the Australian school sector. We also sought to include schools that were high technology-use schools. In the case of Banksia, this was a school in a low SES setting but had a strong focus on technology. It was intended that such sampling would enable us to explore any potential interactions of these variables so that we may be able to identify potential characteristics of classrooms where teachers had been using technology to enhance student learning.

Teachers working in the middle years of schooling, that is the upper primary/lower secondary, were invited to participate in the study. An initial full-day workshop was conducted at which participants were provided with an overview of the project and professional development to support their use of ICTs in mathematics lessons. At a follow-up workshop in the following year, schools were provided with resources to use in the classroom as well as sharing time in which participants shared their learning from the project and the activities they had been undertaking in their classrooms. Regular visits were conducted at the schools, along with phone calls and email conversations.

Classroom data were collected through the use of video cameras. Each school was provided with a camera, tripod and digital videos. In part this method was selected so as to enable considerable data to be collected and subjected to multiple analyses within the context that many of the schools were considerable distances from the University. In one case, the school was over 2000 kms from the University, the next most distant school was approximately 450 kms. As such, a method was needed that would enable some consistency in data collection. However, the method was not easy for teachers to implement. Consequently throughout the project, the research team would visit schools with the intention of supporting data collection. This was met with mixed success. In some cases, it was possible to video lessons, in other cases, despite the distance travelled by the research team the possibility to collect video data was hindered by the lack of lessons that used ICTs being undertaken in the schools. In one case, despite many attempts to liaise with a school to support teachers with videoing classrooms, the camera was returned to the project unused.

Results

Teachers Backgrounds in ICT Use

In this section we draw on the survey data to highlight the backgrounds and issues surrounding teacher knowledge, skills, and confidences in the use of ICTs in the middle years of schooling.

Technology Usage to Support Numeracy learning

In Table Two, the results are school means and then the sample mean for the question "What levels do you think students in your schools use ICTs for supporting and enhancing numeracy learning?" The rating schedule was 1= never; 2 = sometimes; 3= often, 4= very often.

School	Prep	1	2	3	4	5	6	7
Banksia	2	2.5	2.5	2.3	3	3.5	2.5	2.5
Snow Gum	1.9	1.9	1.9	1.9	2	2	2	2
Melaleuca Hills	2.2	2.2	2.5	2.3	2.7	2.7	2.3	2.3
Huon Pine	2.2	2.4	2.4	2.4	2.4	2.4	2.6	2.6
Bottlebrush Plains	2	2.3	2.2	2.3	2.3	2.5	2.5	2.5
Ash Gums	2.5	2.5	2.5	2.5	2.5	3.0	3.5	4.0
Sample mean	*1.9*	*2.2*	*2.2*	*2.3*	*2.5*	*2.5*	*2.5*	*2.6*

Table 3: Grade usage of ICTs to support numeracy learning

What can be observed from *Table 3* is that there is an increasing use of ICTs to support numeracy learning as the students progress through the school years. This reinforces the claims made by Downes et al (2001) cited earlier in the paper. However, what is interesting to note is the reported increase in ICT use in the middle years at Banksia where there is more reported use in these years than the upper years. This is the only school that violated the trend of increasing use as the students progressed through their schooling.

In terms of equity, what is alarming is the degree of usage of ICTs in the independent school in the upper years of schooling. Banksia and Bottlebrush Plains were included in the study because of their work with ICTS, however, they did not report the same use of ICTs in these years of schooling as did Ash Gums (the independent school). This suggests to us, that the independent school may be creating opportunities for their learners which may be very different from that of the state schools, at least in the upper years of primary school. However, as we noted at the commencement of the paper, quantity of access may not necessarily equate with quality. While there are still differences in the reported amount of ICT use between Ash Gums and Bottlebrush, our observations suggest that both of these classrooms provided high quality learning opportunities in terms of the resources available to the students as well as the learning outcomes, albeit, these were very different in structure and organisation. Ash Gums had opted for a withdrawal room where students undertook computer work in a very well supported technology laboratory whereas Bottlebrush Plains had opted for an integrated model with considerable access to computers.

As our study did not focus on the middle years of primary school (i.e. below grade 5), we are unable to comment on the learning environment of the middle years at Banksia. In the upper years, the students had access to both computing laboratory and in-class computers which were located at the rear of the room in a withdrawal room. We can only contend that such an approach may have been taken with the middle years. As such, we are unable to expand on the learning environment in the middle years and hence unable to clarify the learning of the middle years students despite the counter-trend noted in the data.

Programs used to Support Numeracy Learning

This question asked teachers to rate how often they used particular programs to support numeracy learning. The same rating scale was used as for Table Two: 1 = never; 2 = sometimes; 3 = often; 4 = very often.

