Learning through information communication technology: Critical perspectives

The relationship between theory, research and practice with a focus on secondary school mathematics

Technology in secondary schools has become of increasing interest as the power of the micro chip has developed. For the students of Mathematics, computers and hand held graphic calculators need to be accessible to all. They are relevant to the needs of the students' courses and to support and develop their Mathematical learning (Smith, 1997). Secondary School Mathematics today is more than just rote learning or completing a set algorithm, ultimately it is the ability to use the skills taught in Mathematics for everyday life activities. From this base of understanding comes the use of problem solving skills and the ability to think logically. Teachers use themselves and the wealth of subject content along with developing craftsmanship in imparting that knowledge. Together with the students, text books, overhead projectors, white boards, and chalk you can add computers and graphic calculators to the tool box of avenues to enhance learning.

This article looks at the growth of Information Communication Technology (ICT) in Education, some current research and a critical look at ICT with respect to Secondary School Mathematics.

Theory

Our task as teachers is to provide students with the knowledge on how to learn. This is achieved through different curriculum areas to provide students with a knowledge content base that also adds lustre, interest and motivation for the students in that learning process. Technology can support that learning by providing a medium that is constructive, active, authentic and cooperative (Jonassen, Peck & Wilson, 1999). Jonassen, Peck and Wilson (1999) discuss a five point social model that is within meaningful learning, and which fits in well with constructivist perspectives.

1. People have always been able learn and adapt to their environment so this requires observational and *active* manipulation.
2. In order to learn, students must also be able to reflect on previous activity in order to *construct* new knowledge.
3. Human behaviour has always had a reason or *intention* for doing something.
4. As teachers we sometimes reduce an idea to its simplest form in order to make it easier to teach. In doing this we strip away the richness and the *authentic* aspects of that idea for our students.
5. In the world today, the catch phrase globalisation has taken on a greater meaning as we can watch live television from almost any part of our world. We naturally seek and have to work with others in a *cooperative* environment whether we are learning, living or working together.

Metacognition

Metacognition can be described as the thinking behind the doing or a knowledge of cognitive processes as well as the controlling, monitoring and evaluating the use of them. (Flavell, 1979). In effect we really have two things occurring. Firstly the cognitive goal of learning and parallel to that we have a metacognition which promotes the constructivist link between knowledge and experiences (Anthony, 1994). Just as the richest of learning can be lost when content is over simplified to the learner, so too metacognitive teaching models need to be constantly fluid between the teacher and the learner. The teacher can facilitate learning (Lai, 1993) by developing a way of thinking within his/her classroom management. The metacognitive strategies can be most effective when they are used to promote long, lasting learning within a frame work that see students regulate their own learning.

Cognitive and metacognitive strategies

Few students become active learners on their own (Smith, 1997). They will learn this from their social environment, the home, or through a school setting. As teachers, we need to teach students in order to increase quality peer interaction within a constructivist framework to enhance learning. By developing a classroom culture that encourages and supports this, we as teachers can provide a motivation to learn. This cycle will then start to spiral into a life long enjoyment. Two children sit down in front of a new piece of software such as 'The Amazing Writing Machine'. A few simple words here and there can be enough to see the children explore and use the program's features (Allomes Kelland, and Lowary, 1997). The teacher can play a very important part in this process as the more complex features are explored. The knowledge gained from the way program writers use various conventions will help the children with the next piece of unseen software. The key has been in providing a supportive social learning environment which is advocated in recent research.

From pencil and paper to silicon chip

For the Mathematics teacher, computer software is available but at a cost, and it must include the software and site licences. Mathematics teachers may use spreadsheets or computer algebraic and symbolic software. In terms of what I call standard software, such as spreadsheets, they don't necessarily fit in well with the practical aspects of the Mathematics classroom, because they are generally located in a computer lab, so they are not something you can use for two minutes and then continue with the Mathematics lesson. Likewise, algebraic software generally requires students to have easy access to desktops at the same time as the topics are being taught, and for a continued period of time. This is something that is not always possible within most secondary school 'lab' settings. What is more useful and viable for Mathematics teachers, is handheld graphics calculators, for which a class set can be purchased for the price of little more than one good desk top computer. The only real downside appears to be, that students need to become familiar with its use. With most computer software, pull down menus and on screen, help make learning how to use the software easy. The graphics calculators have a much smaller screen so there is a very limited amount of help and clues to know what to do next.

