Literature Review

The IMPACT of ICT on

LEARNING and TEACHING

A literature review by Dr. C. Paul Newhouse for the

Western Australian Department of Education.

December, 2002

This review set out to identify and evaluate relevant strategies in local, national and international research and initiatives related to measuring and demonstrating the impact of ICT in schools with regard to: students, learning and the learning environment; teachers and teaching strategies; organisational change; and other areas relevant to teaching and learning in WA government schools. This will include the presentation of definitions of common terminology.

As a result a framework was developed to articulate the areas of impact of ICT in schools and strategies for monitoring and evaluating each of the areas of impact at the school and system levels. This framework is provided in a separate but associated document.

Companion Document

Based on this review of the literature a framework for describing and monitoring the progression of teachers in their integration of ICT in learning and teaching processes was developed.

A Framework to Articulate the Impact of ICT on Learning in Schools

by C. Paul Newhouse, December, 2002

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Introduction: Computers & Learning

From the earliest times when computers were commercially available, they could be found in use in educational institutions, and educators (e.g. Bork, 1980; Carnegie Commission on Higher Education, 1977; Papert, 1980) argued that computers should be used to support learning. There has always been huge community support for this as illustrated recently in a survey of voters in the USA which indicated greatest support for expenditure on ICT in schools when compared with a list of alternative expenditures in education (Lemke, 1999). However, there has always been debate among educators on how the technology should be used and what improvements in student learning could be expected.

Initially computers were used to teach computer programming but the development of the microprocessor in the early 1970s saw the introduction of affordable microcomputers into schools at a rapid rate. Computers and applications of technology became more pervasive in society which led to a concern about the need for computing skills in everyday life. As public awareness grew, this need for computer literacy became extremely influential and many schools purchased computers based on this rationale.

The 1990s was the decade of computer communications and information access, particularly with the popularity and accessibility of internet-based services such as electronic mail and the World Wide Web. At the same time the CD-ROM became the standard for distributing packaged software (replacing the floppy disk). This allowed large information-based software packages such as encyclopaedias to be cheaply and easily distributed. As a result educators became more focussed on the use of the technology to improve student learning as a rationale for investment.

Today computers in schools are both a focus of study in themselves (technology education) and a support for learning and teaching (educational technology). Rationales can be presented for both computer literacy and using computers as part of educational technology. This review will concentrate on the latter but will address the issues surrounding computer literacy where relevant. The focus of this review will concern the use of computer technology as an aid to learning and teaching in schools. How can computers help students, teachers and administrators? When should computers be used in the classroom? What is the effect of computer use on teachers, students and learning within the classroom and school?

This review will aim to describe the ways in which computer use in schools impacts on learning, learning environments, students, teachers, and schools. In order to accomplish this the review will explain a conceptual framework within which to address these concerns. Then the review will analyse and synthesise current research in the area to suggest a framework to articulate the areas of impact of ICT in schools and strategies for monitoring and evaluating each of the areas of impact at the school and system levels.

The review begins with a background to the use of computers in schools, then touches on the rationale for computers in schools, followed by a discussion of the findings of current international research on the impact of ICT on aspects of learning and schooling. This leads to the review of initiatives to develop frameworks for describing and monitoring the areas of impact of ICT in schools. This is then set within an Australian and Western Australian context to suggest such a framework. Finally, implications are drawn for WA government schools and recommendations made.

The assumed context for the review is the set of conditions currently prevailing or planned for Western Australian government schools. Principally the context is dominated by the implementation of the Western Australian Curriculum Framework that sets up an outcomes-based approach to education within a developmental-constructivist view of learning. This focuses on what students do, think and understand rather than on the input of teachers and thus has ramifications for any evaluation of the use of ICT by students and teachers.

Schools, Learning and Computers

Any discussion about the use of computer systems in schools is built upon an understanding of the link between schools, learning and computer technology. When the potential use of computers in schools was first mooted, the predominant conception was that students would be 'taught' by computers (discussed by Mevarech & Light, 1992). In a sense it was considered that the computer would 'take over' the teacher's job in much the same way as a robot computer may take over a welder's job. Collis (1989) refers to this as "a rather grim image" where "a small child sits alone with a computer" (p. 11).

During the late 1970s and early 1980s, computers became more affordable to schools, permitting a rapid decrease in student-to-computer ratios. While tutorial and D&P software continued to be developed (Chambers & Sprecher, 1984), a range of other educational software was developed that was not based on the premise of teacher replacement, for example, simulation software, modelling and tool software. However, the major argument used to support the introduction of greater amounts of computer hardware into schools concerned the perceived need to increase the level of computer literacy of students (Carleer, 1984; Downes, Perry, & Sherwood, 1995).

Towards the end of the 1980s and into the 1990s, while the computer literacy rationale still remained (Hannafin & Savenye, 1993; Hussein, 1996), the major rationale for having computers in schools was more concerned with the need to use computers to improve student learning (Welle-Strand, 1991). Broadly speaking, computer literacy is a component of Technology Education, which is distinct, but not necessarily separate from, using technologies such as computer systems to support learning and teaching processes. The latter is generally referred to as educational technology; and is applied to a wide range of technologies such as blackboards and chalk, pencils, books, and slide-rules to television, facsimiles, and computers. This review will focus on the use of computer systems as educational technologies.

Since the beginning of the 1990s, educators have been particularly concerned that very little of the potential of computers to support learning in schools seems to have been realised, despite a sufficient installed base of computers. Numerous studies (Becker, Ravitz, & Wong, 1999; DeCorte, 1990; Plomp & Pelgrum, 1992) have shown that few teachers facilitate substantial student use of computers. Therefore, while it is assumed in this review that computer support for learning is essential, some discussion of the rationale is required as a background to later discussions concerning models for the use of computing systems to support learning and teaching.

Computers solve problems

Technology is developed to solve problems associated with human need in more productive ways. If there is no problem to solve, the technology is not developed and/or not adopted. Applying this principle to educational technology would mean that educators should create and adopt technologies that address educational problems, of which there are many. Further, a technology will not be adopted by educators where there is no perceived need or productivity gain. This is what Lankshear and Snyder (2000) refer to as the 'workability' principle. Therefore, when discussing applications of computer technology to education the question must always be asked, "What educational problem(s) needs to be addressed?". This question needs to be asked at all levels of decision-making, from the teacher planning a programme, to a school administrator purchasing hardware and software, to an educational system officer developing policy and strategic plans.

At the teacher level the question becomes: am I satisfied with the educational opportunities I am able to offer children in school classrooms? While teachers should never be completely satisfied, and they will always strive to do better, the question really is whether what they provide adequately develops the potential of the students and adequately prepares them for a productive life in society. Many educators (e.g. National Centre for Vocational Education Research, 2002) and educational commentators (e.g. Murdoch, 2001) believe that what is offered in school classrooms in developed countries such as Australia is hopelessly inadequate to match the needs of our society and the needs of individual students. Schank and Cleary (1995, p. ix) put this succinctly when they state, "Today's schools are organized around yesterday's ideas, yesterday's needs, and yesterday's resources (and they weren't even doing very well yesterday)." An increasing number of educators (e.g. Schlechty, 1997) are sure that part of the solution is to provide better technology support for learning environments. Schank and Cleary (1995) argue that we know enough about learning to support it with computer systems, using software that allows children to experience activities, at school, that have been impossible or difficult, and thus avoided in the past.

At the school and system levels the educational-problem question becomes whether the resources available to the school are being most efficiently employed to provide the most effective educational opportunities for students. It becomes much more a question of productivity, a balance between inputs (resources) and outputs (learning outcomes). Investing in computer technology means reducing investment in other resources (e.g., books, teachers, buildings). Will using computers provide better learning outcomes than the equivalent investment in those other resources? If so, what level of investment in computers compared with other resources will provide the optimum output? Very few educators and educational commentators would advocate no investment in computers, even if only using a computer literacy rationale. A few advocate an investment that supports almost all education being conducted electronically, particularly online, often referred to as e-learning (e.g. Bonk, 2001). Most are somewhere between these extremes.

At the political level the question comes down to whether an adequate investment is being made in education when compared with other services that our community requires. Providing computer technologies for schools has usually involved increases in investment in education that must be justified to the community, and that is usually done by quoting student:computer ratios. While research tends to have been somewhat inconclusive, increasingly studies are showing investments in computer technologies result in significant improvements in learning, however it is measured. For example, a study in West Virginia (Mann, Shakeshaft, Becker, & Kottkamp, 1999) found an average effect size of over 0.4 standard deviations, which was claimed to be more cost-effective than a reduction in class sizes. Education is central to the long-term well-being of our society and individuals, teachers and students need all the support they can get; hence the need to consider the potential of all available technologies.

This discussion will assume that educators should create and adopt technologies that address educational problems and/or improve productivity. The rationale for the use of a technology to support learning should arise from dissatisfaction with the educational opportunities offered to learners and a striving to do better.

Avoid Techno-centric Thinking

Warnings have been made for decades about falling into the trap of what Papert (1987) calls 'technocentric thinking'. Most educators would claim not to be technocentric; however, when discussing the use of computers in schools there is always the danger that the focus will be on the technology, particularly the hardware. When making decisions about the use of computers in schools, particularly budgetary decisions, there is a tendency to start with a consideration of the hardware, then the software and perhaps consider the users and learning last and least. Rather, most educators (e.g. Fullan, 1995; Means & Olson, 1994; Papert, 1987) would agree that all discussions and decisions should be prefaced with a consideration of learning theory and the learning environment; for, indeed, educational technologies are only a mediator in learning processes, and only one of many.

Rieber and Welliver (1989) define educational technology as a process involving, "a systematic approach to identifying instructional problems and then designing, developing, implementing, and evaluating instructional solutions" (p. 22). They argue that, "In order for the full potential of educational technology to be realised, it must be viewed more as a process rather than just the implementation of educational tools" (p. 22). Thus the educational technology process begins with the identification of an educational problem, not with the existence of a technology. In other words, we need to start with the well-supported beliefs we have about learning and make sure that any solutions are consistent with them. There is no doubt that the most commonly held set of beliefs about learning, well supported by research, are those bearing the label of constructivism. As the Committee on Developments in the Science of Learning (2000, p. 10) put it, "the contemporary view of learning is that people construct new knowledge and understandings based on what they already know and believe". Further, there is an assumption that learning occurs within a physical and psycho-social environment usually labelled as the learning environment (Fraser, 1994). These were not the commonly held views of learning when current schooling structures were developed over a century ago. If a rationale for computing is to be grounded in an understanding of the nature of learning and teaching, this must begin with an examination of learning environments and the key precepts of constructivism.

Learning environments

Learning environments in schools typically involve one or more adult teachers connected with a number of students, usually in well defined physical settings. These people interact and form a variety of relationships, creating what Salomon (1994) calls "a system of interrelated factors that jointly affect learning in interaction with (but separately from) relevant individual and cultural differences" (p. 80). This is what Wubbels, Brekelmans, and Hooymayers (1991) term the "relationship dimension" in learning environments at school. The learning environment has a physical as well as a relationship dimension. Physically it may be in a room, full of particular furniture and equipment. Curriculum materials such as books and videotapes may also be present. The curriculum also has a place in the relationship dimension of the environment in that the students and teacher(s) are focused on certain processes and content in the curriculum and have a relationship with that curriculum and the methodologies that are associated with conveying the curriculum. Students and teachers may have very different relationships with different components of the curriculum.

The place of computers in learning for the majority of children is most likely to occur in the classroom and, for an increasing number, at home. Most experts in the field of educational computing (e.g. Lynch, 1990; Olson, 1988; Rieber, 1994) would characterise computers as interactive and thus admit them a place within the relationship structures of the classroom learning environment, not just the physical environment. The majority of school classroom learning environments that incorporate computers could thus be depicted using the model in Figure 1.

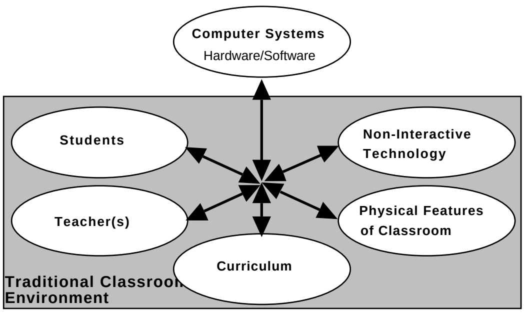

Figure 1. A model to consider the relationship of computer systems to other elements of the classroom learning environment.

The Curriculum and Educational Technology

The curriculum is concerned with **what** is learned and taught and **how** this learning and teaching occurs. What is learned/taught includes objectives, content, and learning outcomes (the knowledge, skills and attitudes that students are intended to demonstrate). The how of the curriculum concerns teaching/learning methodology, teaching strategies and media resources.

Most teaching/learning methods and strategies involve the use of some equipment. Some teaching methods may only include the use of a blackboard and chalk while others may make use of a television or overhead projector. This equipment and its use within the curriculum is often referred to as educational technology. Educational technology concerns the technology that is used to facilitate the teaching/learning process. As such it is included in the ***how*** part of the curriculum. We could consider educational technology as the ***tools of the teaching trade***, part of the medium used to convey the curriculum. Some of these technologies involve the use of computers.

There is a two-way relationship between the curriculum and educational technology in that to some extent they each affect the other. Typically the teacher and other components of the education system determine what is to be taught and learned and then on this basis the methodology (including the educational technology) to be used is selected. Thus the technology used is determined by the intended curriculum. Also part of the context of the curriculum concerns the role of the teacher, the physical setting and the general pedagogical views of the teacher and education system. These are likely to affect the technology used.

There have also been a number of instances where the curriculum has been changed due to changes in technology. In some cases the invention of new technology has added content to the curriculum (e.g. technology based on electricity). In other cases new technology has made parts of the content obsolete (e.g. using calculators instead of logarithms for calculation). And some technologies such as overhead projectors, videos and computers have led to the development of new methods of learning and teaching which were not feasible before their introduction. So in many ways technology can be seen to be affecting the curriculum both in terms of content and methodology.

Already it would appear that the content and objectives of the curriculum are changing to take account of the role of computers in society. For example, with the use of large database systems (e.g. the Web on the Internet) it is more important to know how to retrieve and manipulate information than to remember the information itself. However, in other applications of computers in the presentation of the curriculum, teachers and students will need to decide where the curriculum best needs the use of computers and where their use is inappropriate.

As indicated in Figure 1 computer systems (hardware and software) become involved in the interaction patterns within the classroom environment. This is shown independently of the other educational technologies which are non-interactive. While using an overhead projector does affect the classroom environment in that it takes up space, it requires a screen, a teacher needs to create transparencies to use on it and students may not like reading them, there is no two-way interaction as may be the case with a computer system. A computer system can interact with each student and the teacher differently and can interact with components of the curriculum in different ways.

The basis of learning environments

The classroom learning environment provides a structure to describe the setting in schools within which learning is organised and the roles of the teacher and students occur. However, it does not describe the reasons or purpose behind the construction of any particular environment. This is dependent on the beliefs and actions of those responsible for setting up the environment, particularly the underlying pedagogical philosophy of the teacher. There is little doubt that the pedagogical philosophy to which most ‘Western’ educational leaders and researchers subscribe is that of constructivism.

Learning - Constructivism

Almost all those who advocate major reforms of schooling, particularly through the use of computers, have the view that learning needs to be more informed by constructivism (e.g. Clouse & Nelson, 2000). Often arguments for school reform involve constructivist concepts such as the need for students to develop higher order thinking skills and the failure of current schooling methodologies to provide the opportunity (Campione, Brown, & Jay, 1990; Loader & Nevile, 1991). In the extreme, the technologies of the information age are perceived to be an irresistible force on education (Mehlinger, 1996),

Constructivism has its roots in the psychology-based traditions going back to Dewey (1966), Bruner (1962; 1966), Piaget (1970) and Vygotsky (1978). However, more recently this is supported by biological science-based theory in neuroscience. There is a good discussion of this convergence of support for constructivism in the report by the Committee on Developments in the Science of Learning (2000).

What is meant by constructivism? There is no single definition of constructivism (Perkins, 1992; von Glasersfeld, 1992), and the term is often not defined explicitly by the user of the term. However, there is a common element in the belief that knowledge is constructed out of personal sets of meanings or conceptual frameworks based on experiences encountered in relevant environments. People interact with their environment and as a result develop conceptual frameworks to explain these interactions and assist in negotiating future interactions. As Perkins (1992) puts it,

> ***Central to the vision of constructivism is the notion of the organism as "active" - not just responding to stimuli, as in the behaviourist rubric, but engaging, grappling, and seeking to make sense of things. (p. 49)***

Neurologically, this is the result of complex sets of connections being formed between neurons, these connections being called dendrites (Committee on Developments in the Science of Learning, 2000).

Pines and West (1986) developed what they call a “sources-of-knowledge” model of learning based on constructivism, which I have found most helpful. They discriminate between two sources of knowledge for school children: firstly, knowledge spontaneously acquired from interactions with the environment; and secondly, knowledge acquired formally through the intervention of school. These two sources of knowledge are represented as vines in a metaphor based on the writings of Vygotsky (1978). The former source originates from the learner and thus is known as the upward growing vine. The latter source is formal knowledge imposed on students and therefore is known as the downward growing vine. Therefore, education in schools is concerned with the meeting of these vines that Pines and West (1986) define as four possible paradigms (congruent, conflict, formal-symbolic, and spontaneous), based largely on the relative strengths of the existing and imposed frameworks and the degree to which the frameworks are different.

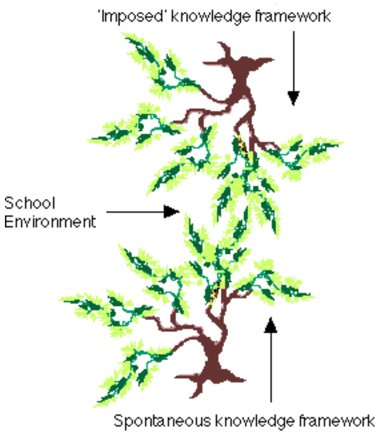

Figure 2: ***Schematic of Pines and West ‘vines’ representing the knowledge frameworks imposed by the curriculum and that spontaneously developed by the individual.***

Clearly then both the knowledge frameworks of students (prior knowledge) and of the knowledge domains relevant to the learning activities must be considered in the integration of ICT. Many educators have argued that the appropriate use of ICT by students can assist teachers in determining and catering for the prior knowledge of students. Further, it is usually also argued that ICT can assist students in engaging cognitively to a greater depth with knowledge domains. That is students are supported in employing the full range of thinking skills within authentic contexts. This is often discussed in terms of cognitive taxonomies such as that provided by Bloom (1964).

Knowledge	The learner must recall information (i.e. bring to mind the appropriate material).
Comprehension	The learner understands what is being communicated by making use of the communication.
Application	The learner uses abstractions (e.g. ideas) in particular and concrete situations.
Analysis	The learner can break down a communication into its constituent elements or parts.
Synthesis	The learner puts together elements or parts to form a whole.
Evaluation	The learner makes judgments about the value of material or methods for a given purpose.