School	Excel	CD games	Web	Logo	Word	Email	Drawing tool
Banksia	1.5	2	2.7	1	2.7	2.5	2
Snow Gum	1.7	2.6	2.3	1.8	3.1	2.9	2.7
Melaleuca Hills	1.8	2.8	2.5	1.3	2.5	2.9	2.7
Huon Pine	2	2.4	2.8	2	3.2	2.4	2
Bottlebrush Plains	2.3	2.8	2.8	1.8	3	2.2	2.8
Ash Gums	2.3	2.7	2.7	2.0	2.7	2	2.7
Sample mean	*1.9*	*2.6*	*2.8*	*1.6*	*3*	*2.4*	*2.5*

Table 4: Types of programs used to support numeracy learning

Table 4 suggests to us that commonly available resources may be a mainstay for teachers in that they are familiar with these and use them in their classrooms. We are unable to comment on the use of some of these tools (email, web-based, CD Games or Word) as we did not observe them. As part of the project, we did support the schools on the use of LOGO, drawing tools, excel and games. We were able to spend considerable time at Bottlebrush Plains and observe the teachers using LOGO; similarly with Snow Gum using drawing tools. What this table suggests to us is that there is little realisation of the power of tools such as spreadsheets or LOGO in middle school classrooms. Given the research that has been conducted with these tools in terms of their capacity to bring about rich mathematical understandings, what struck us was their minimal uptake in all schools in this study, regardless of the demographics of the schools.

Confidence Levels

Part of the capacity to use ICTs has been linked to confidence in using the tool and the disposition then to apply this to the approaches being used in the classroom. Teachers were asked to assess their own confidence levels as they currently feel them and then where they would like to be, similarly for their students. Our intention with this question was to ascertain whether there were some areas which may be more important for teachers than others. The numbers alone are their current confidence levels while the numbers in brackets are their preferred levels)

School	T/ICT	S/ICT	T/ICT for numeracy	S/ICT for numeracy	T/ICT for literacy	S/ICT for literacy
Banksia	3.3 (4)	2.7 (3.7)	2.3 (3.3)	2.3 (3.3)	3.3 (4)	3 (3.7)
Snow Gum	3 (3.6)	2.6 (3.5)	2.6 (3.6)	2.1 (3.5)	2.8 (3.6)	2.5 (3.5)
Melaleuca Hills	3 (3.8)	3 (3.2)	2.8 (3.2)	2.8 (3.5)	2.8 (3.5)	3 (3.3)
Huon Pine	3.4 (4)	2.6 (3.7)	3.2 (4)	2.9 (3.8)	3 (4)	2.9 (3.8)
Bottlebrush Plains	3.2 (3.8)	3.1 (3.9)	2.9 (3.8)	2.9 (3.8)	3.3 (3.8)	3.1 (3.9)
Ash Gums	3.7 (4)	3.7 (3.3)	3.3 (3.7)	3 (3.3)	3.5 (3.5)	3.2 (3.3)
Sample mean	*3.2 (3.8)*	*2.9 (3.6)*	*2.9 (3.8)*	*2.6 (3.6)*	*3.1 (3.8)*	*2.8 (3.6)*

Table 5: Confidence levels with ICTs

With this question teachers used a scale of 1 = very low; 2 = low; 3 = reasonable; 4 = high. The results from this question posed a conundrum for us in that the literature often portrays younger generations as being the techno-savvy generation, and their older peers as more likely to be technophobes. The responses here show a counter position being taken by the teachers. In every case, teachers rank their confidence with technology as being higher than their students – whether for general ICT usage or specifically targeted at numeracy or literacy. Similarly, there are no differences between schools. These ratings are in stark contrast to the data we collected in the subsequent interactions with the participating teachers. In the case of Bottlebrush Plains, for example, the teachers would allow the students to manipulate the technology

It appears from these data that teachers were more confident in using ICTs in supporting literary than in supporting numeracy with teachers and students at the independent school being more confident in all areas than their peers in the government schools.

Skill Levels

In this question, we sought to identify how teachers rated their skill levels, again using current and preferred levels. With this question we were seeking to see how teachers rated their skill levels and where they would like to see improvement, or whether they felt that they had sufficient skill in that particular area.

School	Internet	Excel	Logo	Word	Drawing	Games Educ'l
Banksia	3.3 (3.3)	2.7 (3.3)	2 (3.3)	3.7 (3.7)	3 (3.3)	3.3 (3.3)
Snow Gum	2.9 (3.5)	1.6 (3.2)	1.4 (3.2)	3.3 (3.7)	2.2 (3.4)	2.8 (3.5)
Melaleuca Hills	2.8 (3.5)	1.8 (3.3)	3 (3.5)	2.8 (3.5)	2.8 (3.5)	2.8 (3.5)
Huon Pine	3.4 (4)	2.6 (4)	2 (4)	3.8 (4)	2.6 (4)	3 (4)
Bottlebrush Plains	3.5 (3.9)	2.8 (3.9)	2.2 (3.8)	3.4 (3.9)	3.3 (3.9)	3.3 (3.9)
Ash Gums	2.7 (3.7)	2.3 (3.3)	1.5 (3)	3.7 (4)	2.7 (3)	2.3 (2.7)
Sample mean	*3.2 (37)*	*2.3 (36)*	*1.7 (35)*	*3.4 (38)*	*2.7 (36)*	*3 (3.5)*