The development of graphics calculators today must be considered in the historic introduction to the Mathematics teachers practice from pencil and paper to the silicon chip with log books, to slide rules, simple calculators and scientific calculators. The graphics calculator has the ability to draw statistical and algebraic graphics, numeric and problem solving features to advanced statistics and modeling which would be just some of the general capabilities. For the Mathematics teachers, this leads in the **media wave.** This is the ability to provide students with information from multiple sources that will enhance learning. Relevant visual stimulus from Mathematical computer software, or handheld graphic calculators, can give learners increased signals to improve cognitive learning (Mayer, 1997).

Tutor tutee tool

Teachers need to clearly see the distinctions between using the computer as a tutor, a tutee and a tool. Using the computer as a tutor is closely related to the behavioural theory of learning and is common to Computer Assisted Instruction (CAI) programs such as Drill and Practice. This **Instructional wave** with games, tutorial programmes, simulations, problem solving software and adventure games,.type of learning is usually inflexible and students have little control over what they learn. There is a place for CAI, in education. If a teacher thinks that a particular skill needs to be practiced in a drill type way in order to be mastered, using a computer to do so may be more motivating. Feedback is usually immediate so pupils do not master incorrect skills (Lockard Abrams & Many, 1997). On a critical level what drill and practice does not do, is to foster the complex thinking that takes a student into a higher order problem solving situation, (Jonassen, 2000). It is evident that using computers in this way is limited, and not the main way they should be used.

Using the computer as a tutee, or as a tool, empowers the learner far more than CAI. Using the computer as a tutee implies that the students are teaching the computer. The most well known example of this is the program Logo devised by Papert. This interactive aspect of using a computer took the computer into the **problem solving wave.** It was designed to create a 'rich learning culture where in teaching the computer how to think children embark on an explanation about how they themselves think' (Papert, 1980, cited in Brown & Riley, 1998. p.27).

Using computers as tools is a very effective way of using them in education. Using them in this way is closely related to the cognitive and constructivist theories of learning which look at the mental processes involved in learning. When computers are used in this way or the **mind tool wave,** it ensures that the learner is at the centre of the learning process unlike in the behavioural theory where the computer is at the centre. Computers should be used by students as a tool to explore and learn through discovery, in a way that encourages social interaction between learners as much as possible.

The teacher's role

Teachers have an important role to play in the implementations of constructivist learning for effective use of ICT. Their key role is that of a facilitator. They must be able to help and teach students how to deal with problems, whether they are to do with the materials or the technologies. Students should be encouraged to scaffold knowledge in order to develop their understanding. The role is a very supportive one (Ryba & Anderson, 1990).

Another role for the teacher is that of the planner. Teachers need to plan activities using ICT that fits in with the curriculum. They need to be able to find all the resources necessary for the lesson and be innovative (Lai, 1993), and know what they want the students to achieve.

Teachers also have to assume the role of manager. Like teaching without ICT, teachers need to prepare everything before hand. This includes organizing the layout of the room, resources and equipment to be used. They need to monitor what students are doing, and how they are coping and progressing (Rybra & Anderson, 1990).

An essential prerequisite a good educator who uses ICT will have is a lot of knowledge. The more knowledge an educator has, the more he is able to perceive possibilities for integration, and be confident and comfortable with taking risks and in giving the learning control over to a child centred approach. Good teachers know their subjects well. Their knowledge in two-fold: a good overall pedagogical knowledge of the skills, strategies and techniques needed for capable teaching that are cross curricular, and more dominant specific knowledge of subject content and the particular skills to teach that subject (Brown, 1998).

Research

For senior secondary school students, algebra is one topic that is frequently the most poorly understood. In the Primary School years, children can develop problems in early numeracy because they have been pushed into using standard tried and tested algorithms, before they have had a chance to explore the relationships, language and communication surrounding numeracy concepts. (Fuson, 1979). This exploration stage might be considered the medium which leads students into a deeper understanding. Research by Stephens & Konvalina (1999) compares students in traditional lecture classes in college algebra, with students in college algebra classes utilizing Computer algebra systems (CAS) such as DERIVE, MAPLE, and MATHEMATICA. The mean scores on the final examination were higher in the experimental group than the control group for both intermediate and college algebra. The students also expressed more positive attitudes towards the course and subsequently toward the teachers in the course. However, it should also be mentioned that the research used selected students within the two groups, and they had to reach a certain level of competency in Mathematics and English within both test groups. Just as young children need to explore the topic in a social environment, perhaps the use of algebra software can provide the medium for older students to advance their understanding.

The use of computer algebra systems (CAS) reduces the impact on learning if they are not used as a legitimate tool in assessment. Certainly all New Zealand students have the ability to use handheld calculators as well as graphic calculators, but this is not the case for desk top computers and software, such as CAS. In a study by Pountney, Leinbach & Etchells (2002), they presented a three level taxonomy of learning to base their research on.