Pedagogy and Constructivism

There is often the misguided belief among teachers that constructivism means that all learning must be entirely by discovery and that the teacher and curriculum materials have no place. Perkins (1992) describes two constructivist positions on teaching/learning paradigms as without the information given (WIG) constructivism and beyond the information given (BIG) constructivism. It is advocated that a blend of both approaches is employed. DeCorte (1990) discusses this balance of approaches in the context of using computers in schools,

> ***a powerful computer learning environment is characterized by a good balance between discovery learning and personal exploration on one hand, and systematic instruction and guidance on the other, always taking into account the individual differences in abilities, needs, and motivation between students. (p. 74)***

It is important to not equate particular sets of teaching strategies with constructivism. One teacher may choose to employ certain strategies in a manner consistent with her constructivist notions, while another may employ quite different strategies in a manner that is equally consistent with his constructivist notions. The educator who believes in constructivism should be concerned with personal conceptual frameworks, prior knowledge, students' understandings, the relationship of formal knowledge to spontaneous frameworks, and the attitude of the learner to formal knowledge (Osborne & Wittrock, 1985; von Glasersfeld, 1991).

Vosniadou (1994) argues that a belief in constructivism will determine the type of computer software used in classrooms and the manner in which computer-use is integrated with the curriculum and implemented in the classroom. However, this may be a little overstated, as the fundamental focus for a constructivist starts with the individual student within the context of the environment in which that student is placed. This focus on the student rather than the instruction, typically referred to as student-centred learning, underpins the role and tasks of the teacher.

Once again, a learner-centred approach does not imply a particular set of strategies for a teacher and therefore does not imply a particular set of applications of ICT to the learning environment.

Constructivist Learning Environments

In 2000 the U.S.A. Committee on Developments in the Science of Learning addressed the issue of what should be considered in developing learning environments in their report ***How People Learn: Brain, Mind, Experience, and School***. They defined "four interrelated attributes of learning environments that need cultivation" (p.23).

1. Schools and classrooms must be **learner centred**. (p. 23)
2. To provide a **knowledge-centred** classroom environment, attention must be given to what is taught (information, subject matter), why it is taught (understanding), and what competence or mastery looks like. (p. 24)
3. Formative assessments – ongoing assessments designed to make students' thinking visible to both teachers and students are essential. They permit the teacher to grasp the students' preconceptions, understand where the students are in the "developmental corridor" from informal to formal thinking, and design instruction accordingly. In the **assessment-centred** classroom environment, formative assessments help both teachers and students monitor progress. (p. 24)
4. Learning is influenced in fundamental ways by the context in which it takes place. A **community-centred** approach requires the development of norms for the classroom and school, as well as connections to the outside world, that support core learning values. (p. 25)

This structure provides an ideal and thereby throws some challenges at education systems. Some of these challenges may be met with ICT support.

ICT Integration in Learning Environments

A critical component of theories of constructivism is the concept of proximal learning, based on the work of Vygotsky (1978), which posits that learning takes place by the learner completing tasks for which support (scaffolding) is initially required. This support may include a tutor, peer or a technology such as the applications of computers. This has led to the use the term computer supported learning. Computer supported learning environments are those in which computers are used to either maintain a learning environment or used to support the student learner in this Vygotskian sense (DeCorte, 1990; Mevarech & Light, 1992). Therefore the technology is used to help create the types of learning environments and the types of support for learning that are known to be ideal, that Glickman (1991) argues have been ignored or failed to be implement widely in the past.

The aim is to create learning environments centred on students as learners and a belief that they learn more from what they do and think about rather than from what they are told. If the aim is to offer new learning opportunities, or to improve the way in which current learning activities are implemented, then the overall effectiveness of learning environments and episodes is of paramount concern, not whether they are more effective with or without computers. It is important that the ever changing nature of computer-based technology not overshadow the enduring nature of learning and the solid and ever increasing base of knowledge about learning. This knowledge is not superseded by new technologies; rather, it can inform the use of new technologies when applied to learning. Therefore, in implementing computer support for learning it is necessary to start by deciding what a student, teacher or school wants to achieve. To achieve these outcomes, teachers can then rely on long traditions of educational theory, their own experience and knowledge of the educational situation (e.g., student attributes) to make decisions about what the learning environment should look like, and what inputs into the learning process are required. Finally, teachers can identify what problems are associated with providing these environments and inputs, and tailor computer and other support to provide solutions. In essence, the judgement of teachers and their support structures are relied upon to choose appropriate strategies. This approach ends with decisions concerning computer support rather than starting with such decisions (c.f. Campione et al., 1990).

The Committee on Developments in the Science of Learning (2000) suggested five ways to use ICT to establish and sustain effective learning environments:

1. Real world problems
2. Scaffolding
3. Feedback, reflection and guidance
4. Local and global communities
5. Extending teacher learning

They assert that many aspects of ICT make it easier to create environments that fit the current understanding of the principles of learning. David Jonassen's "Designing a Constructivist Learning Environment" web-site has a section on Tools (http://tiger.coe.missouri.edu/~jonassen/courses/CLE/) where five ICT tool categories for designing constructivist learning environments are outlined. These provide theoretical frameworks to implement the use of computers to support high quality learning environments.

Connecting with the Local Context

The local Western Australian context is dominated by the implementation of the outcomes-based Curriculum Framework (CF). It would be hoped that the CF would be well aligned with contemporary educational thinking and research. Towards the beginning of the CF document there is a discussion of the assumed principles of learning, teaching and assessment. There are seven key principles of learning and teaching and five key principles of assessment (pp. 33-39). These clearly are aligned with the attributes of a constructivist learning environment as discussed earlier in this review. Appendix Table A explains this alignment.

Further, in the document, An Introduction to the Curriculum Framework (1998, p. 9) by the Curriculum Council of Western Australia six statements are provided as evidence guides that teachers are implementing "An outcomes focus in relation to the curriculum Framework" (p. 9). These evidence guides also align well with the attributes of a constructivist learning environment as shown in Appendix Table B.

There is further evidence of the alignment of the Western Australian government schools context with prevailing international understandings in the teacher support document produced by the Education Department of WA (1999) titled, ***Focussing on outcomes: curriculum, assessment and reporting.*** The document states that,

> ***In planning for outcomes-focused curriculum provision, teachers, working individually and in groups, need to review: 1. students achievement; 2. the learning environment; 3. classroom approaches to curriculum provision; 4. pedagogy; and 5. the school plan." (p.11.)***
>
> ***… caters for the developmental needs of students. (p. 12)***
>
> ***… organization and structure of classrooms. (p. 14)***
>
> ***… subject content approach, competencies approach, role performance approach (p.15)***
>
> ***An outcomes focus requires teachers to become more student centred in their approach. (p. 16)***

These clearly align with a constructivist learning environment view of the process of learning and teaching and provide the background upon which to build a rationale for the use of ICT in schools to support these processes.

The Rationale for ICT in Schools

It is necessary to develop a thorough rationale before beginning to use computers in schools and classrooms. There is little or no point in providing computers in schools unless such a rationale has been completed. With the increasing availability of computer hardware it is important that teachers do not become engrossed in the machine but focus rather on their primary role as educators. Teachers need to extend their imaginations with the awareness that as developments in computer technology occur they will be able to achieve more of their goals.

Since the 1960's the computer has been heralded, by some, as the solution to many problems in education. Many early computer scientists saw the possibility of the computer replacing teachers in schools. However these pictures of students sitting behind computer terminals for much of the day have largely not occurred in mainstream schools, and most would not like this to be realised (Collis, 1989). There are three main rationales for ICT in schools: one concerns the organisational productivity of the school, and the other two focus on the needs of students: technological literacy and support for their learning. The latter two rationales are supported by the recent Australian report ***Raising the Standards*** (DEST, 2002, p. 38)

> ***The need for ICT competent teachers stems from the need for ICT competent students and for ICT-rich learning environments that enhance students' learning across the curriculum.***

Apart from in a few exceptional schools, in the 20th century computers had only a minimal impact on what happens in classrooms (Becker et al., 1999). There has been much debate over the reasons for this discrepancy between the potential and what is realised. The computer is one of a range of technologies now available to teachers and students. In past decades technologies such as radio, television and overhead projectors similarly had little lasting impact on the experiences of students and teachers in schools. In these cases a large amount of money was spent on these resources which some would argue would have been better spent on other resources. It is important that scarce resources to support learning in schools are not wasted and therefore care needs to be taken in choosing to use computers to support learning.

Historically, technology has been developed to solve problems, improve living standards and to increase productivity. Therefore, it is reasonable that we should expect educational technology to be developed with similar objectives. Within the educational context these objectives become to:

- Increase productivity
- Solve problems in teaching/learning programmes

Educational Productivity

Productivity is a concept most happily found in economics textbooks where the productivity of a worker or economic unit is defined by dividing the output (revenue) by the input (costs). This is more difficult to define for the education industry since the output is not easily measured, particularly not in monetary terms to compare with the costs. The output is largely the quantity and quality of learning demonstrated by students, or learning outcomes (as shown in the equation below).

$$\textbf{Productivity} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Educational Outcomes}}{\text{Costs}}$$

Outcomes	Quality and quantity of student learning.
Costs	Teacher and student time, classroom materials, equipment, etc.

From the formula above it is clear that to increase productivity either the outputs must increase, the inputs decrease or both. There has been research conducted to attempt to estimate a numerical value for educational productivity. The best known work goes back to that by Niemiec, Sikorski and Walberg (1989) who calculated cost-effectiveness ratios. They found about a 30% average productivity improvement for examples involving computers compared with about 10% for peer tutoring. Unfortunately, educational productivity is difficult to calculate because it is difficult to estimate the value of educational outcomes. Even so it is useful to consider the concept of educational productivity, particularly the effect that educational technology may have.

Educational technology should influence educational outcomes and costs. If the most appropriate educational technology is selected by a teacher then student learning should be optimized, which means an increase in the value of the outcomes. However, the use of some technologies is more expensive than others. ICTs tend to be relatively expensive to procure, install, maintain and support users and this must be compared with the potential outcomes (Lankshear & Snyder, 2000). While it is important to consider educational productivity this should not be the only consideration in deciding to use a technology. There are situations where a certain technology should be used because it solves a major problem in teaching or learning (Lankshear & Snyder, 2000). This could in fact be seen as related to productivity, for if a part of the curriculum is not completed due to a lack of technology then the associated value of the outcomes is zero and therefore the productivity is zero.

Educational Technology Solves Problems

Fundamentally computers need to be used to address problems which occur in the regular curriculum (not 'fitted into the curriculum'). If the computer is a problem-solving machine then it must be applied to typical school problems such as those concerning student learning, teacher instruction, school administration, and so on.

Educational Technology should be selected on the basis that it has the best characteristics for the implementation of the curriculum. An educational technology should be used effectively or not at all. This requires:

- Problems in the implementation of the curriculum.
- Teachers who know how make use of the technology effectively.
- Teachers and students who know how to operate the technology.

The initial questions that should be asked are: "Where are the problems to be solved and tasks to be completed?" and "Is a computer solution the most effective approach?". Potential sources of computer solvable problems in schools include,

- The computer can be used to support learning activities which are difficult to perform in other ways.
- The computer may serve a role to address the needs of special groups of students, e.g. the handicapped, low ability and those requiring extension activities.
- The computer is able to support problem solving activities in many forms. It is well suited for use as a means of enhancing higher order thinking skills.
- The computer should form an integral part of student activities as a productivity tool.
- The computer can be used in many ways as stimulation and motivation for a range of other learning activities and situations.

Student Learning

There are many potential uses for computers in the learning process. In some situations changes in relevant industries makes computer use in schools imperative. For example, to provide courses in music, technical drawing, statistics, and business which do not incorporate computer use reduces the relevancy of the courses to the real world. Here the rationale cries out from the work place but needs to be responded to with carefully constructed learning experiences. How much of our curriculum is made up of historical solutions to past problems? The curriculum needs to be updated continually to take account of the technology prevalent in society.

Any rationale for the use of computers in the large proportion of schooling devoted to 'general' education, such as: mathematics, social science, science, communication and language, requires much more critical examination. Consider the teaching area of mathematics and the problems associated with student learning. Mathematics has tended to be very abstract while most students tend to operate on a concrete level. The use of concrete materials in some lessons is useful but often not convenient. The computer can provide experiences with virtual concrete materials.

In approaching problems associated with remedial and extension students computer use can provide appropriate material and overcome classroom management problems. However, a computer solution is not necessarily the best solution. The problems associated with student learning are most often discipline and even teacher specific. Therefore each teacher needs to consider the problems associated with student learning in his/her subject area and be aware of computer solutions.

Management of Learning Experiences

The management of high quality educational programmes requires and generates large quantities and types of data. Teachers face many management problems which when analysed could be suitable for a computer solution. There are many such tasks which may be both time consuming and tedious for which teachers should consider a computer solution. Such tasks may include: the organisation of assessments, the maintenance of library functions, the preparation of reports and the organization of events. There are many school management packages which will complete tasks such as these and thereby free up a substantial amount of time for other more important tasks. Schools should make use of the opportunity to continually provide more appropriate solutions to the dynamic problems associated with the provision of schooling.

Provision of Support Materials

The access to, and production of, resource materials associated with the processes of learning and teaching learning is readily facilitated by the use of productivity software tools and networked computer systems.

Access to Information

There are a number of reasons for exposing students to using computers to access and present information in schools. First and foremost there is a need to respond to a mass of information. To some extent there is a social role in putting students in touch with other people and their ideas. Also the efficiency of bringing information to students and teachers provides an economic rationale. For up-to-date information or spasmodically used information it is likely that the off-site computer database accessed through the internet will offer the most cost effective solution to information needs. ICT does not only concern gaining access to information but also involves using computer systems to process and interpret the information, to make meaning and present information.

Computer Literacy

When people use computers to help them complete tasks which they regard as problems, then they are likely to have a more positive attitude towards the use of computers, and are likely to look for further tasks which can be completed using a computer. If, however, people use a computer to complete what they regard to be an unnecessary task or in using the computer, the task is made more difficult or less satisfying, then they are less likely to use computers in the future.

Impact of ICT on Learning

While theoretical arguments can be put forward to provide a strong rationale for the use of ICT, the only real rationale is based on whether, in practice, it has a positive impact on learning, the learners, and teachers. This report will now review the impact of ICT on learning, students, the curriculum, teachers, schools, and school systems. The relevant connections between these entities are shown in the diagram below that will act as a theoretical framework for the discussion.

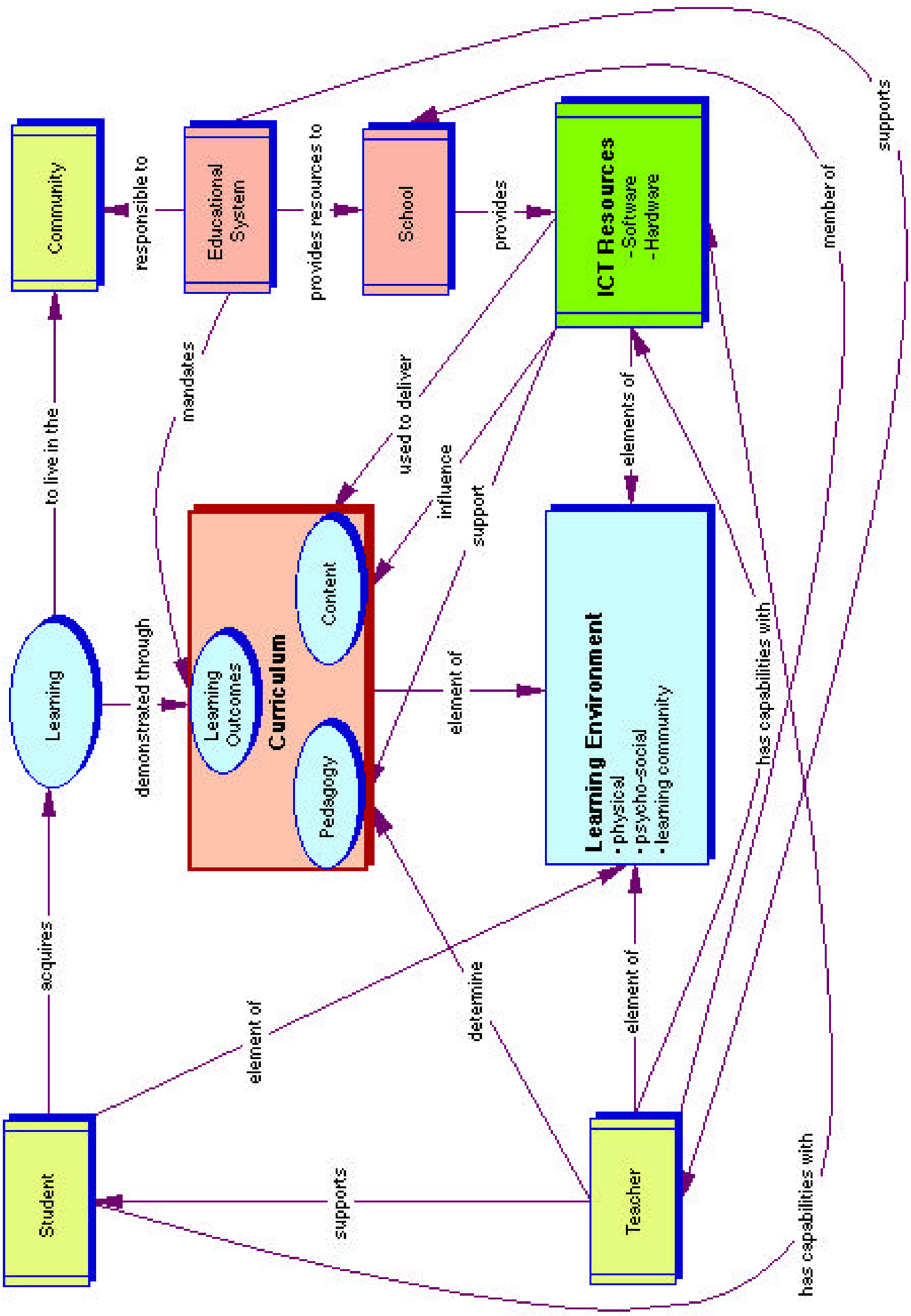

Figure 3 ***Concept map indicating relationships between learning environment entities and external entities.***

No direct link between learning and the use of ICT!

While it would be convenient to be able to make a direct connection between the use of ICT and learning outcomes, most reputable educational researchers today would agree that there will never be a direct link because learning is mediated through the learning environment and ICT is only one element of that environment. Studies that have tried to identify this mediated impact of ICT on learning have found it impossible to entirely remove the effects of other elements of the learning environment.