Table 6: Teachers' skill levels on various programs

These data alerted us to a number of issues – Ash Gums does not see it as important to have skills in educational games technologies. On top of this, the staff were often in the lower ranks in terms of their skill levels against their peers in government schools. This outcome is surprising given the data in Table 3 where Ash Gums uses many of these tools in schools and yet the teachers report not being skilled in their use. Unlike the other schools, Ash Gums has a very contemporary computing laboratory with a designated computing teacher who is keenly interested and highly skilled in the use of technology. Students are taken to this laboratory for their computing lessons and then follow up in class. The classroom teacher accompanies the class to the laboratory to see what they are doing with the expectation that the learning in the computer session will be followed up in class. As such, unlike their peers in the government schools where there were attempts to model this high tech classroom, the resources (teacher and computer) were much more restricted in all state schools by comparison. When these data are considered in the contexts of the schools, it is not so surprising.

As can be seen from this table, the skill levels of the teachers are much lower in the areas directly associated with numeracy – spreadsheets and LOGO, along with drawing tools. As such, the depth of professional learning related to tools to support numeracy learning appears to be limited.

Analysing Teacher Responses: Interim Summary

What these data have enabled us to theorise is the poor outcomes we experienced in this project in terms of the uptake of ICTs to support numeracy learning. By including high-tech (and low-tech) schools in both state and independent sectors, and in high and low SES schools, we had anticipated being able to identify the ways in which teachers used these tools to support numeracy learning. However, the data indicated that there is little uptake in schools. The data here suggest that confidence and skill levels with these tools may be part of the issue. As part of our project we undertook minimal professional development, but participation in the project motivated some teachers to used ICTs. In other cases, the professional development and participation in the project was still insufficient to change practice. As one of our participants noted in interview, “I would like to do more of this work but I need to know how it works but how do I do that? How do I learn?” While such a comment is reminiscent of a particular model of teaching, noted by Clements in the earlier parts of this paper in that she felt she needed to know more about the ICTs (in this case spreadsheets) if she were to use them as a teaching tool, it does suggest that teachers feel they need more support to be able to use ICTs in their classrooms. The data on the uptake across year levels, coupled with the teachers’ knowledge suggest that, in terms of equity, more work may be needed for teachers if they are to begin to add digital capital to those students, particularly those students who are entering our schools behind their more digitally-advantaged peers.

Analysing Video Data: Quality Learning Environments

In analysing the classroom video data, we elected to use two main methods. The first derives from the Productive Pedagogies rating process that was used in the Queensland Schools Longitudinal Reform Study. This approach had been established by the researchers working on that project so enabled a reliable measure to be employed. Furthermore, due to the large data collected in the QSLRS study, there was a resource to which we could compare the data from this study.

A second method, which was more qualitative in approach, sought to describe the features of a lesson in which a teacher used ICTs. This approach aligned with a case study methodology and sought to describe the features of the lesson. In particular, this second method was employed so as to illuminate features of teaching that could not be described or identified through the quantitative approach described above. These two different methods allow for a description of the approaches used by teachers in this study.

Analytic Process: Using the Productive Pedagogies Framework

While a number of analyses are being conducted on these videos, the focus of this paper is on the use of the productive pedagogies framework. We adopted the method used by the research team conducting the wide-scale longitudinal QSLRS project. The method involves 2-3 reviewers observing the lesson, in this case a video of the lesson. Independently they rate the dimensions of the productive pedagogies for overall evidence in a particular lesson. In our case, this involved one of us working with the research team in the initial lessons, and then the research team (3 research assistants) taking responsibility. From time to time, one of the researchers would work with the team to ensure that there was validity within the framework.

At the completion of each lesson, the researchers independently rate the lesson on a 5-point scale where 0 means there was no evidence of a particular dimension of the scale whereas 5 indicates it was evident throughout the lesson. Once these ratings are completed, the team then must agree to a common score. This may require negotiation of meaning around a particular dimension and the degree to which they interpret the presence of a dimension. At the end of each observation, there is a commonly agreed upon score for each dimension of the framework. It is this agreed-upon score that is reported in this paper. These discussions were taped so that in the event of any need to come back to how a score was agreed upon, the tapes could be recalled.

By focusing on the overall lesson the dimensions of the productive pedagogies become significant. For example, it may be the case that in the introduction to a lesson that the teacher uses a particular strategy (e.g. encouraging the students to negotiate the task) but as the lesson gets under way it may be very teacher-directed. As such, the intent of the framework is to examine the overall emphasis of the lesson rather than elements of the lesson.

Productive Pedagogy Ratings

In presenting these data, we used the combined data set of all lessons from all schools. In doing this, our intention is to identify the presence of particular aspects of pedagogy in mathematics classrooms when teachers use ICTs to support student learning. In total, 40+ lessons constitute the collection of lessons. These are from the participating schools in Queensland.