- *Level one includes the basic memorization of facts and manipulation of numbers.*
- *Level two, is the ability to transfer information to new situations.*
- *Level three was explaining the knowledge, justifying and evaluating.*

The third level clearly relates to the accepted higher order of thinking that can occur when students are challenged to scaffold new knowledge and to problem solve from their own knowledge. Within our current system National Certificate of Educational Achievement (NCEA) students are not given the opportunity to use desk top computers as part of their assessment within Mathematics, and this may well be true for many other applications of computer learning. Teachers may use this technology as a tool for learning, but the current New Zealand education system fails us as teachers, as we cannot go that ultimate step and accept the technology for assessment purposes. The key challenges for this would be that all New Zealand students would have to have access or the ability to access CAS or software so that equality is shown to exist for all. This raises the point that graphic calculators which are acceptable, do provide students who use them with an advantage over students who do not. They are also more expensive that other normal scientific calculators.

How do we know we have achieved the core goals of education without quality quantitative research? As educators and teachers we are concerned with our students retaining, understanding and being able to actively use the knowledge we are trying to teach (Perkins, 1992). Selwyn (1997) claims that with the vast increase in Information Technology in schools over the last decade that there should be a similar amount of educational research. He claims there is a lot of qualitative analysis but very little quality quantitative research. Imagine two classrooms, side by side. One has its walls full of exciting posters and examples of student work, the other is bare. The observer may jump to conclusions about which teacher is offering students the ability to learn higher order skills. However the students in the exciting visual classroom may be taught in a teacher dominated passive learning environment and the bare classroom may be filled with student centered constructivist learning. Without unbiased quantitative, data there is no real way to compare various teaching styles. There is a need for educational technology to be examined in relation to society, and not just within the educational context (Selwyn, 1997).

Putting theory and research into practice

During the mid 1990's, River Oaks school sent most of its technological equipment into long term storage. The school had dozens of computers that it could not longer afford to fix or replace. Now the school is no longer built around the computer, as it found it was a target for constructivists based principles offering great rewards, but when the business economy started to droop, the funding dried up. The risk of building an expensive technology base on the promise of business money is difficult to maintain (Robertson 2003) .

How do we start to put current theory and research in practice for the average classroom teacher? This can be achieved by a focus on the classroom teacher and the classroom culture that is developed - not the window dressed technology or the actual specific curriculum area of learning.

Teachers can increase the effectiveness of ICT to enhance learning by firstly having a well developed philosophy of teaching and learning.. From this base line pedagogy the philosophy of teaching and learning will provide the critical link from educational theory to practice (Brown & Riley, 1998). There is a movement among contemporary educators, that the most effective theory by which children learn, is constructivist learning. There are two major positions within the constructivist perspective, one being the cognitive constructivism, and the other the social-cultural theory. They overlap. In the constructivist view to learning, students are required to be actively engaged in a supportive social environment. This theory suggests to us that new skills are best learnt within a context relevant to the learner and the learner needs to be at the centre of the learning process. This is unlike the behavioural theory where the teacher becomes the center of the learning process (Jones & Mercer, 1993).

For the secondary school teacher, a major difficulty is presented within the current National Certificate of Educational Achievement (NCEA). There is a clear difference between the time, it takes to teach an idea using passive learning methods against an interactive, constructivist method of learning. For example, take a secondary school Mathematics teacher, who has to teach at least the basic twenty four credits in a core achievement standards base course. If the maximum number of hours in the week and then year are calculated for that subject, divided by the 24 credits, this allows an average of approx six hours teaching per credit including assessment and reassessment time. This is not a lot of time to allow students the pleasure to have vast amounts of social interaction and to scaffold old knowledge into new, and what about the use of technology in this process?

Providing the students have the skills to make use of the technology as a tool, then this can become a desirable and useful additional feature of the classroom culture. If, on the other hand, the teacher has to teach students how to use the computer, as well as their subject content, then this becomes another barrier, that many, and most, teachers will probably not cross. To do so, may well be at the expense of students not completing the years course content, and they fall into the trap of the students not being able to fully answer all the material they are set within internal or external assessment. The teacher's, competence is reviewed when exam results are revealed in the following school year, and trends are analysed by students, parents, Board of Trustees, Principal, colleagues, and Ministry of Education. In this list, the power of the 'press' should also be considered, as any schools reputation can be splashed across headlines.