There is little purpose in attempting to compare the cognitive outcomes when using computers, with using a textbook or some other resource. Salomon (1994) supports this view by arguing that it is not possible to study "the impact of computer use in the absence of the other factors" nor to assume that "one factor impacts outcomes independently of the others" (p. 80). The educational aim is to embed the computer support in the learning environment (DeCorte, 1990), rather than to try to isolate its effect on learning. Using computers in learning is concerned with methods of using the technology to create environments and learning situations. There have been many decades of solid educational research, not necessarily related to using computers, on which to base decisions about appropriate applications of computers to learning. For example, Mevarech and Light (1992) suggest that the relationships between student characteristics, learning environments, behaviours and schooling outcomes are crucial and need further research, yet there has been much research which has considered these relationships in other contexts than educational computing.

Rieber and Welliver (1989) criticise media comparison studies, claiming that they were of no value applied to research into the use of educational television and therefore many question their value to educational computing research. They quote from the report of a 1984 USA government educational task force which suggested that one of the four important points for improving the use of educational technology in schools was the “identification of instructional problems and development of realistic solutions” (p. 22). As a result, they argue that media selection should be the final step in instructional design, not the first, because “different learning situations call for different instructional elements and certain media have the ability to utilize certain features much more readily than other media” (p. 26). They suggest that the identification of educational problems should be the first step. They cite LOGO as an example where there was “no systematic plan for incorporating this new thinking technology into the schools” (p. 26) and as a result, they argue, it failed.

If the aim is to offer new learning opportunities or to improve the way in which current learning activities are implemented then the overall effectiveness of learning environments and episodes is of paramount concern, not whether they are more effective with or without computers. Therefore in implementing computer applications it is necessary to start by deciding what a student, teacher or school wants to achieve. To achieve these outcomes, teachers can then rely on long traditions of educational theory, their own experience and knowledge of the educational situation (e.g. student attributes) to make decisions about what the learning environment should look like and what inputs into the learning process are required. Finally, teachers can identify what problems are associated with providing these environments and inputs and tailor computer and other support to provide solutions. This approach ends with decisions concerning computer support rather than starting with such decisions (for an example refer to Campione et al., 1990).

A report from the ImpaCT2 study (Becta, 2002, p. 3) conducted in the UK found that,

> ***There is no consistent relationship between the average amount of ICT use reported for any subject at a given key stage and its apparent effectiveness in raising standards. It therefore seems likely that the type of use is all important.***

There can be a positive impact

While there is no direct link between using ICT and student learning the weight of evidence now clearly shows that indirectly there can be a significant positive impact. Over the past 30 years there has been an increasing amount of research conducted to investigate this impact with increasingly clearer findings of positive impacts when ICT is used appropriately.

> ***On average, students who used computer-based instruction scored at the 64th percentile on tests of achievement compared to students in the control conditions without computers who scored at the 50th percentile. (Schacter, 1999)***

> ***\West Virginia's Basic Skills/Computer Education program was more cost effective in improving student achievement than (1) class size reduction from 35 to 20 students, (2) increasing instructional time, and (3) cross age tutoring programs. (Mann et al., 1999)***

> ***Differences in attainment associated with the greater use of ICT were clearly present in more than a third of all comparisons made between pupils' expected and actual scores … (Becta, 2002)***

> ***Given the right conditions for access and use, significant gains in student learning are recorded with ICT. (Laferrière, Breuleux, & Bracewell, 1999)***

Since learning is mediated through the components of the learning environment and particularly the curriculum (pedagogy and content) therefore it is useful to start with a consideration of the impact of ICT on the curriculum.

Impact on the Curriculum

Earlier it was argued that there is a two-way relationship between ICT and the curriculum where ICT may be used to assist in conveying the curriculum but at the same time may change the content of the curriculum. Further, research has shown that the effectiveness in the use of ICT to support learning is a function of the curriculum content and the instructional strategy such that when appropriate content is addressed using appropriate strategies students and teachers will benefit (Cradler & Bridgforth, 2002). The impact of ICT on curriculum content may be viewed in terms of:

- Declarative knowledge - describes objects and events by specifying the properties which characterize them, or 'knowing that'
- Procedural knowledge - focuses on the processes needed to obtain a result, or 'knowing how'

The use of ICT impacts on both declarative and procedural knowledge to such an extent that clearly the current curriculum and models of teaching and learning were not designed to accommodate the increasingly rapidly expanding quantity of knowledge (Riel, 1998). For example, the quantity of declarative knowledge is growing rapidly, largely fuelled by the efficiency of ICT, while at the same time ICT provides tools to more readily access that knowledge. The technology itself has added large quantities of declarative knowledge. The skills and knowledge required in society and workplaces is different now from when schools were first instituted. Rather than students requiring specific bodies of declarative knowledge they require very flexible and general sets of procedural knowledge. These tend to involve conceptual understanding, problem-solving, personal interaction, and using resources (Riel, 1998). Much of the procedural knowledge required is supported by the use of ICT.

Most educators would perceive the impact of ICT on the curriculum to be positive. With the use of ICT students can use more primary source material and be encouraged to address real problems and develop analytical and interpretive skills (Riel, 1998). The classroom can be transformed into a learning community making it "possible for many more people to be a part of the learning process in an open and continuing dialogue." (Riel, 1998, p. 9).

So the use of ICT impacts on both the 'what' and 'how' of the curriculum. Riel (1998, p. 12) provides a typical example of this dual impact,

> ***Students can use hypertext to organize their learning, but they can also use hypertext as a form of expression. Writing in hypertext is a new skill. It is conceptually different than sequential writing. It allows for a different form of interaction between author and reader and larger communities of people.***

While the impact will be evident on almost all disciplines of learning the degree will vary substantially between disciplines. However, some research has indicated that there is more variation due to the teacher than the area of the curriculum (Becta, 2002). The Committee on Developments in the Science of Learning argued that there have been large impacts on mathematics and science.

> ***… dynamic models in interactive multimedia that provide visualization and analytic tools are profoundly changing the nature of inquiry in mathematics and science …These changes affect the kinds of phenomena that can be considered and the nature of argumentation and acceptable evidence" (2000, p. 215)***

Clearly the curriculum must remain relevant to societal and workplace needs. While it is reasonable for "… children's school-based learning now, connecting in meaningful and motivating ways to their school-based learning later" (Lankshear & Snyder, 2000, p. 130) at some stage this ''trajectory' needs to connect with non-school discourses. In other words, ultimately school-based learning must connect with "… what people need to learn in order to participate in contemporary social, economic and cultural mainstream life" and increasingly this includes ICT-related practices (Lankshear & Snyder, 2000, p. 126).

Finally, part of the curriculum is the way in which learning is assessed. Many educators and researchers have found that a focus on rigorous paper-based external examinations and tightly prescribed learning outcomes is not conducive to teachers facilitating ICT to support learners (Eadie, 2000). This has often been one of the explanations for the reduced use of ICT by students in secondary schools compared with primary schools. Cunningham (1992) clearly argues why the approach to assessment must change to reflect a change in pedagogical philosophy.

> ***Under objectivism, someone decides what it is the student should know, constructs a task analysis of that knowledge, analyzes the learner's existing capabilities, designs a strategy to communicate the required information to the learner, then tests to see if the communication process has been successful.***
>
> ***... The constructivist would proceed by selecting tasks that are relevant to the child's lived experience....***
>
> ***... The teacher or instructional developer then provides access to tools that can be used to better understand or construct solutions to the problem. ...***
>
> ***... No separate test is required. The "proof", if you will, of the success of the learning is the successful completion of the task. (****Cunningham****, 1992, p.38)***

Assessment based on levels of learning outcomes has been used in a number of countries such as the testing associated with the National Curriculum in the United Kingdom. At the school level Schagen and Hutchinson (1994) found that there were a "..variety of different methods used to award Levels based on marks obtained or performance on Statements of Attainment (SoA)." However, at the national level there are a number of National Curriculum Assessment tests which must be completed by all students of selected ages. Tests of reliability on these tests have found that in some cases "pupils of similar ability could be assigned Levels two or more apart" due to statistical error or other factors such as context and test construction (Schagen & Hutchison, 1994, p.220). Attempts at national testing in the USA have similarly gathered a great amount of criticism with reports that teachers' reactions range from ignoring to cheating (Reeves, 1992).

Many educators recommend that outcomes-based curriculum requires assessment processes associated with student profiling through records of achievement. This allows assessment to emerge naturally from the task rather than being an additional feature of a curriculum. Student profiling also encourages a range of assessment tools to be used which could give a more holistic and accurate portrait of a student (Horton, 1990) with both formative and summative value.

The use of RoA almost certainly implies the need for the maintenance of some sort of student portfolios, collections of evidence of student activity. There are many resources for teachers already available to assist in the collection of portfolios and the structuring of performance tasks. Almost certainly teachers would need computer support to adequately implement a system of profiling through records of achievement. This support would need to be ubiquitous and networked.

While teachers are encouraged by outcomes-based curriculum to take a more constructivist approach to classroom learning it is clear that this will not happen without changes to many assessment procedures. Assessment will need to incorporate evaluation methods based on an holistic Records of Achievement student profiling approach. These should include self-evaluation, teacher reflection on interaction with the student and the student's interaction with other components of the learning environment. This requires the collection, storage, and organisation of a large quantity and range of types of data that is realistically only possible with computer-based support systems. Teachers will need technological support for the administration of the curriculum, particularly to support the assessment of learning outcomes for students. This support will need to be ubiquitous.

Impact on the Learning Environment

It has been argued earlier that ICT is a mediator of learning as a component of the learning environment. While it is difficult to measure and directly demonstrate the impact of ICT in schools on learning it is possible to suggest possible impacts by connecting ICT as a mediator with well researched theories of learning and strategies for providing learning opportunities. The Committee on Developments in the Science of Learning completed such an exercise and stated that "several groups have reviewed the literature on technology and learning and concluded that it has great potential to enhance student achievement and teacher learning, but only if it is used appropriately" (2000, p. 206)

It is generally agreed that in education the unique instructional characteristics of computers needs to be exploited (Committee on Developments in the Science of Learning, 2000). There are four distinct characteristics of computer technology which have clear implications for using computers in the classroom: logical programming, interactive control, graphics and audio output, and information processing. There are many ways in which these characteristics could be used and have been shown to support students and teachers in improving learning outcomes and increasing productivity. The degree to which each of these should be applied will depend on an array of variables such as the developmental age and personal characteristics of the student, the characteristics of the learning environment, and the nature of the curriculum content.

Investigating Reality and Building Knowledge

ICT allows students to investigate more thoroughly the real world (Réginald Grégoire inc., Bracewell, & Laferriére, 1996; Riel, 1998). They can more readily access information sources outside the classroom and can use tools to analyse and interpret such information. Information may be accessed through online systems or through data logging systems (Riel, 1998). The technologies allow them to receive feedback, refine their understanding, build new knowledge and transfer from school to non-school settings (Committee on Developments in the Science of Learning, 2000). In the past this has been difficult to provide in schools due to logistical constraints and the amount of material to be covered all of which can now be addressed with ICT support (Committee on Developments in the Science of Learning, 2000). Feedback can also be more on the basis of how experts reason (Committee on Developments in the Science of Learning, 2000). What can be learned is broadened and deepened (Réginald Grégoire inc. et al., 1996).

Active Learning and Authentic Assessment

In many classroom situations it is difficult to allow students to be sufficiently active as participants. Typically students are often passive, spending a lot of time listening or reading. It is well known that students are more likely to be interested and attentive and will achieve a wider range of learning outcomes if they can be active, learning by doing (Committee on Developments in the Science of Learning, 2000; Réginald Grégoire inc. et al., 1996). Their engagement with the curriculum will increase as they are afforded opportunities to create their own information and represent their own ideas (Riel, 1998). Computer software can be used to provide students with learning experiences where they are interacting with the computer system. Alternatively the software may support activities where they interact with other people either in person or on-line (Riel, 1998). In all these cases the student has more influence on the learning processes and the activities can be more responsive to the needs of the student. This better facilitates the development of conceptual frameworks by students to assist in deeper levels of learning (Committee on Developments in the Science of Learning, 2000; Réginald Grégoire inc. et al., 1996). The use of online systems to support active learning through providing forums for feedback and reflection have been shown to promote greater depth of explanations by students of varying ability (Committee on Developments in the Science of Learning, 2000). Where assessment emanates from active learning it is termed authentic. The use of ICT often encourages active learning and results in more authentic assessment.

Engage students by Motivation and Challenge

The interactive and multimedia nature of modern computer systems has provided the opportunity for software developers to create increasingly more stimulating features. Many studies have found that students like to use computers and are likely to develop more positive attitudes towards their learning and themselves when they use computers (Réginald Grégoire inc. et al., 1996; Schacter, 1999). Computer systems do provide the opportunity to create a wide range of interesting learning experiences (Committee on Developments in the Science of Learning, 2000). This is likely to help to maintain student interest and interest a wider range of students (Cradler & Bridgforth, 2002). The interactive and multimedia features within software can be used to help students grapple with concepts and ideas (Committee on Developments in the Science of Learning, 2000). Students can more readily be provided with similar information and experiences within a variety of contexts (Committee on Developments in the Science of Learning, 2000).

Provide Tools to Increase Student Productivity

In the past students have spent a lot of time doing repetitive, low-level tasks particularly involving writing, drawing and computation. While it may be necessary for students to develop these skills at some time on most occasions they are pre-requisite to some higher-level task. Unnecessary repetition of low-level tasks is inefficient, non-motivational and may obscure the real purpose of the learning activity. Many computer applications provide the tools to support students in quickly completing these lower-level tasks so that they can focus on the main purpose of the activity. Word processors, graphics packages, database packages, spreadsheets and other software support the performance of students. The use of scaffolds and tools can help students to solve problems that may have previously been considered to be too difficult for them (Committee on Developments in the Science of Learning, 2000). Studies have shown that students often learn more in less time, that is their productivity increases, when they use computer support appropriately (Schacter, 1999). Such scaffolding tools are often referred to as Electronic Performance Support Software (EPSS).

Provide Scaffolding to Support Higher Level Thinking

There is an increasing range of software tools which can be used to support the development of higher level thinking skills such as application, analysis and synthesis (Réginald Grégoire inc. et al., 1996; Riel, 1998; The National Foundation for the Improvement of Education, 2001). Tools can be used to analyse data, present data, link data or information, present information in different formats, simulate environments and conditions, and support interactive communications (Committee on Developments in the Science of Learning, 2000). This allows teachers to consider providing a range of activities to assist students to become critical thinkers, designers and problem solvers (Committee on Developments in the Science of Learning, 2000). Computer systems provide a wider range of motivating situations in which students can develop and apply these higher level thinking skills and provide opportunities to develop 'deep knowledge' (Committee on Developments in the Science of Learning, 2000; Schacter, 1999).

Increasing Learner Independence

Computer systems are increasingly being used to provide learning experiences when and where they are needed. This provides students with greater independence not only in terms of when and where they learn but also what they learn (Cradler & Bridgforth, 2002). It is not necessary for all students to do the same thing at the same time. Teachers may provide students with access to software allowing students to select different learning experiences. The class does not have to be treated as one group. Individuals or groups of students may consider learning topics independently of the teacher (Réginald Grégoire inc. et al., 1996). This is often discussed in terms of lifelong learning, learner-driven learning or project-based learning (Riel, 1998). ICT tools can be used to create records of thoughts and support reflection and assessment of progress (Committee on Developments in the Science of Learning, 2000).

Collaborative and Cooperative Learning

Researchers have found that typically the use of ICT leads to more cooperation among learners within and beyond school and a more interactive relationship between students and teachers (Réginald Grégoire inc. et al., 1996). ***Collaboration*** is a philosophy of interaction and personal lifestyle where individuals are responsible for their actions, including learning and respect the abilities and contributions of their peers. ***Cooperation*** is a structure of interaction designed to facilitate the accomplishment of a specific end product or goal through people working together in groups. Studies have found that ICT provides good support for team-based project work (The National Foundation for the Improvement of Education, 2001). The use of ICT to support collaborative and cooperative learning is extrapolated to the support of a learning community (Riel, 1998).

Tailoring Learning to the Learner

In most traditional learning situations it is not possible to provide each student with an instructor and for that instructor to specially design learning experiences for that student. The closest to this is the apprenticeship system. The programmability and interactivity possible with computer systems provides the opportunity to develop software which simulates the role of an instructor. Intelligent tutoring software may use information about the student to recommend appropriate sequences or sections of a tutorial for the student. Many studies have found that using computer-based instruction can increase achievement scores by at least one standard deviation although this is not uniform nor consistent across all areas of study (Schacter, 1999). The ideal is that the software allows the student and/or teacher to tailor the learning experiences to suit the individual student (Cradler & Bridgforth, 2002). Each student may encounter different experiences when using the same piece of software. The technology has been used successfully for teachers to give students feedback that is more timely and more individual (Committee on Developments in the Science of Learning, 2000). Assessment of learning can use more demanding methods and better diagnose the needs of learners (Réginald Grégoire inc. et al., 1996). The use of online technologies is often used to provide more individualised programmes (Eadie, 2000). Computer software can also be used to support children who require individual learning programmes (e.g. gifted, distance education or remedial). Students can be provided with computer support for learning activities tailored to their individual needs. Studies have shown increased achievement in special needs children when computers are used (Schacter, 1999).

Overcome Physical Disabilities

The variety of input and output devices available provide the opportunity for students who are physically handicapped to be involved in the same learning activities as other students. For some students computers provide the only environment which they can manipulate and the only tools that reduce their level of disability. Modified keyboards and mouse-drivers may be used to allow extremely handicapped students to use regular software packages.

Summary of Research Base for Positive Impact of ICT on Learning Environment

The following table provides examples of research reporting positive impacts of ICT use on learning through learning environments.

Table 1

Research findings for a positive impact of ICT on learning through learning environments.

Positive Impact of ICT	Examples of Supporting Research
Investigate reality and build knowledge	In Canada research results point to the “transition from closed to open teaching and learning environments” (Laferrière et al., 1999). Students using the CSILE application showed gains on measures of depth of understanding and reflection (Scardamalia & Bereiter, 1996). Students use ICT to analyse, organize and creatively represent real information in constructing knowledge (Bereiter, 1998).
Promote active learning and authentic assessment	An evaluation of IMMEX Teacher Institutes have shown statistically significant improvement in teacher preparation to: manage a class of students who are using hands-on/laboratory activities, use a variety of assessment strategies, use performance-based assessment (WestEd, 1998). Students using the CSILE application showed gains on measures of progressive thought and reflection (Scardamalia & Bereiter, 1996). ICT may be used to support students to design and produce their own knowledge representations and thereby engage with powerful learning experiences (Berge & Collins, 1998). The evaluation of learning outcomes requires methods that measure understanding. These can be supported by the use of ICT (Brown, 1994).
Engage students by motivation and challenge	Students have more positive attitudes towards their classes and learning when ICT use is included (Baker, Gearhart, & Herman, 1994; Kulik, 1994). The use of ICT has consistently improved students’ attitudes towards learning and their own self-concept (Sivin-Kachala, 1998). Educational technology has had positive effects on student attitudes toward learning and on student self-concepts. Evidence of such is strongest in language arts, mathematics, science, and telecommunication/video technologies. (The Software Information Industry Association., 1999) Content-related graphics (both static and animated) and video can help improve student attitudes and motivation in mathematics and science. (The Software Information Industry Association., 1999)
Provide tools to increase student productivity	Students tend to complete more in less time when they use ICT (Kulik, 1994). Students using an integrated learning system to support the development of skills in spelling, vocabulary, reading and mathematics showed improvements more cost effective than other major initiatives (Mann et al., 1999).