Dimension of Productive Pedagogy	Mean	SD	Comment
Depth of knowledge	1.64	1.36	
Problem based curriculum	2.19	1.38	medium
Meta language	1.69	1.07	
Background knowledge	1.76	1.16	
Knowledge integration	1.48	1.27	
Connectedness to the world	1.38	1.44	
Exposition	1.19	1.64	
Narrative	0.31	0.78	low
Description	2.24	1.02	medium
Deep understanding	1.43	1.47	
Knowledge as Problematic	1.14	1.47	
Substantive conversation	1.26	1.40	
Higher order thinking	1.31	1.55	
Academic engagement	2.23	1.38	medium
Student control	0.79	0.92	low
Self regulation	3.24	1.12	high
Active citizenship	0.30	0.78	low
Explicit criteria	2.83	1.17	high
Inclusivity	0.33	0.75	low
Social support	2.51	0.25	high

Table 7: Results of Productive Pedagogy Analysis

The results in *Table 7* give some indication of the scoring of pedagogy when teachers used ICTs to support mathematical learning. While it was not possible to apply a reliable inferential statistical measure on these data, it is possible to note some trends. On a 5-point scale, scores below one included student direction, active citizenship, inclusivity and narrative. These aspects of productive pedagogies were consistently poorly attended to in the teaching of mathematics. This can also be seen in the low standard deviation measures suggesting that it was relatively common across all sites.

In considering those aspects that scored above the midpoint (i.e. above 2.5) self regulation, explicit criteria and social support scored well. Just below the midpoint, also worthy of consideration, were problem-based curriculum; description; and academic engagement. Perhaps, for us, the most disconcerting aspect of these scores is the low scores for intellectual quality and relevance dimensions. Given the massive amount of work that has been undertaken in this reform as well as mathematics education more generally, these scores are alarming. However, they are not surprising since they are aligned with the scores obtained in the original QSLRS.

Productive Pedagogies Discussion

The key categorisation framework, but not the only one, that we wish to use here to discuss the results and their potential effect on students is that of Bernstein's visible and invisible pedagogies. For Bernstein the dominant communicative principle in the classroom is the interactional which regulates 'the selection, organisation, sequencing, criteria and pacing of communication (oral, written, visual) together with the position, posture and dress of communicants (Bernstein, 1990, p 34). The communicative principle offers recognition and realisation rules which need to be acquired by communicants in order to achieve 'competence'.

The framing of the pedagogic interactions can range from strong to weak. In the latter case the pedagogy is what Bernstein calls invisible, that is, means of gaining the approved discourse and being able to demonstrate the acquisition of that knowledge are hidden from the students. Middle-class children, however, have generally acquired these rules from their home life and are therefore not disadvantaged by the weak framing, whereas working class children have not and therefore find themselves in a position where they cannot demonstrate their knowledge. Research (e.g. Cooper and Dunne, 2000) shows that mathematics questions set in everyday contexts are a form of invisible pedagogy in that pupils who have not acquired the appropriate way to read such questions may find themselves responding in everyday mode and not the 'esoteric' school mathematics mode that is required. As teachers we tend to assume that pupils have picked up the correct reading in informal ways, and we are rarely explicit about those recognition and realisation rules. We know, however, that such classrooms fail most students for a range of reasons. In particular, if children cannot meet the requirements of reading, coping with the pacing of school discourse, and so on, at the early stage of their entry into schooling they are likely to find themselves in an unending spiral of remedial situations, through which they are publicly identified and because of which they fall further and further behind (Bernstein, 2004, pp. 204/5).

Research shows that working within a progressive paradigm, that is, where the pedagogy is invisible, but mitigating the weak framing through strengthening some of the features of the pedagogy can make a substantial difference to the success of disadvantaged students (e.g. Morais, Fontinhas & Neves, 1992).

Looking at the outcomes of the productive pedagogy research, the higher scores indicate both invisible pedagogy (self regulation) and aspects of visible pedagogy (explicit criteria). Potentially that can indicate pedagogical interactions that respond to popular calls for a reform curriculum mitigated by a strengthening of the framing that can assist students from traditionally failing social groups to acquire the rules they need to succeed in mathematics (Lerman & Zevenbergen, 2004). The low score on narrative, which is contrasted against an expository style of teaching, also indicates a strengthening of framing towards, in fact, a more traditional (in Bernstein's terms, performance) mode. The scores just below the middle of problem-based curriculum seem to indicate the teachers' compliance with the curriculum aspect of the New Basics in Queensland.

The low score of student direction, however, appears to contradict the teachers' use of explicit criteria. Teachers' lack of awareness of the different needs of different social groups in terms of criteria may be reflected in the low score on inclusivity.

We remind readers that all the lessons that were observed, video-taped and analysed using the productive pedagogies framework were ones in which the teachers were using ICTs. Of course there are many ways of using ICTs and not all of them enhance the learning of mathematics in the same way, or even at all (for further discussion of how teachers in the project were using ICTs see Zevenbergen & Lerman, 2005 and Zevenbergen, 2004). In conclusion we might observe that under the influence of New Basics in Queensland and mediated by teachers' practices, ICTs are being used and the framing of these classrooms may in fact offer the opportunity for successful learning by more students. We conjecture, however, that, without explicit awareness by teachers of the implications of different forms of pedagogy on different social groups the aims of the New Basics in terms of more equitable outcomes are not likely to be met.