Graphics calculators, or handheld technology, enable students to engage in hands on activities that make them "part of the action." If they are introduced early enough into the senior student's mathematical learning and regularly used, they can provide a motivational link for the teacher and student. In traditional lecture settings, some students are more reticent about participating in discussion, but with the handhelds, students can work on problems and become engaged in the process of learning. The negatives are that calculators can be stolen and they do need to be individually set up and compared to a computer networked laboratory. The students also need lots of time to practice and become familiar with the device. Handheld technology also enables students to investigate some topics with relative ease that they might not have previously considered. For example, matrices, regression analysis, recursion, and geometric constructions. The speed at which we can work allows us to look at and learn more information than is possible with just pencil and paper. Even students at year 11 find value in seeing the effects of different transformations when graphing quadratic equations. In a Mathematics text book designed to make use of graphic calculators Wheeler, Neal and Hofmann (1996) claim that the graphic calculator is more than a tool, it provides the students with a method to investigate numerical and graphical processes.

To balance the positive effects that handheld and computer algebra systems (CAS) have to name just two , we must also consider this from a holistic point of view. Clark 1983 cited in Fletcher-Flinn & Gravatt (1995) argued that computer instructed learning has no more long term effect on learning other than an initial novelty. Since that time, the use of computers in schools has increased. The quality of software is more *user friendly* and the hardware is more reliable, faster, and packaged into smaller *user friendly* units. As Fletcher-Flinn & Gravatt (1995) point out, the computer does relieve the over worked 'human' teacher from the demands of endless practice examples and enhancement exercises. The computer media technology will happily supply without a coffee break. So it appears that we have not progressed much from the early computer assisted instruction (CAI) programme dating back thirty plus years. The key point that must be kept in mind is, that these new technologies, are only tools for the teacher to use to enhance learning. They are neither the replacement for the teacher nor the replacement for good learning. The quality of the software and its value to the students must be carefully evaluated so that it fits well with the teacher's educational objectives, and be not just a means of occupying students time.

Overall, the effectiveness of computer-assisted learning has not been conclusively demonstrated in a New Zealand survey (Ministry of Education, 2003) To date, it has been shown to be less effective, on average, than other forms of intervention in education. The Computer-assisted learning programs were generally costly and the evaluations of integrated, learning systems showed highly variable results, the best results appearing to be for basic mathematical skills.

I support the use of spreadsheet within a statistics topic to manipulate large amounts of data in order to save a student time. It is also very useful to quickly change the types of graphs so that students can discuss the use of bar graphs to line graphs for discrete and non discrete data. These are very powerful teaching tools that can be used to visually enhance student understanding. As a mathematics teacher, I feel it's a step backwards if students can not use the software, quickly and efficiently, to sort statistical data either individually or in small groups. These premises can put additional barriers to learning that need not be there. In practice I have usually asked students what skills they have in using certain software before suggesting such a project.

In New Zealand Computer software such as spreadsheets were used by 58.4% of all secondary teachers either "often" or "sometimes", and graphics calculators were used by 37.5% used this resource either "often" or "sometimes" based on a qualitative survey (Ministry of Education, 2002).

Summary

In conclusion, the use of computer technology within the Mathematics classroom can provide a rich environment to higher order learning. The teacher needs to have a sound philosophy of teaching so that a pedagogical link can be bridged to practical issues. A philosophy of teaching that can stem from a behavioural teacher to the cognitive teacher. A teacher, who has developed a strong understanding of his/her own subject will be able to use that knowledge as a base to providing a power of the visually effective technologies, that can easily slot into the students constructivist learning environment. In theory this technology can provide students with learning opportunities. In practice, the current secondary school Mathematics assessment environment has not fully caught up with the media wave. The current technology is just a means to learning. Just teaching students to be familiar with the technology is reminiscent to rote learning tables. Our students should be empowered to learn and to keep learning, not merely be trained.

Teachers need to have strategic contextual knowledge. This is the knowledge of how to make ICT happen for you, your class or your school. As Clark, (2001) points out, to create the link between successful research and authentic practice is not always a direct, easy, or a quick process. But it can happen, if a group of teachers or a school can see the need and develop this into a reality. For this process you need to develop a strategic plan which should include a current profile of where the school is at, the schools vision, its goals and how those goals are to be implemented, an inventory of hardware and software held in the school, a guide for evaluating software, an assessment of current staff and pupil competencies, an overview of the ICT process, a list of ICT competencies for integration and, an ICT skills checklist of what is to be achieved within subjects and levels. The key elements to achieving this vision are that all staff members should be empowered to effectively use ICT to enhance and increase learning, creativity, and the quality of production, and that students should be empowered to use ICT for effective information retrieval, communication, personal productivity, creating and for life long learning.

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