Provide scaffolding to support higher level thinking	It appears that appropriate use of ICT results in new learning experiences requiring higher levels of thinking and problem-solving (Baker et al., 1994). Animation and video can enhance learning when the skills or concepts to be learned involve motion or action. (The Software Information Industry Association., 1999) Canadian students using portable computers created portfolios that demonstrated "advanced technology, inquiry, and meta-cognitive skills as well as deep understanding of a number of topics" (Laferrière et al., 1999). An evaluation of IMMEX Teacher Institutes have shown statistically significant improvement in teacher: knowledge and use of problem-solving strategies in the classroom and present applications of concepts. (WestEd, 1998) Students used simulation and cognitive support software to show improvement in higher order mathematical thinking (Wenglinsky, 1998).
Increase learner independence	Foreign language and ESL (English as a Second Language) students can benefit from presentation of video segments with captioning (i.e., subtitles in the target language) (The Software Information Industry Association., 1999). Students using the CSILE application showed significant improvement in independent thinking (Scardamalia & Bereiter, 1996).
Increase collaboration and cooperation	In courses using computer-based networks, many students who seldom participated in face-to-face class discussions became more active participants online. (The Software Information Industry Association., 1999) Introducing technology into the learning environment has been shown to make learning more student-centered, to encourage cooperative learning, and to stimulate increased teacher/student interaction. (The Software Information Industry Association., 1999) An evaluation of IMMEX Teacher Institutes have shown statistically significant improvement in teacher preparation to use cooperative learning groups (WestEd, 1998) The use of ICT encourages teachers to use more cooperative work and less teacher lecturing (Baker et al., 1994).
Tailor learning to the learner	Addressing language impairment (Turner & Pearson, 1999) Students who are field-independent learners (i.e., learners who rely less on contextual clues in defining meaning) perform better than field-dependent learners when using hypertext. (The Software Information Industry Association., 1999) An evaluation of IMMEX Teacher Institutes have shown statistically significant improvement in teacher preparation to teach groups that are heterogeneous in ability and take students' prior conceptions into account when planning curriculum and instruction. (WestEd, 1998)
Overcome physical disabilities.	There are many case studies where children with physical disabilities may use adaptive technologies to maximise their successful use of ICT (Donegan, 1999).

The Learning Environment as Mediator of Learning

We are interested in what effect the computer is likely to have on the classroom environment and whether it is likely to find a harmonious and useful role in that environment. ICTs provide the support to extend the possibilities for creating learning environments (Committee on Developments in the Science of Learning, 2000). The most important entities in determining a classroom environment are the teachers. In most classrooms it is the teacher(s) who decides what content is important, directs student learning, assesses student learning, structures the environment (e.g. rules and routines) and chooses and provides the materials to be used. However, the student role is also critical.

Teacher/Student Roles

The teacher will always have a role in directing what and how students learn whether this is by controlling the instruction or providing the learning situations. The students will always play both passive and active roles in the teaching and learning scenarios. It is suggested that the balance of control and roles is likely to shift towards student participation with the use of ICT to support learning processes. This transfer of roles or control often occurs spontaneously and naturally in a classroom within an activity (Committee on Developments in the Science of Learning, 2000). Riel (1998, p. 9) concludes that the balance of control may ultimately not be “under the complete control of the teacher, nor under the complete control of the learner” with the “inclusion of many people with differing expertise” as ICT is used to support a learning community.

Teacher as Manager

While computers can be used in a demonstration mode most of the range of computer use involves computers being used by students. Therefore as indicated earlier this necessitates a more ***student-centred*** approach. A ***teacher-centred*** approach could still be adopted through use of selected demonstration and tutorial applications. To accommodate a significant role to the computer in the classroom there needs to be a number of changes to the role of the teacher. How significant these changes are for a teacher depends on what they perceive to be their current role. The teacher needs to become a catalyst for learning rather than being the focus. The teacher becomes a learning model for the students not an expert in everything. The teacher is a facilitator of cooperative learning by involving students in real problem-solving. In the apprenticeship model, the teacher may use ICT to model an activity and then scaffold the learner (Committee on Developments in the Science of Learning, 2000).

Teachers need appropriate communication and management skills. For example, clear instructions (verbal and written) have to be presented so that most students do not need to call on the teacher for assistance regularly, appropriate tasks have to be assigned to individual students, ground rules have to be established for interaction with other students and computer equipment, and hardware and software have to be made available to students when they need them.

It is acknowledged that a problem for teachers using computers is evaluating whether students are engaged and with what. Further, teachers must evaluate student learning needs in order to provide them with appropriate tasks and software. Problems concerning evaluation require teachers to spend more time in one-to-one interaction with students and to have skills in interpreting student output (e.g. spoken, written).

Student Responsibility for Learning

While the teacher’s role in the classroom is fundamentally important to computer-supported learning, the student’s role is also significant. If the environment is to become more ***student-centred*** then there is a necessary shift of responsibility for learning away from the teacher and toward the student. Students need to become more self-directing and motivating and thus take more responsibility for their own learning. This is not to say that the teacher has no responsibility. The teacher needs to provide a structure within which students can learn. This includes providing tasks, asking questions, providing resources, and setting ground rules. Students themselves can become the experts on particular topics (Riel, 1998).

Innovations involving the use of computers invariably place additional demands on students. For the students it may represent a new approach to learning in which they have to develop confidence and competence. It has been noted that there may be significant changes to their role which are complementary to changes in the teacher's role. This may require them to develop skills concerned with taking more responsibility for learning and relying less on the teacher. They may need to develop skills in making decisions for themselves and with other students. In addition, practical skills such as the ability to follow instructions presented on paper, by a teacher or on a computer screen need to be developed.

Students will also need to develop skills in determining and assessing their own learning. For example, self-directed learning using computers usually implies the use of more visual forms of instruction and information than verbal. Therefore students need to have increased levels of comprehension and concentration. Students need to develop skills in recording and evaluating their findings and progress. With the help of the teacher they need to be able to interpret their findings and make decisions about directions for learning.

Models of Implementation

It has been noted in the last section that the effectiveness of computer applications is very much dependent on the manner in which they are implemented. While it is important to have well designed software, appropriate hardware, and skilled users, all of this is in vain if the application is poorly implemented in the classroom (Committee on Developments in the Science of Learning, 2000). Implementation requires integrating the application into the curriculum so that it is a meaningful experience for students and the management of the classroom environment, including teacher and student roles and behaviours, computer and non-computer resources and materials.

Given that an application is appropriate, successful implementation depends on good planning by the teacher, and appropriate teacher and student behaviour during class time. Planning needs to entail - integrating the application with other instructional and learning strategies, preparing support materials, developing strategies for the management of hardware, software and students (e.g. providing access, timing). Teacher behaviours include: using the management strategies, monitoring student progress, guiding student learning, and coping with unforeseen problems. In addition appropriate student attitudes and behaviours need to be fostered. For example, students may have to work independently and follow written or screen instructions. Therefore, if the students do not possess the skills to work independently and follow instructions carefully then it is likely that the implementation will be ineffective no matter how well planned the activity, or skilled the teacher.

It is important in the long term that teachers develop their own methods and strategies for implementing appropriate computer applications, however initially teachers find it useful to follow models based on successful implementation by more experienced teachers.

The Models

A model for implementation is a blueprint based on experience and theory which can be used to guide the teacher. Any model will reflect in a dynamic way a set of values and perceptions. Consider three general models for the integration of computer use into the classroom, with each model representing a different emphasis on the interaction between students, computer system and teacher.

Whole-Class Model   One-to-One Model   Group-Work Support Model

These models largely reflect the nature of the interaction between the students and the computer(s) (Figure 4) but do not necessarily dictate a particular mode. Often the availability of hardware, software and the design of software may dictate which model is used. In the whole class model a computer system is used in learning experiences which involve all the students working as a large group and often this will involve demonstration mode computer use. It is a teacher-centred model with the emphasis on the teacher controlling any computer-student interaction. In the one-to-one model the emphasis is on the computer-student interaction and therefore it is more student-centred. Typically this involves each student working individually at a workstation but not necessarily all at the same time. The group work model implies that students will work in groups of two or more with groups having access to a workstation. Here the emphasis is on student-student interaction with the computer system and teacher facilitating this interaction and the completion of group based tasks. Naturally there are many variations on each general model.

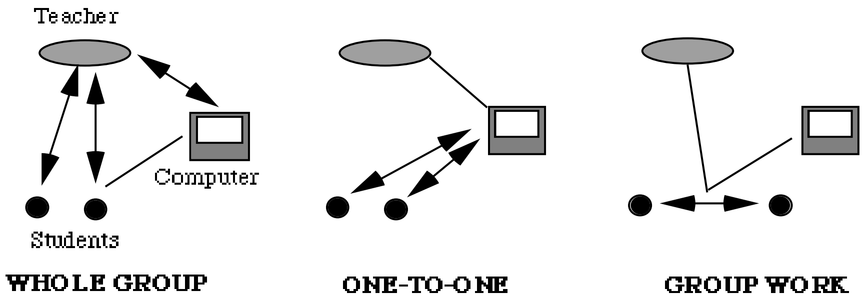

Figure 4 Three general models of interaction for the implementation of computers in classrooms. Main interaction is shown with double arrows, support interaction shown with thin line

A number of key parameters may be identified in describing the implementation of computer supported learning environments or activities. Here we define eight distinct implementation models based on the parameters: location, student/computer (S/C) ratio, method of providing access to computers, control of computer(s), task direction (by whom), and operating instructions (strategy for provision).

Table 2

Implementation models for the use of ICT in learning environments.

Model	Loc#	S/C Ratio	Access*	Control	Task Direction	Operating Instructions
1. Whole-Class 'Lock-Step'	Lab	1 or 2	Unlimited	Teacher	Teacher	Demonstration
2. One-to-One Teacher Control	Lab	1	Unlimited	Teacher	Teacher or Computer	Demonstration or text
3. One-to-One Student Control	Lab	1	Unlimited	Student	Student	Demonstration, on-line or text
4. Group-Work Support (Laboratory)	Lab	1 comp per group	Unlimited	Students	Students	Demonstration, on-line or text
5. Whole-Class Demonstration	Lab or Class	Total of 1	None	Teacher	Teacher	Demonstration, front of class presentation
6. One-to-One Rostered	Class	> 1	Roster system	Students	Teacher or student	Demonstration, on-line, peer tutoring or text
7. One-to-One Self Select	Class	> 1	self-selecting queue	Students	Teacher or student	Demonstration, on-line, peer tutoring or text
8. Group-Work Support (Classroom)	Class	< 1 comp per group	roster, self-selecting queue	Students	Students	Demonstration, on-line, peer tutoring or text

 # Location: Lab implies either going to a laboratory of computers or using enough portable computers.
****Self-selecting queue implies that students go to a computer when there is one available.***

Different Roles for Different Environments

The role of the computer within the learning environment concerns the way in which it is used in the teaching and learning processes. The computer may assist the teacher in instructing, instruct students, aid student learning or be a tool to complete tasks. The role the computer plays has implications for the choice of hardware, software and teaching strategies by the teacher. Also there are implications for both teacher and student roles.

The following will outline the fundamental considerations for the implementation of each model. The hardware and software requirements are not necessarily dictated by the model being implemented, rather more related to the mode of computer support (i.e. tutorial, simulation etc.). Hardware and software requirements are discussed in the next section.

Roles for Computers

Many classification systems have been devised to describe the roles of computers in learning and teaching. For example, Perkins (1992) proposed five generic categories to describe the variety of ways in which educational technology can be used in classroom learning: Information Banks, Symbol Pads, Construction Kits, Phenomenaria, and Task Managers. He defines ***Information Banks*** as resources whose main task is to provide a source of information about topics. ***Symbol Pads*** he defines as resources, such as word processors calculators and pencils, which are designed to provide construction and manipulation of symbols. ***Construction Kits*** are resources such as Lego and laboratory apparatus which allow learners to assemble entities. ***Phenomenaria*** resources allow learners to scrutinise and manipulate phenomena (e.g. microscopes). Finally ***Task Managers*** are those resources which set tasks for learners and may also help with the execution of the tasks and provide feedback. Clearly as a learning resource, computers have the capability to fulfil all these roles.

Schanks and Cleary (1995) focus on what they call, ***goal-directed learning***. They discuss the need to develop active learning environments in which students are encouraged to pursue intrinsically motivating goals which are related to intended learning outcomes. They suggest that computer software can be used to support this scenario. For example, they created a simulation, ***Sickle Cell***, of a medical counselling situation which includes a blood laboratory where the goal is to "identify the clients' gene types" which is related to the intended outcome of "learn[ing] about red cells and hemoglobin". They recommend a range of software tools to support goal-directed learning with scenarios.

1) Simulation-Based Learning by Doing Tools

> ***Tools that will enable people to "learn by doing" by placing them within simulated situations that replicate real world environments.***

2) Knowledge Organization and Retrieval Tools

> ***Tools that can help organize the massive amounts of video, textual, and machine readable data required.***

3) Teaching Tools

> ***Tools that will support different teaching methods which are appropriate in different contexts.***

4) Tools to Enhance Thinking

> ***The computer has the power to serve as a real thinking aid by asking pertinent questions that help the user clarify his thoughts.***

5) Interaction Tools

> ***There are many ways to enhance the process of interacting with a computer such as with natural language processing tools.***

Classification According to Degree of Learner Control

Another method of classification is according to the degree of learner control over the application of the computer (Figure 5). That is, the control of the learning sequence is seen to vary from situations where the teacher or computer is in control to others where the learner is the determinant of the process. The diagram below shows a spectrum of the different applications using common descriptive terms that are defined. These categories of use are briefly described in Table 3.

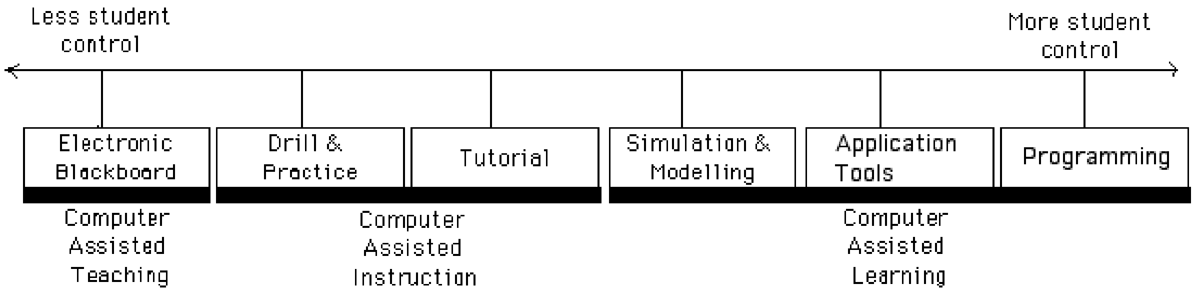

Figure 5 Classifying computer use in schools according to the degree of student control.

Table 3

A classification system for educational applications.

Classification	Description
Electronic blackboard	Teacher presents information as text or graphics to whole class.
Drill and Practice	Student revises knowledge and skills.
Tutorial	Student is presented with new information.
Simulation	Student uses computer to imitate a real situation.
Modelling	Student uses computer to create an environment whether realistic or imaginary.
Application Tools	Teachers and students complete tasks using software packages such as word processors, graphics packages and databases.
Programming	Student develops sets of instructions for computer in order to solve a problem.

A software package can not necessarily be classified by an educational application as it will depend on how the software is used. For example, a teacher could use a slideshow authoring package as an ***electronic blackboard*** application to present information on some topic. Alternatively students could use the package as an ***application tool*** to present their own interpretation of information they have collected. Similarly many software packages may be used as tutorials or drill and practice depending on the background of the students.

Electronic Blackboard

The computer is used mainly by the teacher, and projected onto a large screen, often using a multimedia projector for whole-class demonstration or interaction to present information, or illustrate concepts and ideas. The computer system can be used to present dynamic graphics, sound and video and may be interactive. The usual format of a piece of software designed for use in a demonstration mode is one where the teacher interacts with the software to control a display on the screen. The computer assists the teacher in the presentation of instruction. This allows for a ***teacher-centred*** approach with the computer saving the teacher time and improving the quality of presentation. It can involve some student interaction, for example, using handheld input devices (Committee on Developments in the Science of Learning, 2000, p. 219).

Teacher and student roles

The teacher plays the major role with the computer playing the role of the ***teacher's aide***. The students have a relatively passive role in that they are required to observe the computer screen and listen to the teacher's instructions. While this may be an efficient use of one computer in a classroom the learning cannot utilise the interaction capabilities of the machine. Further, the skills of the teacher in using the hardware and the software become critical with the teacher needing to feel confident and in control. The teacher must provide explanations to supplement the images created by the computer and needs to develop skills in integrating the computer output with the overall presentation.

Hardware and Software

Since the emphasis is on presentation the output and processing capabilities of the computer system are crucial. It is necessary to have a good quality large display device with perhaps a smaller monitor for the teacher. A fast processor is needed to allow the presentations to flow smoothly. Only one copy of each piece of software is required and therefore it is worth paying for high quality materials with graphic and audio output. Software should be interactive with a high level of control. The computer should not be used just to replace an overhead projector, textbook or video recorder since these are all less expensive and more effective at non-interactive presentations.

Tutorial, Drill and Practice

Tutorial applications are designed to present specific content typically presented using a variety of media, allowing the user some interaction with the information (navigation). High quality tutorial packages will include features such as assessment of prior learning and preferred learning style to direct students to the best sequence (e.g. Committee on Developments in the Science of Learning, 2000, p. 218). Good quality tutorial applications are expensive to produce and have limited application, usually only relevant to use once with a student. Drill and practice applications provide students with environments in which to practise skills by responding to stimuli. Often gaming environments with graphics and sound are used to provide additional motivation. With the drill and practice environment it is assumed that the content has been previously encountered but needs consolidation. Most packages allow students to operate at an appropriate level of difficulty. Many also maintain databases of student performance and/or responses.

Support for Learning

The emphasis in tutorial, drill and practice applications is upon individualised instruction, revision and evaluation with more interesting environments than alternative strategies and the computer as a more patient tutor. The computer can provide a variety of response situations and provides positive feedback. This allows teachers to give consideration to the individual needs of students which traditionally has been a problem with large numbers of students and very little time. The computer takes on part of the instructional role of the teacher with the teacher managing the instruction. The software needs to be matched to the curriculum and therefore is typically content or skills based. There are many educators who feel that this is a trivial or inappropriate use of a computer. However, such software may be used in the development and maintenance of lower level skills (sub-skills) necessary for later progress. There is a danger that such applications focus on student memory of content, although they can be developed to focus on student understanding. These applications are usually easy for teachers to integrate with the curriculum and implement in the classroom.