Creating a Quality Learning Space: A Case Study

In this section, we discuss the experiences in one classroom. This episode is taken as one example of many of the quality experiences we observed in the project - and there were many. The classrooms varied in terms of approaches and content. The episode we explore in this section is representative of one example of what we saw as quality (and rated highly on the productive pedagogies rating scale). There were other examples in other classrooms and schools. We select this one as representing the quality that was apparent across schools.

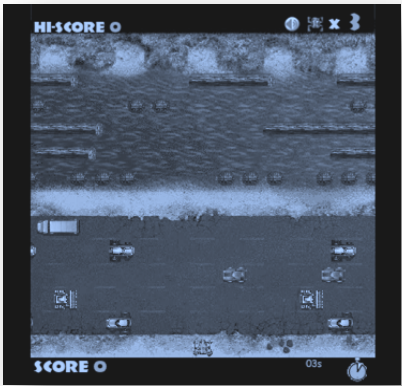
Classroom Ethos

The classroom from which the data are drawn is a multi-age classroom consisting of three year levels - Years 5, 6, and 7 – so the students are aged from 10-13 years. The teaching space is a double teaching area with two teachers and approximately 58 students. The teachers co-plan their teaching within their classroom and across the sector (i.e. the two other multi-age classrooms at this level). The organization of the classroom is such that the teachers devote a full day's work to these units ("Rich Tasks" as described by Education Queensland 2003). One teacher works with students on aspects of the task that support the learning needed for developing concepts while the other teacher works with the technological aspects of the unit. As such, at any particular time, approximately $^{1}/_{3}$ to ½ of the class could be using ICTs. We have focused on this aspect of the classroom to document how the teachers scaffold student learning when using ICTs to support mathematical learning.

In this classroom, Christian has established a practice which he describes as only giving them a part of the information that is necessary and then leaving them to 'discover' what else they need. He is happy for the students to share their findings with other students rather than expecting all students to discover what is needed to solve the task. He describes his process as being akin to problem posing where he poses a task for the students who then are given some information which will help them to get started on the problem but will need to work through the task in order to discover what is needed to continue. This form of teaching is commonplace in his classroom.

Christian also offers other prompts to the students. These can be in the instructions or information that he has printed and placed on walls. This enables students to work independently when they are stuck at particular points. It also enables the teacher to work with the students who are focused on the problem and not aspects of the task that could be achieved through other means (such as when students have not paid attention to instructions etc).

In planning the overall Rich Task, the teachers have identified the particular skills and knowledges the students will need to be able to construct the final model. They have then broken these down into smaller tasks and embedded them into more meaningful contexts. One such task required the students to construct a dynamic model of the Solar System. To be able to construct the commands for the turtle to draw the solar system, the students need to be able to program the turtle which requires an understanding of the programming language. This includes directions and distances, as well as constructing shapes. In the first extract taken for this paper, the teachers have planned the learning so that the students will be able to develop understandings of direction and distance. In the full day, the students constructed a replica of the game “Frogger” or “Hopper” where a frog hops across a road and river. The students need to construct a pad to control jumps up, down, left and right. To create the illusion of hopping, the commands are in units of ten with pauses. The students construct a control pad when four turtles have been used for each direction. This enables them to move the turtle around the screen with the arrow keys. This process developed their thinking and knowledge in relation to the programming knowledge while providing a context that engaged the students.



Teacher Beliefs and Pedagogy

Over an extended period of time, one of us has been involved extensively with Christian and his school. Christian has taken a considerable leadership role within the school as a teacher-leader, that is, as a classroom teacher he has been instrumental in instigating and leading many reforms. Most recently, he has been working with two key reforms – New Basics and Philosophy in Schools –which resonate with each other. New Basics is a reform in Queensland schools that radically reconceptualises curriculum, pedagogy and assessment (Education Qld, 2005). Philosophy in Schools is a movement that exposes teachers and students to the use of philosophy to contest taken-for-granted views of the world through a particular strategy. As part of the New Basics reforms, schooling is broken into three-year blocks (Years 1-3; 4-6; 7-9; and 10-12) and within these blocks, students work on developing repertoires of practices (skills, knowledges, dispositions) that will support them in a rich learning experience (Rich Task). Within such tasks, there is considerable integration of knowledge across discipline areas (transdisciplinary knowledge).

In his approach to teaching, Christian has a disposition to “think outside the square” and decided that rather than make a model where there was papier maché models hanging from the ceiling, students would use computers to do it. Having no knowledge of Microworlds, he began researching how it worked and what he would need to know to support his students’ learning.