While it appeals to the public imagination (computers teaching students) even the best tutorial package can't adequately replace an average teacher. Tutorial software may be useful as supplementary material for some students for enrichment and remedial situations. Some research has shown improvements in skills such as reading, language arts and mathematics of up to 30% when computer-based tutorial and drill and practice software are used (Mann et al., 1999). These applications have become increasingly sophisticated with the higher quality packages implementing strategies based on many years of educational research, for example, expert systems and cognitive tutors and apprentices (Committee on Developments in the Science of Learning, 2000).

Teacher/Student Roles

The computer has the role of tutor with the students responding and the teacher facilitating or supporting the interaction between the student and computer. The main interaction is between the student and the computer with the computer dominating this interaction. The student is relatively passive although controls the pace of interaction and may have some navigational control. The teacher is concerned with managing the computer system and students. This involves selecting appropriate computer applications and ensuring the students have adequate access. The selection of applications involves integrating the computer instruction into the curriculum and matching it to the individual needs of students. In many cases it is not appropriate to rely solely on computer instruction, other forms of instruction and revision should be used in conjunction with the computer application.

The teacher has to ensure that students are sufficiently engaged. Since the usual mode of instruction is one workstation per student the teacher either needs a large number of workstations or needs to roster the available workstations between the students. If rostering is necessary non-computer based tasks need to be provided which ideally should complement the computer-based instruction. If the software is self-paced and involves levels or modules, then students need to be directed by the teacher and/or the software to the appropriate level or module. These require a high level of organisational skills. The teacher also is concerned with evaluating the effectiveness of the instruction and revision. Student progress needs to be assessed in some way. In some cases the package may help by keeping records on student performance and progress. These then need to be interpreted by the teacher to monitor student behaviour.

Hardware and Software

The software must be highly interactive otherwise a book would be a more appropriate but at the same time it must cover the content and skills adequately. If the software is to be used for self-paced learning, then it is important to know how the package teaches and under what conditions. Students need access to appropriate software, which usually requires a well catalogued library of software. Typically they are media intensive so they require either fast networking capabilities or large local storage.

To implement these applications effectively usually requires one computer workstation per student and thus is more difficult and expensive to implement. However, in some cases it is an advantage to have students working in pairs because they can help each other (peer tutoring). The output capabilities of the system are important and therefore it is necessary that each workstation have a good quality, colour monitor. Further, since applications also involve student input and the input capabilities of the system are also important. Devices should be chosen which allow students easy and quick input. For many students the keyboard is frustrating to use and therefore consideration should be given to devices such as the mouse, joystick, concept keyboard etc. Audio input-output may be inconvenient as it may disrupt other students, but headphones can be used.

Simulation, Modelling and Programming

Computer systems can be used very powerfully in providing support for students to investigate ideas and concepts through modelling and simulation (Committee on Developments in the Science of Learning, 2000). Generally these involve software that is typically referred to as simulation, modelling or programming. The computer can be used to test out ideas and hypotheses. This may involve the use of specific simulation packages, using the computer to set up artificial environments for modelling, or through having students develop expertise and skills in the principles of programming the computer. The software provides students with the opportunity to supply the computer with instructions either through a programming language or control of parameters of an environment. Programming provides the greatest level of control of the user over the computer.

Simulation software involves imitating real or imaginary situations using the computer to represent the situation using mathematical models with which the user interacts. The user responds to situations presented by the program to affect some particular outcome. With practice and experience, the learner is able to determine the factors and variables which the programmer has incorporated into the system and replay their performances to try out possible improvements (Committee on Developments in the Science of Learning, 2000). The use of simulation software in technical training has been successful with training times diminished by as much as 95% (Committee on Developments in the Science of Learning, 2000). Studies have shown significant gains in achievement scores in areas such as mathematics when simulation and higher order thinking software is used (Schacter, 1999).

Modelling software differs from simulation software in that the computer provides the tools to create a model for a real or non-real environment. It provides the students with greater scope for visualising, designing and controlling an environment (Committee on Developments in the Science of Learning, 2000; Riel, 1998). When used in this way, the computer follows the instructions provided by the student. The learning situation revolves around the task of creating the environment and instructions to investigate that environment.

Support for Learning

The computer provides a means of developing successful strategies to solve a wide range of interesting and challenging problems. This enables the computer to be used effectively in situations where only limited hardware is available. The students are often able to work together to attain some common goal, and the experience gained is seen to develop cooperation and interaction skills which are transferable to other aspects of the school curriculum. The computer is made to respond to a variety of different responses from the user and as a consequence the learner is able to control much of the interaction. The control in the teaching/learning situation has thus been turned towards the user and away from the computer.

In the developmental approach to learning a student should develop concepts, moving from a concrete to an abstract understanding of the concept particularly through visualisation (Committee on Developments in the Science of Learning, 2000). Many applications, particularly those involving dynamic visual displays, allow students to perform concrete manipulations of an environment which at a later stage allow the development of abstract conceptual understandings. A number of studies have shown gains in problem-solving, communication abilities, and attitudes (Committee on Developments in the Science of Learning, 2000). Often these applications support collaborative experiences that help students “understand complex systems and concepts, such as multiple causes and interactions among different variables” (Committee on Developments in the Science of Learning, 2000,p. 212).

It is important that computer use not take the students away from the ‘real’ world but be seen to enhance their perceptions of the ‘real’ world. As one educator has so aptly put it,

> ***The computer should never be used as a substitute for interacting directly with the environment. Children should paint with real paint brushes, dance real dances, and collect real flowers rather than just doing these things on a computer screen.” (Adams, 1985, p.35)***

Simulation programs have the ability to compress time, deal with large sample spaces and duplicate expensive, massive, delicate or dangerous equipment and experiences. The computer is able to provide a means of replicating the experiences in instances where the actual experience is difficult to adequately provide. The software is usually designed to promote the development of higher order learning skills such as problem solving and formal reasoning, as well as providing instruction in important areas of the curriculum. The computer provides a flexible environment in which students can test ideas, develop concepts and solve problems. The accent should be on open-ended learning and investigation.

The programming language Logo is often promoted as a system which is able to provide microworld environments for students to explore. Much research has been conducted into the use of Logo to support the development of problem-solving skills with some positive results (Schacter, 1999). Logo allows not only mathematical modelling but also language modelling through its use of natural language commands. It provides environments in which students can model and experiment.

Teacher/Student Roles

The emphasis is on learning rather than instruction with the student-computer interaction central but with the student in control. The structure is provided by the teacher and software and typically there is also interaction between students and teacher and between the students themselves. Many packages are intended to promote cooperative learning by encouraging students to work in small groups and share their findings and understandings. The students' focus should be on the problem, concept or task, not on the use of the computer.

Since the dominant role is played by the students they need to develop a strong sense of responsibility for their own learning and develop skills associated with the management of time, concentration, self-discipline, attention to task and ability to follow instructions. They need to develop skills in reflecting on learning experiences and selecting and using learning (problem-solving) strategies.

While the focus is not on the teacher's role it is nonetheless very important as a manager of students, learning resources and to some degree of learning itself. The teacher will need to set broad learning objectives and task descriptions for students, and provide feedback and monitor progress. The teacher will need to provide students with access to hardware and software and ensure they know how to use them. The teacher needs to be seen as both a supporter of and model of 'learning'. That is on one hand the teacher motivates, coordinates, sets the guidelines and helps students develop learning strategies while on the other hand he models learning by being involved in the students learning not as an expert but as a fellow learner. This frees teachers to set problems or tasks that are not necessarily centred on their areas of expertise but this may unsettle teachers by placing them in the vulnerable position of 'not knowing'.

Software and Hardware

Students need sustained access to appropriate computer systems. This will require a class to have access to a number of workstations and a quantity of high quality software which is flexible enough to allow them to test out their ideas. It is not always necessary to have one computer per student as the software may be suited for group use or may be incorporated with a number of tasks which are not computer-based. However, it is important that as students attend to their learning activities that they have almost immediate access when they perceive that a computer application is appropriate. Therefore an ideal situation would be to have a number of workstations scattered around the edge of the classroom or in a readily accessible area.

The hardware requirements centre around the input/output and processing capabilities. Students need to interact with the computer system easily and therefore clear output is required (e.g. high resolution colour screen) and input devices need to be selected which allow quick and accurate input. To investigate ideas in reasonably complex computer-based environments students need quick response from the computer system, and therefore a reasonably fast processor and large amount of memory is required. The software should be sufficiently open ended to allow students to experiment but at the same time should use instructions which are easy to follow so that students do not use too much time learning the commands for the package. Ideally software should be used which attends to a number of different concepts at different levels.

Application Tools

A huge amount of software has been developed to replace many tiresome and tedious tasks such as producing documents or graphics. The computer offers a flexible tool which may extend the capabilities of the user and allow information to be represented in a variety of ways (Committee on Developments in the Science of Learning, 2000). In many cases this may provide tools to scaffold the learning for the student (Committee on Developments in the Science of Learning, 2000). There are also many applications designed for the production, analysis and communication of information (production, cognitive and communication tools). While most of this software has been developed for use in the workplace, increasingly it is finding relevant use in schools. Educators need to use technologies that “draw both from knowledge about human cognition and from practical applications of how technology can facilitate complex tasks in the workplace” (Committee on Developments in the Science of Learning, 2000,p. 214).

Further to giving access to information through databases and providing processing and interpreting tools, computers can also allow students to create their own information from original data sources, often using the Internet. The Internet provides a number of facilities that provide communication and information access tools, including: Electronic Mail (Email). Listservs, Usenet newsgroups, and the World Wide Web (WWW).

Support for Learning

It is the way software is used that makes it a particular type of application tool. For example, a graphing package could be seen to be used to complete a routine graphing exercise or to allow a student to test a model. Here the computer will be considered a tool when it is used to help complete tasks which extend the capability of the user. For example, in solving a geometric problem a student may wish to draw a diagram using a computer, or in preparing a group presentation on a local area survey students may want to use a word processor or graphing package. In both cases the computer is used to support the problem-solving process but is not central to the major theme of the problem, that is the geometric problem or the survey.

Often the computer may be used to complete 'tedious' and/or 'menial' tasks allowing teachers or students to focus on the objectives of the tasks rather than the mechanics of the tasks. By completing such tasks it allows students to apply themselves to realistic problem-solving. In the past many problems set for students of all ages and in a variety of subject areas have tended to be very contrived or over-simplistic due to the processing difficulties associated with realistic problems.

Teacher/Student Roles

The role of the student is central. The teacher supports the student by providing appropriate hardware and software and training in the use of the software. This does not necessarily require the teacher to have a high level of expertise in the use of the software, and support materials may be used.

The education system as a whole, and teachers in particularly have found it difficult to adjust to students having access to high powered computer processing. Many traditional skills associated with curriculum areas such technical drawing, art, mathematics, writing, industrial arts and music become less important as new skills emerge. Students using computers may have the capability of producing far higher standards of work than their teachers have ever been able to. This is one area of computer use where we should expect the computer to change the way we teach and what we teach.

Software and Hardware

The hardware requirements of the computer system will depend on the type of software required. However the quality of printers is often of importance. It is important that the software and hardware work together so that the tasks are completed to a higher standard with less difficulty. Some of these packages have been designed specifically for children. Care needs to be taken in applying software designed for adults to the needs of children.

Impact on Teachers and Pedagogy

Teachers are a key component in the learning environment and therefore the impact of ICT on teachers and the strategies they employ to facilitate the environment are critical. There sometimes appears to be an assumption that using ICT to support learning requires change for all teachers whereas clearly some teachers (the authors included) have been creating appropriate learning environments for years without using ICT. However, these teachers tend to use ICT because they readily perceive that in doing so they will provide even better such environments (Becker et al., 1999). The impact on teachers is varied and idiosyncratic although some general areas of impact may be identified as,

- the balance of roles they play with a perceived risk of reduced influence,
- providing greater access to information, leading to increased interest in teaching and experimentation (Cradler & Bridgforth, 2002),
- requiring more collaboration and more communication with teachers, administrators and parents (Cradler & Bridgforth, 2002),
- requiring more planning and energy,
- requiring the development of skills and knowledge of ICT, and
- providing more time to engage with students, leading to greater productivity (Cradler & Bridgforth, 2002).

The impact on pedagogy can be summarised as being strategies that are,

- more learner-centred,
- more cooperative and collaborative,
- more active learning, and
- based on greater access to information and sources of information.

These impacts on pedagogy have been discussed in earlier sections of this review but relate directly to impacts on teachers, in particular the roles they play, their use of information, and their workload.

Impact on the Roles of Teachers

The link between technological development and the transformation of learning is clear in history, for as Rieber and Welliver (1989) point out, "the lecture-and-text-based model of teaching and learning is itself the product of the introduction of a new technology, the printing press, into 16th-century European culture" (p. 25). The question then is how will the participants in school-based learning adapt and apply the technology, and what models of teaching and learning will result? From the premise that “experience with computer tools can fundamentally alter teaching”, Miller and Olson (1994, p. 136) argue that an important neglected reason “why computers have not altered curriculum in the manner predicted by some educators” is the “influence of traditional teaching methods and routines of practising teachers”. They conclude that, “Although critics raised numerous questions concerning the unrealized potential of computers, few looked at how traditional classroom practices affected its use” (p. 126). Collis (1989) reasons that “many elements of traditional school organization will, and should, remain regardless of IT’s potential” (p. 17), and suggests that teachers will always need to be instructional leaders, that there is always a need for human-to-human interaction and motivation. Also Becker (1994) points out that it will be necessary to produce systematic evidence that the teaching practices best supported by computer-use such as discovery-based learning and problem-solving, do result in improvements in student competencies. Even if this is the case, Fullan (1996) argues that such systemic change is complex and difficult to achieve, particularly at the classroom level.

Riel (1998) perceives that current notions of using computer systems to provide just-in-time learning “massively undervalues the role of the teacher” (p. 1). In fact teachers and other experts will be required to support students in handling “conflict and multiple perspectives” (p. 6). This will in turn develop in students the understanding of the need for interdependence. This is supported by the Committee on Developments in the Science of Learning that concluded that “effective use of technology involves many teacher decisions and direct forms of teacher involvement.” (2000, p. 219).

While it is clear that the role of teachers will continue to be critical, the composition of that role is likely to alter to require a greater range of skills and understandings. Teachers need to be more skilled in directing students through the huge quantities of rich information (Riel, 1998). If the aim is to use ICT to involve students in more cross-discipline project-based learning, this requires teachers to have an understanding of a wider range of disciplines and learning within those disciplines (Riel, 1998). Students will continue to need “guidance and assessment by skilled teachers.” (Riel, 1998, p. 5). The impacts on teaching strategies will lead to changes in the composition of the role of teachers. For example, high level access to computer support for learning tends to encourage teachers to use more cooperative group work and less teacher stand-up lecturing (Schacter, 1999). They are less likely to take on the role of content expert where they will increasingly cooperate with other teachers (Réginald Grégoire inc. et al., 1996) and even “invite distant ‘team-teachers’ from any field, with any expertise, to work in the classroom.” (Riel, 1998, p. 15).

The potential of computer technology for teachers and students is broad and generally accepted but that potential needs to be realised in the classroom. To begin to consider whether that potential is being realised, or is likely to be realised we need to consider what teachers and students do in classrooms and how the technology they use relates to the tasks they complete and roles they play within the classroom environment.

For the teacher wanting to facilitate the use of computers there are two broad sets of tasks.

1. The integration of the application into the teaching/learning programme, the curriculum.
2. The implementation into the classroom which involves management of the classroom environment: roles, behaviours, and materials.

In integrating the application into the curriculum the teacher needs to make the application meaningful for the students. One of the teacher’s roles in this is to help students interpret their experiences. It can be argued that the computer permits a much richer exploration of experience, but demands a high level of competence on the part of the teacher to permit students to fully benefit from this experience. The teacher requires skills to initiate, organise and evaluate, and often needs to be prepared to change while still being critical of the use of technology such as computers. It is likely that without substantive long-term change computers will become an expensive way of ‘doing the same thing’. So teachers need to develop the ability to judge whether or not a particular piece of software will provide the learning claimed by the publishers and whether this learning is relevant to their classroom and curriculum. They need to determine the situations in which the computer is best able to support their programme of instruction, considering short and long term goals. While initially the short-term goals may be limited they should be aimed at achieving the long-term goals rather than representing indiscriminate use. Long-term goals for facilitating computer use could include the following: having the students become independent learners, and using the computer for the development of higher order learning skills.

For the teacher there is a risk of losing his established influence over the values and directions of classroom activity. Therefore the potential of computers disturbs some teachers who are concerned about their own role and influence in the classroom. To help teachers to avoid developing a resistance based on this conception it is important that they be encouraged to reflect on the impact on their role and on that of the students. Initially this calls on teachers to reflect on current practices and bellliefs which may be difficult particularly if it is not encouraged by their education system. After considering the wider issues teachers then need to think about how they exert influence in their classrooms. This may lead them to consider changes in their teaching practices to incorporate computer use more readily into their classrooms. Some research has identified that changes may be more pronounced for many secondary school teachers than primary school teachers (Becta, 2002).

Access to Information

The amount of information in the world is growing at an increasing rate. For teachers and students this means that firstly, there is more to know and secondly, it is important to be able to sift through information efficiently. Computer systems provide tools for collecting information, organising information, processing information and communicating information. Students and teachers now have to learn to use the tools effectively. There are diverse skills and technologies to adjust to and new attitudes to form.

As with any technology, if ICT tools become prominent in schools then it is likely that assessment methods in schools will need to be reviewed. Currently most assessment is still based around the use of textbook technology and based on a factual retention approach to learning. This style of assessment is unsuited to the ICT environment and therefore other more appropriate means of evaluating student learning will need to be devised. For example, if students have been learning the ICT skills concerned with collecting, selecting, processing and presenting information then this needs to be assessed, not whether they can remember the information itself. If a student has been creating music through a synthesiser and computer package then it is not appropriate to assess her playing the trumpet or guitar.

Educators are also concerned about the validity of much of the information available on the Internet. Because it is relatively easy and inexpensive to distribute information using the Internet, anyone can do so without the information being validated by anyone else. This was less the case with printed and audio-visual (e.g. tapes) information because they were expensive to produce and had to be purchased by the school, teacher or student. It is now more important for students to consider the validity of the source of any information they get from using the Internet. They need to consider who may have been responsible for providing the information and why the information has been made available. For example, information provided by a government agency should be treated differently from that provided by a business organisation or that provided by a University.

ICT gives teachers access to information to support them in trying new strategies, thinking, reflecting on practice, and engaging with new material (Committee on Developments in the Science of Learning, 2000). Teachers “need support in making use of new technologies to enhance their personal work before learning to use them in their teaching” (Lankshear & Snyder, 2000, p. 121) much of this support may be accessed more readily using ICT (Réginald Grégoire inc. et al., 1996).

Energy, Hard Work and Perseverance

There is no doubt that teachers who use ICT in classrooms have to demonstrate high levels of energy, hard work and perseverance, often in the “face of considerable odds” (Lankshear & Snyder, 2000, p. 110). If they are early adopters then they are required to be resourceful and overcome many barriers to “make things work”. Planning learning experiences involving computers takes considerable time and demands complex scheduling and resourcing. Therefore, teachers using computers in the classroom should not act in isolation from each other. They need to have access to resources which will supply ideas and material for different classroom applications. Schools need to subscribe to relevant journals and have publications which will enable teachers to gain ideas for classroom uses. Teachers within schools can also be used to provide ideas and activities to peers so that valuable uses can be identified and implemented by others.

Placing a computer(s) in a classroom is equivalent to placing a machine such as a television or overhead projector and also to placing another person into the room. It is a machine in that it takes up space, needs to be operated, can be switched on and off etc. It is like a person in that it interacts in a two-way relationship with students and teachers. Both of these have implications for the teacher in deciding to use computers in the classroom. The teacher and perhaps students need to know how to physically operate the machine and how to overcome any normal problems which may occur.

While for many teachers computer implementation may require changes in attitudes and classroom practices for most teachers, there are a number of practical skills which need to be developed. There are computer operation skills and classroom management skills which present an obstacle to a number of teachers. Teachers need the opportunity to interact and familiarise themselves with the technology. In many cases, as teachers develop the confidence and skills in personal computer use, they are then able to implement and support classroom applications.

Finally, the potential reasons for using computers have implications for teachers associated with each one. Table 4 matches possible implications for teachers with the potential reasons for using computers in the classroom. The implications which would result in advantages to the teacher are indicated with an *. From the teacher's point of view there are likely to be many more disadvantages or difficulties than advantages.

While computers may be seen to have great potential in education, at the same time they present teachers with some additional obstacles to overcome. Most of the potential benefits are directed towards the student in improved learning and instruction. Very few of the benefits are directed towards the teacher's tasks in the classroom. More importantly it is not clear that this potential is associated with the aims and objectives which teachers (and students) bring to the classroom environment. For these and other reasons many teachers have only made limited, if any, use of computers in their learning programmes.

Table 4

The Implications for Teachers in Using Computers in Classrooms.

Potential	Implications for Teacher
Dynamic learning	Students may learn outside the teacher's own area of expertise. More difficult to direct and manage student learning.
Student motivation	Students are easier to manage and direct towards the tasks.* Students may be distracted by the computer from the tasks the teacher has intended.
Removing tedious tasks	More satisfying for teacher to direct less tedious tasks.* Some teachers may prefer students to complete tedious, routine tasks as "busy" work.
Instruction to fit the learner	Relieves the teacher from needing to spend a lot of time with students who need extra practice, catch-up or extension work.*
Independent learning	Learning may not direct itself towards the teacher's objectives. Additional coordination of the classroom, students and materials is required.
Extending student thinking	Student thinking may go beyond the teacher's experience or capabilities which may reduce the confidence of the teacher.

Teachers need to continually work at updating their skills and knowledge in the operation and use of ICT. This is in addition to their need to be up-to-date with curriculum content and pedagogy. It is therefore important that they be supported very carefully in practical and motivating ways. Not surprisingly a number of studies have found that, "Personal access for teachers to a computer for the purpose of preparation and planning is one of the strongest influences on the success of ICT training and subsequent classroom use." (Office for Standards in Education, 2002, p. 3). Also supportive, enthusiastic and visionary leadership has a positive impact on teachers' attitudes and behaviours (Becta, 2002).

Impact on Schools and Educational Systems

Schools and educational systems must provide the infrastructure and support for students and teachers, and the maintenance of constructivist learning environments in which ICT is used. At the same time ICT tools will assist schools and educational systems in carrying this out.

Research has consistently shown that few schools and teachers implement computer support to a degree where the potential benefits are likely to be realised. There are a number of significant problems which impede and prevent teachers from achieving the full advantage offered by computer applications. Cradler (2002) gave seven requirements for effective use of ICT in education:

- Suiting technology to education goals and standards
- Having a vision for the use of technology to support curriculum
- Providing for both inservice and preservice training
- Ensuring access to appropriate technology
- Providing for administrative support for technology use
- Providing time for teachers to plan and learn how to integrate technology
- Providing for ongoing technical support for technology use

In general, these requirements fall into five areas of impact:

- providing the infrastructure of hardware and software,
- providing curriculum and technical support for teachers,
- school organization, design, policies and practices,
- schooling, and
- management support.

Schater (1999, p. 5) claims that the "level of effectiveness of educational technology is influenced by the specific student population, the software design, the educator's role, and the level of student access to the technology." Clearly with the critical role played by teachers, education systems need to take account of the needs of teachers first (Lankshear & Snyder, 2000). The problems teachers have with the use of computers may be viewed in terms of: access to adequate infrastructure, and access to support for implementation using that infrastructure.

Providing the Infrastructure

The infrastructure requirements may be viewed in terms of the electronic resources, hardware, users, and implementation. The relative lack of good quality software and associated courseware is well documented and is being attended to by software producers and educators throughout the world. The problems associated with hardware were mainly a lack of it, however there is still a major problem with the appropriateness of the hardware used.

The use of inappropriate hardware, the lack of useful software and the difficulty in gaining adequate access to computer systems were noted as major obstacles to the use of computers by teachers and students. The choice and distribution of hardware and software are crucial to the success of computer use in schools.

In the establishment of the computer's place in the school curriculum, the school needs to carefully consider the establishment of a library of software able to support the use of the computer in the ways established in the school's computing philosophy. Schools with a small computing resource would probably need to buy software likely to have wide use in the school. Many packages are of limited use and can only be used for a small number of functions within a limited age group. Some packages require individual access to be of use to the teacher. These may best be used in schools with more resources.

Some packages are more easily integrated into the curriculum than others which may require a degree of teacher involvement and preparation. Many teachers prefer to use software which requires little teacher preparation and planning. In such instances the software can often determine the content of subsequent lessons rather than the teacher or the planned curriculum. When a teacher is made to plan the ways in which the computer will be used, it is likely that the use will be more applicable to the curriculum and more useful to the teacher and students. It must be remembered though, that teachers who are unfamiliar in the use of computers will probably prefer to use software requiring less teacher planning and intervention. Selection of software should meet the needs of the staff as well as the students.

Electronic Resources

If the aim is to provide more student-directed learning experiences then students need to be provided with access to extensive sets of resources (Riel, 1998) which is only feasible using predominantly electronic resources. These resources will consist of data files and software applications (programs) that may be distributed online or on disc. Therefore schools and systems need to provide teachers and students with ready and easy access to these resources. Increasingly this access will be online, particularly for data files, and while there is a huge quantity of such resources there are two major problems:

- Accessing high quality resources,
- Choosing appropriate resources.

There is an increasing quantity of good quality software that needs to be encouraged and supported. The problem is one of providing teachers and students with adequate access. The problem may be a lack of awareness of the existence of the software, the need to purchase licenses to use the software or provide adequate access to hardware to operate the software.

The second problem follows from the first in that the good quality software has to be located and applied to the classroom. This involves the evaluation of software to firstly ensure that it is well designed and secondly to determine when it should be used in the classroom. Software evaluation takes time and requires a certain level of expertise in education and computer use. Typically teachers do not have time to evaluate software and need to rely on promotional material and software reviews which may themselves be biased, inaccurate or inappropriate for the educational setting in which the teacher is operating. Recently teachers have communicated with each other using the Internet to share their experiences and help each other select appropriate software.

Hardware

It is important that students have adequate access to appropriate hardware. Teachers and students need access to computers for substantial periods of time where they are. Since the majority of programs require students to have individual access to computers, the achievement of significant results is dependent upon the amount of computer equipment available for use by the students. Computers are expensive items and it is difficult to afford to purchase an adequate number of computers. This is now less of a problem in WA.

At times schools buy hardware not suited to the needs of their students. Computer technology is constantly improving making it difficult to make purchasing decisions. There are many considerations in the selection of appropriate hardware, most of which relate to the ability of the computer system to facilitate the completion of educational tasks. However, many studies have highlighted the effect of inappropriate hardware (and software) on the attitudes and associated skills of users. The serious unreliability of hardware diminishes the value of computer use in facilitating the completion of the task. This applies to students, teachers and administrators as they attempt to use computers. Many studies also indicate that a large proportion of school staff lack the confidence, knowledge and skills to use computers effectively. Therefore, if the hardware they use is not reliable and/or does not facilitate or improve the completion of necessary tasks, staff will build up resistance to further use and develop associated "phobias".

Unfortunately many schools still make their choice of hardware based solely on price and securing a large number of workstations. The priority may be to purchase the largest amount of hardware for the least price with little reference to why the hardware is being purchased. Hardware should be purchased on the grounds of its practical suitability to the environment in which it is to be used, the availability of software to complete the tasks designated as necessary, and finally price (a lower not primary consideration). Assessing the practical suitability will involve considerations of robustness; maintenance; input and output features; transportability; and compatibility. The availability of software will involve an assessment of the necessary tasks the school wishes to use computers for and the quality of the software to complete these tasks.

It is clear that characteristics of hardware have a significant influence on the ability of teachers and students to use the equipment to facilitate the completion of tasks and solution of problems and on their attitudes towards the use of computers in general. If a teacher tries to use a computer for demonstration and it malfunctions then that teacher is less likely to use a computer for another demonstration. Similarly if a student finds it too difficult to use a computer or is not happy with the quality of the output she may not want to use a computer to do other tasks. Therefore it is important that we select appropriate hardware for the educational environment in which it is to be used. This will require consideration of the characteristics of the:

- users (teachers and students)
- physical setting (the layout of the classroom)
- educational application (i.e. what the computer is to be used for)

The characteristics of the user which should be considered include:

- level of computer literacy (teacher or students)
- developmental age of students
- physical capabilities or disabilities of students

The construction of the hardware should be as uncomplicated as possible (e.g. a minimum of plugs, wires and switches). This may reduce the flexibility of the system but will reduce the number of things that can go wrong. Also the use of the keyboard as an input device should be reduced by incorporating the use of a mouse, joystick, etc. The hardware should not consist of many parts which need to be connected together. Cables are dangerous in classroom situations. Daisy chained power supplies which only require one power-point are useful. All-in-one models (processor box and screen as one unit) reduce the number of connecting cables required.

Most teachers and students have little expertise in overcoming malfunctions in hardware and therefore it needs to be reliable and require little maintenance. In addition the hardware should have good backup support from the vendor. If hardware takes many weeks to repair teachers will lose patience and decide not to use computers.

The developmental age of a student has implications for input, output and processing. Generally younger students need more concrete input devices (anything but the standard keyboard), output which is larger and less complicated (large screens, plotters etc.) but they may not need as fast a processor as older students. It is likely that older students will use more sophisticated software and require faster response from the computer.

While the physical capabilities of many students is determined by their developmental age there are a number of students who have reduced capabilities due to illness, accident or birth defects. These disabilities have implications for the choice of input and output devices.

Most classrooms are not ideal places for computers (refer Table 5). Computers need bench space and a dust free environment which does not vary in temperature too much. So classrooms need small computer workstations that are not affected by chalk dust (if whiteboards are not installed). It is not good to move computers around but schools may want to do this. Therefore the hardware needs to be robust and yet portable. The processor and/or disk drive 'boxes' should be made of tough material.

Table 5

Problems Related to Classroom Physical Characteristics.

Characteristic	***Problem***	***Solution***
Chalk	Dust in disk drives	Whiteboards or don't use removable disks
Space	Need substantial bench space	Small ***foot-print*** workstations
Temperature	Processor overheats	Fans or air-conditioning (less of a problem today)
Power-points	Each workstation needs power	Power-points around edge of room, portable computers
Movement	Students may knock equipment	Strong, durable construction Minimum number of plugs and cords.

A major determinant of what comprises appropriate hardware is the educational use or the role the computer is going to play in the teaching/learning process. The ideal is to choose a computer system by the types of applications the school wants to use. It is often not appropriate that computer hardware should be selected on the basis of one or two software packages. Some general guidelines on the hardware requirements for the various categories of computer use in schools are given in Table 6.

Table 6

Hardware Requirements for Educational Computer Applications

Role	***Input/Output***	***Processing/Main Memory#***	***Storage****
GENERAL+	Keyboard & mouse	Adequate to run operating system + application	Hard Disk + removable disk of some type
Demonstration	Large monitor or projector	Fast processor	Hard disk + CD-ROM
D&P			Hard disk + CD-ROM
Tutorial	High resolution monitor		Large HD + CD-ROM
Simulation	High resolution monitor	Fast processor	Hard disk + CD-ROM
Programming	Printer		
Tool Application	High quality printer	Lots of RAM	Large hard disk

#Generally the more main memory the better as too little may limit the software which can be used.
****The more storage available the better to provide for the storage of data and organisation of software library.***
+Typical requirements for all applications.

Networking

The networking of educational technology resources benefits students, teachers and schools by: facilitating information technology learning activities, giving ready access to software, allowing a variety of communications, reducing costs of equipment, increasing processing power, and facilitating the management of student learning (Cradler & Bridgforth, 2002). Networking supports the development of broader learning communities (Eadie, 2000) and have been shown to lead to general improvements in learning and teaching (Office for Standards in Education, 2002).

Today networks are more diverse in nature and may contain many computer processors, with a large variety of peripheral devices. A network may include optic fibre cable telephone and/or radio (wireless) connections or may include audiovisual networks (e.g. digital TV) (Eadie, 2000). Three categories of network scenarios should be considered in the use of computer networks in schools.

- intra-school networks
- inter-school networks
- external networks (Internet)

An intra-school network (intranet) could link together classrooms with the library, staffrooms and administrative area. The network could, among other things, include data storage devices such as compact discs and video discs, student and teacher workstations and a variety of printers. This would allow teachers and students to access data in other areas of the school without leaving their seats and teachers could transfer data and communicate with other teachers and the administration. Modern local area networks allow the networking of many devices including computer systems which are not compatible (do not have the same operating system). This means that schools do not necessarily need to purchase only one 'brand' name of equipment in order to set up a network.

Inter-school networks (also probably an intranet) could be attached to the intra-school network by use of the telephone system. Such networks would allow teachers and students to communicate between schools, share resources and data. Some areas of education such as distance education are using network teleconferencing where groups of students can interact with a teacher or another group of students using telephones. This could be greatly improved with the use of computer networks.

Added to the intra-school network could be the possibility of communicating with commercial and government network systems. The opportunity to access external networks makes a wide range of resources and data available to students and teachers. This is now facilitated by the Internet.

Hardware Organisation for Adequate Access

There are a number of methods which can be used to distribute access to computer systems. The way in which access to computers is organised in a school needs to reflect the manner in which it is intended to use the computers. For a school which has a substantial amount of computer hardware there is the choice between putting a lot of the hardware into specifically designed computer laboratories or distributing a lot of the hardware throughout the school. Schools need to develop explicit policies to guide the manner in which access to computers will be provided. These policies should start by considering curriculum-related objectives and the manner in which teachers want to integrate computer use with their curriculum.

Where the focus is on developing computer literacy through formal programmes it is quite likely that computers will be organised into laboratories. Where teachers want to support group-based activities and use simulations and tutorials it is likely that they will want a few computers in their normal teaching rooms.

In most situations there are fewer computers available than would be ideal and therefore schools need to carefully consider the best way of organising adequate access by students and teachers. Here are some examples of the strategies which may be used by schools.

Laboratory. A group of computers are made available in a central location which may be booked by a teacher. This may be a dedicated classroom, part of the library or part of a learning resource centre.

Mobile Trolleys. A desktop computer can be put on a trolley which a teacher may book and wheel into the normal classroom.

Mobile Laboratory. A number of reasonably portable computers (ideally notebook or palmtop size computers) may be available for a teacher to book for a lesson. The computers are brought in and set up for the lesson and returned at the end.

Classroom Computer(s). One or more computer(s) may be allocated permanently to a teacher's classroom.

Some schools find it convenient to place workstations in central work areas such as libraries or staff and student common rooms (Eadie, 2000). Often these areas are not bookable by a class and are available to students on a first come basis.

The central location may be part of a learning resource centre (e.g. library) where areas are set aside for whole class or one-to-one implementations which require a large number of workstations (Eadie, 2000). Other areas may be set aside for complementary purposes such as for group work, non-computer activities and individual computer work. This arrangement affords the teacher greater flexibility in implementing applications and a support person may be allocated to a centre to manage the computer systems (Eadie, 2000).

The mobile options which allow teachers to book one or more computer(s) to take to their classrooms makes it easier for applications to be integrated with the normal teaching programme (see Figure 6.2). This means that some person needs to take responsibility for maintaining a booking system and teachers need to take responsibility for setting up and returning computers. This can be onerous and require a greater level of technical expertise. Some schools have sets of portable computers available for loan from a central location, either to individual students or for classes of students.

In many cases the ideal is to provide computers permanently (or for an extended period of time) in regular classrooms. In this situation teachers can plan well ahead for computer applications and can take on responsibility for those computers thus sharing the responsibility throughout the school. Students also become familiar with these computers and can take on some responsibility for them. Teachers are able to try a variety of implementation and strategies and can integrate computer applications naturally with their curriculum activities. The computers are available when and where they are needed. Some research has shown that when compared with computer laboratories the use of computers in classrooms can lead to improved student achievement, increased teacher confidence and a greater range of integration with the curriculum (Mann et al., 1999). The major disadvantage is that if the computers are not used regularly then they are not available to other teachers and students and are thereby a wasted resource. Often teachers want a projector or interactive whiteboard connected to a computer in their classroom for whole-class presentations (Eadie, 2000). While this is often an expensive and unnecessary requirement it needs to be considered if the teacher is to be encouraged to use ICT to support learning.

Curriculum and Technical Support for Teachers

The curriculum and technical teacher support requirements may be viewed in terms of supporting users, implementation, and appropriate pedagogy. User problems are probably the most obvious in that much of the resistance from classroom teachers to the use of computers across the curriculum is put down to a lack of knowledge and skills in operating ICT. However, the implementation of computer applications has been hampered by the lack of experience of teachers and the lack of consideration of appropriate educational problems to solve. All of these barriers may be addressed by considering technical and curriculum support for teachers (Becta, 2002).

Supporting Users

The users of computers in schools include students, teachers and administrators. In education there are implications associated with these requirements for all types of users. The most serious for classroom use of computers are those associated with teachers. Many teachers lack the knowledge and skills to use computers and in addition are not enthusiastic about the changes and additional learning associated with bringing computers into their teaching programmes.