The learning environment and how Christian had learned about computers became the catalyst for how he reorganised his classroom. Students worked in pairs at the computers. A main computer was used to project on to the white board. Christian worked in a traditional mode at the front of the classroom, modelling the examples in a format that is typical of most classrooms. As examples are explained, students control the display computer so that a range of mediums are used simultaneously. Christian supported the students' control of the main computer for a number of reasons which he has progressively discussed over the projects. He felt that he understood the basics of how the Microworlds environment works but also recognised that some of the students are more advanced in their knowledge of the program. Usually these were the students who had been in Christian's class in previous years or who had access to technology in out-of-school contexts. These students had become very involved with the package and would spend any free time playing with the software so that they were highly competent with the commands and interface. At one point, he proposed that the students were more competent than him, as a consequence of which he felt that it was most appropriate for them to be in control of the technology. Christian also argued that it was good role modelling to have students working with the technology in that it created a distribution of control and power within the classroom. Christian would often prompt those with the computer by indicating he was not sure what needed to happen knowing that the students would be able to work through the problem. He also felt that, with the students working on the computer modelling the process in a digital format, he was able to provide other mediums for understanding the concepts that were embedded in the lesson.

In setting up the classroom, Christian was keen for the students to interact with each other and to share information. To establish an environment where the students could take risks, Christian saw it as critical that students felt safe in what they did, "that it was OK to make mistakes"; "that it was OK to copy off the people next to you"; "that is was fine to ask for help from others"; and "that students needed to share their findings with others". He saw that many of these characteristics were ones that were embraced within the world beyond schools so felt that they should be encouraged in the environment that he was developing with the computers.

Planning

Teaching effectively often requires teachers to think through what is intended and potential barriers to learning (Mousley, Sullivan, & Zevenbergen, 2004). In planning for learning, Christian (and his teaching partner, Mary) undertook a backward mapping process that is commonly used in planning for Rich Tasks (Education Queensland, 2000) or mathematical investigations (Zevenbergen & Griffin, 2005) where the goal is considered and then teachers identify the necessary learning experiences that will create opportunities for students to learn the necessary skills, knowledges and/or processes that will enable them to complete the performance assessment item.

There were many features of the program [Microworlds] that students would need to use to complete the project successfully. In addition, there were many new mathematical concepts that students would have to come to understand for successful completion. We didn't want to 'teach' these features and mathematical concepts in a formal expository way, rather we wanted to create a problem solving community where students could do as many steps in the problem solving process as they possibly could with teachers providing just the right amount of support at just the right time. With this in mind, we devised a series of small projects, which would enable students to master the necessary program features and mathematical concepts needed for the final major project. We arrived at these particular mini-projects after reflecting on the experiences we had had when we created our own dynamic model of the solar system. (Zevenbergen & Judd, 2005)

Using Technology to Enhance Learning

ICTs can be used in much the same way as other technologies, including calculators. The extensive literature on calculators has brought forward strong arguments for calculators to enhance deep understandings of many mathematical concepts (Groves, 1993; Ruthven & Chaplin, 1997; Stacey & Groves, 1996) across sectors of schooling. More recently, research on the use of graphing calculators has shown the potential of these technologies to enhance learning (Goos et al, 2001). The ways in which Christian plans the use of ICTs to support learning is such that the technology is integrated into the learning environment. His approach is shown below:

> *We use technology in the classroom in the main, trying to get it a seamless part of the curriculum. We don't look at the computers as an object of study, we look at them as an opportunity to further the classroom goals. Wherever possible, because we're working with Rich Tasks, the tasks that we elect to do have fairly prominent parts of them that need to be in some way constructed or developed through the use of computers.*

From his approach, Christian sees technology as a tool to support learning rather than as an end in itself. This theme is consistently evident in his teaching approach.

Below we present some classroom dialogue from the Microworlds context discussed above.

Task: Constructing a Control Pad Using Microworlds

In this section we draw on an episode from a much larger unit. The unit requires the students to construct a dynamic scaled model of the Solar System using Microworlds. This was the first time the class had used this software package, so some scaffolding was needed to support both the mathematical and technological learning. In terms of the mathematics, the unit was rich in scale and ratio. Students had to construct scaled models of the planets, their moons, and the distance between the planets relative to each other and the sun. This knowledge then had to be transferred into LOGO language and then programmed so that the turtle would be able to draw the Solar System. The data used in this paper is a part of the unit where the students are constructing the directional control for the Hopper game.

Teacher (T) points to one of the quadrants and asks students (S) to open up the arrow. Turtle commands appear on the screen.

T: OK, these are the instructions. Let's just see if you understand what this one stem of the instruction is saying here. [points to the first cluster of commands]

T: *It says, "Hey Turtle One, I'm talking to you". You can see that with the T1 and then the comma, it is actually saying something to the First turtle. It saying "set your heading to Zero, North* [T points north, i.e. up with large ruler]; *Move forward 10 paces* [pointing to the next sequence in the command] *and do that once.*

Teacher then explains that the turtle only needs to do this once or it will go for a lot longer. He then asks student to select the command and then copy.

Student copies the command, T waits and Ss chatter while the S does the command copy. T then points to the East arrow and explains that they are now going to look at what they need to do to get the turtle moving to the East. Asks S to click on East arrow (to bring up command on screen)

T: *If we paste in the instruction from before, what will we need to do to get it to go East?*

[pauses for a considerable time]

Many students have their hands raised. Some students are working at computers. He stops and then suggests that they think about the question. He then rewords the question by asking:

T: *My question is this: What part of the instructions do I need to change to make it go East?*

Looks at the S at the computer who is unsure and seeks her input. No response, other students mumbling responses. T seeks input from other student who is not sure and offers an incorrect suggestion. T does not correct but stands with ruler pointing up (to represent North) and reminds students that when pointing up, this is zero degrees. He then rotates ruler through 90 degrees to show an Easterly direction.