The skills, knowledge and attitudes of a teacher are an important determinant of the effective use of computers to support learning for her students. This will require some initial training but will need on-going provision of professional development to maintain the appropriate skills and knowledge. There are still many teachers who do not have an adequate level of computer literacy and others who have negative attitudes towards using computers. This will impede the successful integration of computer support within the curriculum.

In addition teachers need to not only be ***computer literate*** but they also need to develop skills in integrating computer use into their teaching/learning programmes. While these skills in integrating the computer into the curriculum may be helped by some in-service training, they primarily develop out of experience in using computers in the classroom. Currently most teachers have little such experience primarily due to a lack of opportunity.

Any change to the curriculum whether concerning content or pedagogy requires time and effort on the part of those involved in the change. Most people who have been doing a job, for which they are trained, for a length of time are reluctant to change what they are doing unless they are convinced the time and effort will improve the job for them. Therefore there is a natural resistance to change (in physical terms known as inertia) which is further heightened if it is felt that the changes present some sort of threat. Unfortunately computers present a threat to many teachers because they feel under-confident in using the technology, and worse, some believe that their jobs may be threatened (an old fear which is not well based).

The natural resistance of teachers to change is very evident with the use of computers because of the widespread nature of the changes associated with computer use. Not only do teachers need to spend time learning about the technology and how to use it, they also they need to adjust to changes which may be required to their role in the teaching/learning process and to the strategies they use. We have noted earlier that computers can be used in a wide variety of ways by students, characterised by the degree of control they have over the computer. Many teachers who are used to being in control of the teaching/learning process and environment are reluctant to transfer some of that control to the students.

Teachers will use computers increasingly (in and out of the classroom) if they become associated with successful computer use. This is likely to involve some additional teacher training and demonstration of successful use. The use of computers in schools is most often hindered by the lack of evidence available to teachers that its use actually enhances student learning (i.e., it assists their teaching tasks better than do other media). For all users of computers in schools it is important that computer use (particularly initial use) leads to success. If not it is preferable to offer no computer use rather than to entrench poor attitudes, knowledge and skills.

Supporting Implementation

We have indicated in a previous section that while the selection of hardware and software is important, possibly of prime importance is the implementation of computer use. Some of the obstacles associated with implementation relate back to problems of lack of teacher skills and poor choice of hardware and software. Many of the problems concern a lack of consideration of what are suitable educational obstacles for computer use to tackle.

To make the best use of the machines, schools need to buy computers for specific purposes. They need to see the computer as a means of solving some problem or helping to attain some goal. In this way, the computer can become an essential component of the school programme, helping in defined and planned ways.

Computer support for learning may not be suitable for all parts of the curriculum. Computer support is particularly relevant to parts of the curriculum which involve the development of conceptual understanding or where repetitive tasks need to be performed. Any activity requiring the handling of large amounts of data or graphic representations are also likely to be suited to computer support. Computer support will be less suited to situations requiring direct person-to-person interaction or an understanding of human nature. Electronic communications are useful when face-to-face contact is difficult. However, when face-to-face contact is possible it should be used. It is still the case that a good human teacher is better than the best computer system.

It is important to select appropriate applications to use with students. Computers should not be used as a general panacea to educational problems. Rather they should be used as specific solutions to well chosen problems. It is possible that inappropriate applications may do more harm than good, particularly where students perceive that the computer is not supporting their learning. There is often a tendency to focus on the computer rather than the learning. Teachers need to develop experience in choosing when to use computers and when not to, by being aware of the types of tasks which computers do well.

The importance of school support for teachers in the implementation of ICT was highlighted in a recent report from the Office for Standards in Education (2002, p. 3)

> ***The NOF training is most successful where senior managers in schools take an active interest in teachers' progress, where there is effective peer support, and where groups of teachers meet for part of the training. Teachers left to their own devices to use distance learning materials in their own time rarely make the same headway.***

Supporting Appropriate Pedagogy

> ***What has not yet been fully understood is that computer-based technologies can be powerful pedagogical tools – not just rich sources of information, but also extensions of human capabilities and contexts for social interactions supporting learning. (Committee on Developments in the Science of Learning, 2000, p. 230)***

The job of teaching is diverse in nature with each teacher bringing to it their own meaning and set of beliefs they have about teaching and learning upon which they base practice. Effective use of ICT is a matter of "becoming proficient with a range of interlocking, complementary procedures, knowledges, understandings and dexterities" (Lankshear & Snyder, 2000, p. 122). This involves the two-way relationship between ICT, curriculum and pedagogy. This develops as teachers have contextual experience with the use of ICT.

In the ideal classroom environment the central problems are those concerning student learning and the associated teaching strategies. If every class was an ideal classroom then the findings from a good deal of research would lead us to believe that computers would find an important place in most classrooms. In the real classroom teachers have problems associated with factors such as:

- controlling the classroom environment;
- ensuring students complete the course;
- keeping people such as principals, senior teachers and parents "happy"; and
- reducing the amount of work for the teacher.

In considering whether a teacher is likely to use computer technology in the classroom the real classroom needs to be addressed and not the ideal. This discrepancy alone may explain why some technologies such as blackboards, textbooks and video cassette recorders are well used by teachers while other technologies are not. It is known that teachers need opportunity to be reflective and have a "grounded familiarity with computer technologies" (Lankshear & Snyder, 2000, p. 121) and "extended immersion" supported by "participating in communities of practice" (p. 122) with "more access to computers and time". This means that ICT use must be valued in the school.

Changes to Schools and Schooling

The potential use of ICT to support students and teachers has challenged the structures, policies and practices of both schools and schooling itself.

Changes for Schools

Lankshear and Snyder (2000) suggested five patterns in the practices of teachers using ICT in classrooms, that have implications for the organization of schools. These are generalisable to schools rather than individual teachers that may be atypical. The five patterns are: complexity, fragility, discontinuity, conservation, and limited authenticity.

Firstly, classrooms are “complex, self-organising, adaptive systems” (p.112) such that the addition of a highly interactive component such as ICT “produces a compound effect” requiring classroom practices to “reorganise themselves which involves changes in roles”. This requires a negotiation among the elements of the classroom and affects an “entire mindset” (p. 113) for the teacher. Secondly classrooms are fragile with regard to the “loss of certain components” (p. 114) such as an expert, a piece of software or a communications connection. School systems must support teachers and students in their use of ICT to minimise this fragility. Thirdly, effective learning requires continuity across programs and over time. In the use of ICT this requires “detailed, systematic, careful planning” (p. 115) within a school and between schools. Fourthly, there is a natural tendency to “conserve familiar forms and routines” (p. 117) which often results in “the forced accommodation of new technologies to classroom logics in ways that severely [limit] their potential applications”. This leads to the final pattern of practice, in that “many uses made of new technologies … have limited authenticity” (p. 118). That is that there is a lack of connection between school-practices and societal-practices. This goes to the heart of the rationale for schools and schooling. A critical issue is that most teachers “lack knowledge of authentic embeddings of the technological tools in mature versions of social practice” (p. 120).

The impact on schools may be viewed in terms of the physical structure of schools, the organization of schools, and the policies and practices of schools.

Physical structure of schools

As most schools are not designed to include ICT, redesigning takes time and expense (Eadie, 2000). Even the physical security of hardware and software, and of students taking computers home have provided challenges for the physical structures as well as the practices of most schools (Eadie, 2000). In a comparative international study Eadie found that “although some classrooms remain apparently untouched by technology, many classroom configurations have changed to incorporate easy access to the computer(s) and to facilitate the discussions, problem solving and decision-making that inevitably follow their use.” (Eadie, 2000, p. 11). She identified the following trends in the use of classroom spaces with ICT:

- Rearranging the classroom
- Creating new spaces from old configurations
- Providing centralised, shared facilities
- Creating dedicated, flexible classroom space
- Developing virtual classrooms and campuses
- District networks creating learning communities
- Web hosting by an external provider
- Classroom redesign for maximum flexibility
- Wireless technology offers new options
- Changes in traditional library areas

Organisation of Schools

Eadie (2000) found a range of creative ways schools around the world are rethinking the timetable to use ICT to support the needs of learners; in particular methods to provide larger chunks of time, more flexible access to ICT, and more cross-curricula and open-ended tasks.

Knowledge construction is a community activity where learning is enhanced from contact with the wider community (Committee on Developments in the Science of Learning, 2000, p. 224; Riel, 1998). Riel explains that this means that schools need to involve more heterogeneous grouping, community organization, collaboration, interdependent teamwork, and to allow input from a range of expertise. Riel (1998) and others stress that learning and building knowledge is viewed increasingly as a community activity where schools in the past have tended to be isolated from the community.

"As teachers learn to use technology, their own learning has implications for the ways in which they assist students to learn more generally: they must be partners in innovation, they need time to learn, they need collegial advisers rather than supervisors." (Committee on Developments in the Science of Learning, 2000, p. 227)

Policies and Practices of Schools

There are many areas of policy and practice in schools that have been challenged by the presence of ICT. For example, there are a number of issues which schools have had to confront in connecting to the Internet. The most controversial has been concerns about student access to inappropriate information. There has also been concern that children may communicate with people whose intentions are inappropriate. Schools need to develop Internet access policies which include students entering contracts for appropriate use, the installation of filtering software, and providing access in areas which are highly visible to staff. None of these measures guarantees that students can't access inappropriate information but they do minimise the likelihood.

Another issue is that concerning copyright of material. Many schools want to provide copies of material from their own server computers because this reduces the communication costs involved in all students accessing the material over the Internet. There are legal implications for school systems, schools and teachers. Therefore there is a need for policies and information managers (probably librarians).

There is the issue of equity of access and experience where schools need to be agents for reducing disparities rather than increasing disparities between students and between teachers (Lankshear & Snyder, 2000).

> ***For learners in classrooms, the implication is that equity demands not merely attending to matters of physical access to machines and software but also ensuring good learning opportunities to gain proficiency with the cultural and critical aspects of technoliteracy practices that make for socially rewarded forms of competence. (Lankshear & Snyder, 2000, p. 128)***

There are also issues with the use of the Internet to help link parents with schools (Committee on Developments in the Science of Learning, 2000, p. 224).

Change in Schooling

Educational leaders in many countries recognise the need for change in schooling and curriculum with the advent of ICT (Eadie, 2000). For example, schools may need to down-size, become more collaborative and flexible, and emphasise communication, community, and creativity (Eadie, 2000).

Supporting Management with ICT

Computers are increasingly being used for management or administrative tasks at all levels of education. Most organisations today use computers to assist in management functions. Computers may improve efficiency in many of the tasks required in the operation of organisations. In the same way educational organisations can use computers to operate more efficiently. Schools involve large numbers of people which leads to the need to create efficient management and administrative functions. Computers can be used in a variety of ways to support the operation of schools. They can be used as a tool by the classroom teacher for course preparation, student and resource management, and record keeping as well as by the school administration for many of the tasks which are required in the running of a school.

Teacher Use

There is a vast array of software designed to support teachers in their administrative tasks. Using computers to support these tasks has a number of benefits for teachers particularly in increasing their productivity by saving time. Teachers spend a large amount of time in non-teaching tasks such as planning, testing, marking and recording. The use of a computer can minimise the time spent on these tasks as well as helping to improve the quality of the way the tasks are performed. Some of these applications are: Storing Student Marks, Course Planning, Instructional Materials, Creating Tests, Marking Tests, Student Records and Reports, and Computer Managed Learning (CML)**.**

School Use

Custom-built school administrative packages are also widely used and may include many of the teacher-use applications discussed earlier. Many schools are large and complex organisation with thousands of students and hundreds of teacher, a large budget and many resources to manage. The administration of a school is more efficiently and effectively accomplished with the support of appropriate software. In particular software is used for the following functions.

- Maintaining Student Records
- Managing Curriculum Content
- Supporting Pedagogy
- Maintaining Timetables and Classes
- Financial Management
- Assisting Communication
- Supporting School Libraries

Databases are maintained to include a large amount of information about each student which can be easily retrieved and analysed when required. Networked systems provide the opportunity for a range of people (teachers, administrative staff, parents and students) to access this information where appropriate (security can be maintained using levels of access).

Particularly in secondary educational institutions the use of software to support timetabling has become important. The allocation of students, staff and rooms to classes can be very complex and therefore time-consuming to complete manually. Similarly the financial management of an educational institution can be very complex and therefore the use of appropriate software including databases and spreadsheets is required. This allows accurate financial records to be maintained and supports budgetary decision-making at all levels with the organisation. This is particularly important in schools which have a high level of autonomy in their financial management (e.g. private schools).

Communications within an organisation is always important, and also efficient communication with those outside the organisation is often crucial. As with other organizations, schools are increasingly using computers to support communications. This may be simply broadcasting notices to staff, providing bulletin boards and chat facilities. Electronic mail facilities have allowed staff to easily communicate with each other and relevant people outside the school. Teachers or administrators may also use computer communications to transmit or receive data files on students, administrative tasks, policies and so on.

School libraries use computers to maintain records of items, borrowings and borrowers. Many use bar-code readers to improve efficiency. Increasingly libraries are providing access to electronically stored information through both local disk-based reference material and on-line materials available using the Internet.

Learning Management Systems (LMS) provide integrated systems to support educational systems, schools, teachers, parents and students in describing, organising, analysing and communicating. In some countries comprehensive systems have been in place for a number of years such as in UK where the National Grid for Learning (NGfL) has been found to significantly enhance the available of resources in schools for teachers and students (Office for Standards in Education, 2002).

System Level Use

Education systems are often large and dispersed. Traditionally a large number of staff and other resources have been required to maintain these organisations. Computer systems have become an essential management tool for such organisations. For example, computer communication systems allow a large dispersed organisation such as a school system to maintain efficient channels of communication.

Impact on Students

The use of ICT in schools should have a positive impact on students in terms of supporting their learning and providing them with relevant technological literacy. Earlier sections have discussed the potential for supporting the learning of students, and in particular addressing their individual learning needs. This section will consider the development of student technological literacy. In addition to these primary impacts there may be secondary impacts on students connected with not only the use of ICT but the way in which it is implemented. Earlier it was highlighted that there may be an impact on the roles that students play in the learning environment. This will suit some students and may not be comfortable for others. Also while most students tend to become more engaged or motivated when using ICT, this is not the case for all students.

The Road Ahead study [The National Foundation for the Improvement of Education, 2001 #407, p. 12] in 2000 findings included:

- increased technology capability and skill;
- a surprisingly strong emergence of students as teachers;
- increased motivation for learning (focused around the introduction and initial use of technology);
- improved achievement in core subjects as measured by test scores in some cases, and grades or student products in other cases.

Student Perceptions, Roles and Engagement

When ICT is used to support learning it is intended that this should increase the engagement of students and in most cases increase their independence, so that students are not only required to use ICT competently but may also be required to adjust to changes in their role. That is, using ICT has implications for students beyond their ICT literacy into their perceptions of and preferences for their roles as learners. Early discussions have highlighted that in many cases the students' role becomes more:

- Independent and responsible
- Cooperative and collaborative
- Directive and negotiative

Students need to develop skills associated with time and resource management, concentration, self-discipline, attention to task and ability to follow instructions. Any changes in role and requirement for new sets of skills needs to be introduced and supported carefully with consideration for those students with opposing perceptions and inadequate previous experience. In a recent Western Australian study with a Year Eight class using computers it was found that while almost all of the students had good ICT skills and positive attitudes there was a tendency for students to want to work by themselves and depend on the teacher (approximately 50%), that was not conducive to computer supported project work and independent online activities.

An important issue is that students respond to and use computers in different ways. It is clear from research that most students like using computers although usually at least 5% do not. In a 1991 survey of the MLC students using laptop computers, 95% liked using their laptops, and most students preferred the appearance of work completed on a computer, with 85% preferring it to paper and pen, dependent on the task (Loader, 1993). Rowe (1993) found that children differed markedly in their use of laptops and the effectiveness of that use. She defined two groups of students, the top and bottom 20% in terms of computer expertise based on student and teacher rankings. She also developed a set of indicators of effective laptop use that were used for profile matching to create four groups of students:

orchestrators, ***amplifiers***, ***machinists***, ***perseverators***. ***Orchestrators*** were seen as those who intertwine learning and computer use and were confident computer users. ***Amplifiers*** regarded the computer as a separate area of learning while ***machinists*** viewed the computer as non-essential, mainly for use in calculation and word processing. Finally, ***perseverators*** made limited use of computers, mainly copying others and using drill and practice packages.

The sense of personal identity is an important issue for learners, particularly for children. There is no doubt that most educators would see value in students being able to personalise the tools they use and this is very much the case with computer systems. In parallel with other forms of literacy, Rowe (1993) emphasizes the importance of computer literacy and that a student “make the computer part of oneself” (p. 71). This is more readily accomplished where the user interface can be customized by the student and the array of tools available can match the needs of the student. However, this means that in a class every student’s system will be different, making it more difficult for teachers and support personnel to provide technical and operational support to the student. This means that the student must be more independent in the use of the computer. In many school situations students are not permitted to customise their own interface, and that may lead to less engagement and empowerment for students.

The provision of more flexible access to ICT requires greater personal responsibility which may be lacking in some students. For example many studies have shown that students will use their computer systems for inappropriate activities from downloading offensive material to playing games during class activity time. This problem was highlighted by a report by SRI International (Crawford & Vahey, 2002) on the use of Palm Pilots in schools where teachers reported some problems with “game playing and off-task beaming” (p. i). On the other hand the report found that some teachers reported positive unplanned uses of the PDAs due to student “discovery of additional software” (p. 41) which is more likely when the students are given more flexible and responsible access.

Does the use of ICT lead to greater engagement and thus improved learning outcomes? Reiger and Gay (n.d.) conducted research on the value of handheld computers to collect data and provide multimedia information on field excursions for students. Their findings were preliminary and inconclusive. Walker, Rockman, and Chessler (2000) found that the students using laptops had improved writing skills and confidence in computer use in comparison to other students, but results on standardized tests were inconclusive. Some students may become frustrated when they perceive that their ICT skills are being underestimated and under-utilised (Becta, 2002).

Student Technological Literacy

The terms computer literacy and computer awareness are used frequently in educational circles resulting in a wide variety of definitions. The definitions of these terms that will be used in this review are provided in the Terminology section. There is significant debate over many issues related to computer literacy. Even that students need to be computer literate can’t be assumed. There are differing opinions over how this should be achieved, the extent to which schools should be responsible and the teaching/learning programmes which should be adopted. It is therefore important that all teachers develop an informed opinion as they do in the debates over numeracy and language literacy. This review concludes that it is the responsibility of all teachers to develop those skills and understandings required to equip students to live in a technologically based society, but that some teachers may also have a greater responsibility.

During the 1990s the Technology learning area evolved in Australia (known as the Technology and Enterprise learning area in Western Australia). Other countries refer to this as Technology Education (e.g. USA). In Australia Technology Education has developed out of a number of disparate content areas each with a significant base of practical skills with varying degrees of specified content knowledge. In primary schools students encountered aspects of technology education in science and crafts. In secondary school students often had the choice of manual arts (e.g. woodwork), home economics, computing, business and so on.