T: *So if I move through this many degrees to be going East, what have I done?*

Students offer a range of ideas, some debate as to what is being asked. Students talking as a group. Informal consensus emerges as a few students become more convinced that it requires a turn of 90 degrees. Christian stands and listens to students without commenting.

S: *90*

T: *OK, so change that to 90*

Boy at computer is a bit slow as he changes the 0 to 90. Teacher asks if it is OK. Change to 90 is done and then teacher tells "Press OK". Teacher points to East arrow with the ruler.

T: *OK, so now we have got our North and East Arrows working. So who wants to set up their own arrows now?*

Students indicate that they are ready to go.

T: *Alright then, away you go.*

Students move to desks and begin to work on their computers. The lesson continues with students working in pairs at the computers. As they create the command for the East button, there is some discussion on recalling the process. When they move to the South button, there is considerable discussion as students negotiate the changes to the commands they need for the southerly direction. As some students co-construct the new command – that being a change to 180 – there are gleeful comments coming from workstations as success is achieved. Students are happy to share their findings with others who ask. Other students continue to work in their pairs until they solve their own command instructions.

In this transcript, the ways in which Christian scaffolds learning and interactions becomes apparent. As can be seen, he affords control of the computer to the students while he models aspects of the learning in other mediums (board, tools, etc) so that there are concurrent modes of representation available to the students. It is also possible to observe the ways in which he interacts with the students to challenge their thinking and move them forward in technological thinking as to how to construct the control pad.

Christian's use of questions to provoke thinking and co-construction of meaning is apparent when he asks students to consider how to make the turtle turn 90 degrees. He allows considerable talking and arguing to occur so that the students talk through the problem and the necessary strategies to solve the task. He does not intervene but rather allows the students to come to a consensus. This is a strategy that he uses throughout his teaching. He advocates strongly for its use as he believes that this encourages the students to think through the problem and draw on their mathematical and technological knowledge to solve the problem.

Christian articulated his strategy as one where he believed it was critical for the teacher to give the students enough information so that the students could see the problem, but without too much guidance to constrain their thinking. The debates that emerged when they were discussing how to construct the "east" command enabled students to talk through the potential strategies that they would need to work through the problem. This discussion was critical in shaping their thinking and strategies needed for the construction of the 'south' command that occurred in the next phase of the lesson. Christian did not want to intervene on this latter part, believing that if he had provided "enough rope for the students, they would be able to work out the problem themselves" (post lesson interview).

Analysing Teachers' Strategies

As we mentioned above, we are examining the teaching of one teacher who is successful in terms of equity, not student learning. In order to be able to make justifiable and useful statements about such pedagogy we will now re-examine his teaching using the tools of the Bernsteinian framework described above. Our intention is that this will serve as an illustration of the application of one systematic perspective. Clearly the study needs to be extended across a range of teachers and pedagogic forms. We will examine most but not all of the features of the framing; to say more would require a longer paper. Bernstein describes strengths by using + and – signs. Very weak framing, which is characteristic of reform classrooms, would be labelled F^{--}, whereas very strong framing, characteristic of traditional classrooms, is labelled F^{++}.

Hierarchy

In these exchanges it is clear that Christian takes on the role of transmitter and regulates the interactions such that the pupils learn the rules of being acquirers[3]. Authority of knowledge, as well as the 'moral' authority, rests with the teacher, although he sets up learning relationships that enable the pupils to feel themselves in control of their own learning, as in the episodes described in Goos, Galbraith and Renshaw (who the F is this?) (1999). These positions have been established by the teacher over time and are evident in the extract. Christian reviews the prior work, with the appropriate form of participation of the students, and when he turns to them to say, "Who wants to set up their own arrows now?" the students respond appropriately again, according with his expectations. We would therefore label this F^{+}.

Sequencing

Christian carefully sequenced learning activities so that the overall goal of the teaching (a dynamic solar system constructed in Microworlds and convincing arguments arising from the data analysis) was progressively developed through crafted activities (such as the Frogger/Hopper example) which identified particular skills and knowledges that the students needed. These could be mathematical or technological, but in either case, there was a planned pathway for the students to build progressively their learning from each session to the next. While Christian did not make these explicit to the students, the mini-tasks he developed were seen as activities in and of themselves but, more critically, developed the knowledge needed by the students for subsequent activities. The example provided in this paper is one of many sequenced activities that students undertook as they developed the repertoires needed for the final product and indeed even in this short extract we see a summary of the foundational work on the Control Pad before the students are set to work to develop the activity. We would label this F^{+}. Stronger framing might be evident in a textbook based classroom where students also know what comes next in their learning.

[3] The terms 'transmitter' and 'acquirer' are to be understood as descriptions of roles, or of positions, not in terms of a particular form of pedagogy. In common language these terms are nowadays taken to be pejorative and typical of an unpopular form of pedagogy, called indeed transmission teaching.

Criteria

As an essential part of the teaching process, criteria were made explicit to the students. This is one of the key elements of the productive pedagogies framework (Education Queensland, 2000). Christian's class were given these criteria at the commencement of the overall tasks so that the students were acutely aware of expectations. Throughout the tasks, criteria were negotiated by the class – to clarify what was meant or to adjust what could be expected as the tasks progressed. This final point needs to clarified in that the criteria were renegotiated as the demands of the task were realised. In some cases what were anticipated to be easily obtained outcomes were too challenging for the students whereas in other cases, students readily met and exceeded criteria. Throughout the process, students were an integral and central part to the explication and negotiation of criteria, but always within the bounds set by Christian. Again we would label this F^+.

From the extract and our extensive observations of this classroom, appropriate pacing was a key strategy employed by the teacher. Christian readily placed "cheat sheets", diagrams, charts and instructions around the classroom so as to enable students to work through the tasks in ways that were appropriate to them. He did not see such scaffolds as shortcuts as the ethos that had been developed in the classroom was one where students would use the written scaffolds when needed or when they felt overwhelmed. Christian recognised that over time, students engage at different levels – some days a students would be highly motivated, other days less motivated. Through the provision of the sheets, students chose the pathway they needed at particular times.

In terms of his teaching Christian's oral pacing was quite different to the fast pace of many traditional classrooms. Christian, through his Philosophy training, strongly supported students having time to think before responding. The ethos of the classroom was one where students had learned to consider their responses. This strategy meant that students were given considerable time between the time a question was posed and the seeking of responses. In the extract, following his question, "If we paste in the instruction from before, what will we need to do to get it to go East?" Christian waits quite a long time, even after a number of students have responded with an answer of 90 degrees. A more strongly framed classroom might see the teacher pushing on immediately the first 90 response was given, whereas in a more weakly framed classroom the teacher would not have responded at all but let the students go off in their own directions. We would therefore label this F^-.

Position of communicants

As noted earlier in this paper/report, the positioning of students in the classroom was one where they were in pairs at computers, on the floor or at the back of the room controlling the software. Christian would assume positions all over the classroom depending on the discussion and focus. The positions available to students facilitated a very different dynamic in the classroom from that of the more traditional, didactic environment. There was no clearly identified position of control. Sometimes this was with Christian, sometimes with the students controlling the software, sometimes with the students on the floor or at desks. The positioning of the communicants is not obvious from the extract. We would label this F^-.

Selection of communication

Christian established the acceptable norms of communication; what was appropriate for students to say, when, and also the degree of control of the communication that he kept in his hands. Such a degree of control, though, is not that of the traditional classroom. We would label this F^+.

Feature of pedagogy	Strength of Framing
Hierarchy	F^+
Sequencing	F^+
Criteria	F^+
Pacing	F^-
Position of communicants	F^-
Selection	F^+

Table 8: Communication Framework

Although the general characteristic of Christian's classroom is that of a liberal-progressive pedagogy, some elements of the form of pedagogy are stronger than is typical. We would argue, in a similar way to that we used when describing the classrooms in Boaler's recent study (Boaler et al, 2004); this strengthening enables the rules for recognising what counts as the task and for realising an appropriate text to be available to a wider range of social backgrounds than is normally the case.

Initial observation of the outward features of Christian's pedagogy would lead one to assume framing of either F^- or F^{--}. In fact through the more detailed analysis we see that his teaching falls between F^- and F^+. If the pacing of this lesson is considered as an example, we argue that the strategy used by Christian, namely that of a slower pacing, that this is an more enabling pedagogy as it allows students to engage with the content of the lesson – mathematically and/or technologically. Christian's pacing also enabled students time to think through issues individually and collectively, so that they were more able to talk through their thinking processes with peers to form a more informed (rather than reactionary) response to the questions being posed in the lesson. Christian actively encouraged students to talk with each other in their preparation of responses. He did not evaluate their responses as they were offered, often deferring the responses to the class to evaluate, build upon, challenge, until a response could be negotiated that made sense to the group could be tendered. This strategy was enabling for all students.

Similarly, having various forms of text (written, visual) placed around the room enabled students to engage with the content in ways that were in their control. The shift from the teacher to the classroom in terms of who controlled interactions was a very different situation than that found in most mathematics classrooms. As such, this would be a more inclusive practice in that it allows students access to information in their time, at their pace, and at the time of need.

In this paper we have set within the context of mathematics teaching in Queensland, with all the affordances and constraints of State policy, but also within the pedagogic ideals and goals of a particular (highly regarded) teacher a framework for analysing teaching, independent of classifications such as reform or traditional. We suggest that the framework can enable a systematic examination and comparison across teachers and across sites and at the same time provide a perspective that can lead to changes that can improve the opportunities for pupils to succeed. Following Bernstein's argument that invisible pedagogies can lead to pupils from underprivileged environments failing disproportionately, particular aspects of a teacher's pedagogy, such as pacing, can be strengthened, and the outcome in terms of improved pupil learning can be measured.

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