A newer term technological 'capability' is now used to describe being able to do something with the resources of knowledge and skills to satisfy a human need or transform the world in a way that results in "improvement" (Kimbell, 1994, ***Technological capability and its assessment in the UK National Curriculum.*** Presented at the conference of the Australian Council for Education through Technology.). This is technological literacy. When the knowledge and skills are associated with computer technology then this clearly fits within the definition of computer literacy. Computer literacy is thereby a part of technological literacy.

The Technology and Enterprise learning area is involved in the development of skills in handling materials, and operating equipment and systems. An outcomes-based approach to Technology and Enterprise requires students to focus on the technology process rather than the systematic development of a prescribed list of skills. Therefore there is a need for learning programmes which allow students to develop skills in the context of outcomes.

The distinguishing difference between the concepts of computer literacy and computer awareness concerns the ability to use the technology. A computer literate person can use a computer effectively but may not understand its role in society nor the implications of this role. A computer aware person may have a lot of knowledge about computers but may not actually be able to use a computer. Naturally it is possible (and perhaps desirable) that a person is both computer literate and aware. In fact most computing courses incorporate objectives designed to enhance the literacy and awareness of students.

Initially computer literacy (this review will use the term computer literacy to encompass both computer awareness and literacy) can be seen in terms of the knowledge, skills and attitudes a person needs to possess. In this way a computer literate person may possess:

- **Knowledge** about systems, components, operations, capabilities and limitations,
- **Skills** in using computer systems to perform relevant tasks, and
- **Positive attitudes** toward computer use personally and in society.

These are necessary for a person to gain the benefits from computer technology in meeting their needs. This must be considered in terms of present needs and future life. Also a person needs to contribute to a society which is to some extent dependent on computer technology and makes substantial use of computers and associated technology. The extent to which computer technology is embedded in the normal operation of the society and in the day to day needs of an individual are important determinants of the level of computer literacy required. The computer literacy requirements of someone living in Australia are different from someone living in Chad, as is it for a space scientist compared with a gardener.

Computer literacy is relative to the person, the community and to the technology available. Computer technology (hardware and software) is continually evolving and therefore a person's level of computer literacy needs continual maintenance.

Problem-Solving Users

The fundamental definition of computer literacy concerns people being able to use computer technology to facilitate the completion of necessary tasks and the solution of problems presently associated with their lives. This probably implies that a person also possesses positive attitudes to future use of computers in order that she remains computer literate. Computer literacy then is concerned with the way in which a person sees the computer fitting into her life now and in the future. It involves building up a series of useful concepts about computers so that a person wants to use computers, knows how to use computers and uses them in a useful and appropriate manner.

Translated into the school environment this means that we want to produce students who use and will use computers in their lives to solve problems and complete tasks. We want problem-solving users (students) with the knowledge and skills to make the computer work for them. The diagram in Figure 6 pictorially depicts the characteristics which could be used to define a person's level of computer literacy. A person may see himself as a user of computers, or not, may have a definable attitude towards computer use, and may possess a certain level of knowledge and skills associated with computer use. The shaded region is most likely to represent the problem-solving user.

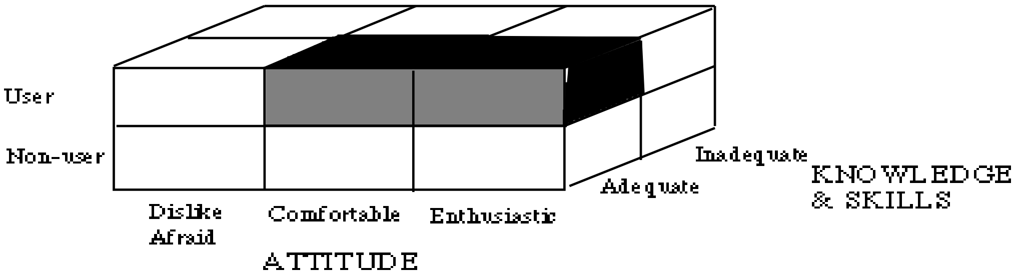

Figure 6 The Problem-Solving User

Most people can be placed somewhere in the three dimensional diagram above. In producing computer literate people we want to be able to place them in the two shaded boxes.

There are many different approaches to providing such programmes largely because the technology changes rapidly and it is difficult to define computer literacy in measurable terms. However in formulating policies and courses schools need to consider: the nature of communications between students and computers, the learning environment in which the computers exist, the nature of student learning and concept development.

Computer systems are designed to suit particular tasks, and therefore to develop computer literacy computer systems are needed which have been designed for use by students to complete necessary tasks they have. This involves students learning about the nature of the machine and its communication design. Students need to develop an understanding for what the machine can do and the limitations under which it operates. Students need to perceive the computer as a useful tool rather than feeling that they themselves are the tools of the machine.

The environments that students find themselves in can be categorised as: school, home, and community. In the home environment students use some computer applications, however, this largely reflects a transfer of learning from school. Students with a home computer have a significant advantage in using computers because home use increases the confidence of the students. However, home computers are primarily used for games.

In the school environment students may encounter computers in computing or non-computing courses. Many programmes not designed to address computer literacy partially satisfy these objectives.

The teacher is a model for the interactions that need to be handled in modern life and is a mediator of learning to relate to a machine. The peer group in the lives of students largely influences the attitudes and motivations held by students. For most students the school environment is the most important environment in which they develop attitudes and conceptions about computers. The people and experiences at school provide most students with the motivation, modelling and information conducive to computer use.

The conceptual framework which users develop to cope with using computers seems to be determined by: the user's previous experience with computer systems; the user's knowledge of the workings of a computer system; the concepts which the designers of computer hardware and software have incorporated into a computer system; and the task environment in which the computer is being used. Papert (1987), introduced the role of cultural background in learning and in developing concepts to use the potential of computers. He claimed that most people, particularly children, have in their culture or environment very little of the systematic and process thinking inherent in computers. He proposes that many people are hampered by their beliefs about their own lack of capabilities in these areas of thinking.

Therefore, students need to be supplied with non-threatening computer environments in which they can explore and manipulate their own potential and that of the computer. In this way students will develop workable conceptual frameworks for computer use.

The Problem-Driven User

As a consequence of the general objectives of computer literacy, consideration needs to be given to the circumstances under which a student is likely to make use of computer technology now and in the future. The perceptions students have of their future use of computers will be largely determined by their present use of computers. A person is likely to use computers when (s)he :

- has activities or tasks which a computer can facilitate completion more easily, to a higher standard or more quickly.
- is aware of how a computer could be used to assist in these tasks.
- knows how to go about getting the appropriate software and hardware.
- has the knowledge and skills required to use the software and hardware.
- enjoys using a computer to complete tasks and has a confident attitude.

From this list of requirements the knowledge, skills, attitudes and conceptions required for the present use of computers by students could be identified. With respect to the use of computers in society, particularly in employment, some skills such as keyboarding and knowledge such as the functions of a computer system, which are more generalisable, could be acquired at school. However, much of the knowledge and skills required are application specific and therefore could not be acquired by students at school. If this is the case then it is important that students develop perceptions and conceptions which are transferable from one computer environment to another (particularly from school to the workplace). Students need to develop an understanding of the machine, what it can and can't do, how it is instructed and how it is used in the world. They need to develop a working relationship with the machine and be permitted to discuss and challenge the information and experiences they are provided with.

There are a number of factors which need to be addressed in providing computer literacy programmes.

- Students need to use 'friendly' computers
- Students need to use software which completes tasks they need to do.
- Software needs to be based on processes students are familiar with.
- Students need regular access to computers.
- Students need to be given knowledge on which to base useful concepts.
- Students need to succeed in using computers and enjoy using them.

The problem of achieving universal literacy through school based courses is seen in the fact that even though many school systems share the same common goals, the courses developed to achieve them can vary greatly. It is difficult to create a course of instruction able to provide the necessary skills, knowledge and attitudes given the dynamic nature of the technology.

In the formulation of broad and specific computer literacy policies and curriculum there are two issues that are clear. Firstly, there is a high degree of complexity in the development of student attitudes and conceptual frameworks which are conducive to perceptions of the computer as a useful problem-solving machine. Secondly, if students are going to develop these attitudes and concepts then the appropriate experiences will have to be provided in the school learning environment.

Short computer literacy courses at school are unlikely to facilitate the development of appropriate attitudes and conceptual frameworks for computer use. It also seems that the use of the machine at home or in the community is unlikely to be of significant value in achieving these goals. Students need to be provided with a range of computer experiences and need to be provided with the information and permitted the time and opportunities to develop a workable conceptual framework for computer use. To some extent all students need these experiences and opportunities if it is perceived that our society is going to increasingly become permeated with computer technology.

At present the responsibility for providing these experiences and opportunities clearly rests with the schooling system. If students do not get these at school most of them will not receive them at all. It is likely that these experiences and opportunities need to be provided both in specialised computer literacy courses and in all other subject courses in which the students are involved. Almost certainly they need to be provided over all the years for which the students are at school, particularly the secondary school years. If students experience successful computer use and are provided with enough information they are likely to begin to develop workable attitudes, perceptions and conceptual frameworks which will ensure they are in a position to “exploit” the technology rather than to succumb to being its “victims”.

Some research has shown that with sustained use of ICT integrated across the curriculum and implemented in the classroom there are no significant differences between the positive attitudes and skill levels of boys and girls (Mann et al., 1999).

The Responsibility of All Teachers

In Australia the curriculum for Technology Education encompasses all years of schooling. It is seen as the responsibility of all teachers in the same way as language literacy crosses all learning boundaries. However, as students get older they are likely to encounter an increasing number of specialist teachers as the use of technology becomes more sophisticated.

Primary school teachers integrated technology education activities with themes and activities associated with other learning areas. For example, young children may design and make a mouse house as part of a theme on animals and their habitats. This would use non-computer technologies such as card and tape. The same children may create a fathers’ day card using desktop publishing software and a digital camera. Older children may be asked to make a robotic system with materials such as provided by Lego.

In secondary schools students are typically given increasing choice in the technologies they use to develop higher levels of literacy. Initially they may encounter learning programmes which give them experience with a range of technologies. Later they may chose to focus on food technologies, plastics, robotics, Internet technologies and so on. Many of these technologies will include some relationship with computer systems. Some students will focus very definitely on developing a high level of computer literacy by selecting learning programmes associated with programming computers, developing interactive multimedia materials or skills in maintaining and networking computers.

A Review of Frameworks Designed to Articulate the Impact of ICT in Schools

This review has discussed the manner in which the use of ICT impacts on students, teachers, schools and school systems. Clearly the desired outcome is for a positive impact on learning through support for constructivist learning environments. However, it is not possible to measure this impact independently of the other components of the learning environment and other mediating factors. It is possible to describe and measure the impact of the use of ICT on teachers and school and system communities in terms of support and requirements.

A little work has been undertaken to develop various types of frameworks that include aspects of the impact of ICT use on dimensions of schooling. Typically these provide descriptions of effective use of ICT in schools and the support requirements for such use. Some provide instruments to assist in assessing the adequacy of these supporting requirements and/or the effectiveness of the ICT use. Three examples of more developed frameworks are discussed in this section.

Technology in American Schools: Seven Dimensions for Gauging Progress

The Milken Family Foundation is a private non-profit organization whose mission is to discover and advance inventive and effective ways of helping people help themselves and those around them lead productive and satisfying lives. It was founded by the Milken brothers and focuses mainly on education, medical research and Jewish culture. One of its initiatives is the Milken Exchange on Educational Technology (http://www.milkenexchange.org) that conducts research, presents news and reports into the use of ICT to support learning in schools.

In 1998 the Milken Exchange on Educational Technology published a report titled, Technology in American Schools: Seven Dimensions for Gauging Progress (Lemke & Coughlin, 1998). Then in 1999 a companion publication was released titled: Professional competency continuum: professional skills for the digital age classroom (Coughlin & Lemke, 1999). This included discrepancy analysis tools (questionnaires) for use by policymakers and school planners. Since then further publications have been released leading from these, including: Transforming learning through technology.

Their intention was to create a framework to support educators in “charting their course toward the effective use of technology in learning and show evidence of progress along that path” (p. 3). The framework is intended to provide indicators for policymakers to assess the status of schools in terms of their use of ICT to support learning. The focus is very much on public return on investment in ICT in education. However, they also consider that it will focus vision, provide a research agenda and a planning tool. The framework is presented as a set of seven interdependent dimensions: Learners, Learning Environments, Professional Competency, System Capacity, Community Connections, Technology Capacity, and Accountability.

They provide a continuum of progress for each dimension, based on the “stages of instructional evolution” from the ACOT program, using three levels: Entry, Adaptation, and Transformation. For each dimension a number of key areas are identified and also described in terms of the three levels. For example, for the first dimension, Learners, the key areas are: Fluency (proficient in the use of ICT), Strengthening the Basics (learning the “basics with more depth and understanding”), Developing Higher Level Skills (“thinking, understanding, constructing knowledge and communicating”), Increasing Relevancy (“real-life applications” and emulating the workforce), Motivation to Learn (intrinsic), and Recognition of Tradeoffs (making choices about using technology in society).

This seven dimensions framework appears to confuse system, school and classroom teacher variables. It would be much more useful to separate them. For example, this would allow for the identification of the current practices of a classroom teacher and then consider the reasons for those practices and what is required to progress. This may then require an analysis using a school or system framework because there may be obstacles to progress for the teacher that are results of school or system variables.

There also appears to be confusion over the purposes of using ICT to support learning – computer literacy (curriculum content) and/or computer supported learning environments (curriculum medium). That is, some teachers (more than others) need to use ICT to connect with workplace and society conditions (e.g. Business Education teacher using MYOB). For a Physical Education teacher this may not be a reason for using ICT. However, all teachers may use ICT to support learning environments (the processes of learning) to improve them in many ways (learner-centred, knowledge-centred etc.).

National Educational Technology Standards for Teachers (NETS)

The **International Society for Technology in Education** (ISTE) NETS for Teachers Project, was developed with a grant from the US Department of Education, as part of its Preparing Tomorrow's Teachers to Use Technology initiative. ISTE facilitated a series of activities and events resulting in a national consensus on what teachers should know about and be able to do with ICT. At the same time they worked on a NETS for Students Project. It should be noted that Intel, Apple Computers and the Milken Exchange on Educational Technology all provided substantial contributions to the projects.

The project aimed to provide models for teacher preparation programs to use in incorporating ICT in the teacher preparation process and disseminate these promising practices for preparing tomorrow's teachers to use ICT effectively for improving learning. Major functions of the project were to (International Society for Technology in Education, 2000):

- develop a comprehensive set of performance-based technology foundation standards for all teachers reflecting fundamental concepts and skills for using technology to support teaching and learning;
- define essential conditions for teacher preparation and school learning environments necessary for effective use of technology to support teaching, learning, and instructional management;
- develop standards-based performance assessment tools for measuring the achievement of the technology foundation standards and as a basis for certification, licensing, and accreditation;
- identify and disseminate models of teacher preparation where candidates receive experiences preparing them to effectively apply technology to support student learning; and
- establish a **N**ational **C**enter for **P**reparing **T**omorrow's **T**eachers to Use **T**echnology (NCPT3) which will provide coordination, leadership, and support for the PT3 initiative and dissemination of program results.

The project describes standards, assessments, and conditions that facilitate the use of technology to support student learning. Assessment systems are designed to assist teacher preparation programs in evaluating the success of their programs in preparing their candidates and graduates in use of technology to support student learning. As with the Milken Technology Exchange's model from the outset this project has not taken account of the two general rationales for the use of ICT and has subsumed ICT support for processes of learning and teaching within the technological literacy rationale.

NETS for Teachers provides a set of standards and performance indicators that "all classroom teachers should be prepared to meet" (International Society for Technology in

Education, 2000, p. 9) and that can be accessed from their website (http://www.iste.org/). These are grouped under six general classifications:

(1) Technology operations and concepts

(2) Planning and designing learning environments and experiences

(3) Teaching, learning, and the curriculum

(4) Assessment and evaluation

(5) Productivity and professional practice

(6) Social, ethical, legal and human issues

There is a recognition that for ICT to be used effectively requires more than just the technology and competent teachers. The report outlines essential conditions to create learning environments with ICT support.

- Vision with support and proactive leadership from the education system
- Educators skilled in the use of technology for learning
- Content standards and curriculum resources
- Student-centred approaches to learning
- Assessment of the effectiveness of technology for learning
- Access to contemporary technologies, software, and telecommunications networks
- Technical assistance for maintaining and using technology resources
- Community partners who provide expertise, support, and real-life interactions
- Ongoing financial support for sustained technology use
- Policies and standards supporting new learning environments

Clearly the focus is on providing constructivist learning environments supported by ICT which are referred to as "new learning environments".

EnGauge: A Framework for Effective Technology Use in Schools

This framework developed for the North Central Regional Educational Laboratory (NCREL) of the USA attempts to provide a comprehensive analysis of "critical factors in the educational system that strongly influence the effectiveness of learning technology" (North Central Regional Educational Laboratory, 2002). The framework identifies six "essential conditions for effective technology use",

(1) Forward-Thinking, Shared Vision

(2) Educator Proficiency with Effective Teaching and Learning Practices

(3) Digital Age Equity

(4) Effective Teaching and Learning Practice

(5) Robust Access Anywhere, Anytime

(6) Systems and Leadership

Each condition has between five and eight components. Each condition has one or more associated questions that could be used to monitor and analyse the impact of ICT on students, teachers, schools, curriculum and educational systems although much of this would need to be inferred. Examples are provided in Table 7 below. In essence the framework is intended to be used as a checklist for schools to evaluate their use of ICT and support for such use.

While the framework aims to be used at a school level, the conditions and components have a mixture of issues pertaining to teachers, administrators, school communities, and school systems. For example, the Digital Age Equity condition is largely a concern of schools and systems whereas the "Relevance" component of the Effective Teaching and Learning Practice condition is largely dependent on the individual teacher. This would make it difficult to monitor and analyse the impact of ICT and to develop plans for the future.

Table 7

Examples of EnGauge framework components and questions

Impact on:	Example of a framework component and question(s)
Students	Stakeholder Commitment: Were all stakeholders involved in creating the vision? Is the vision understood and committed to by the full range of stakeholders? [Assuming students are stakeholders.]
Teachers	Relevance: Are students working on substantive projects addressing issues that have meaning, reaching out beyond the classroom to real-world practice?
Schools	Technology Resources: Are equipment and digital resources strategically deployed and sufficient to meet the needs of learners and educators?
Curriculum	Alignment to the Vision: Are content, instruction, vision, and assessment aligned to take full advantage of technology for learning?
Educational Systems	Connectivity: Does the telecommunications infrastructure provide appropriate, robust communication from every learning setting? Does that access extend beyond the school day and outside the school facility?

ImpaCT2 in the UK

This project was commissioned by the Department for Education and Skills in the UK and managed by Becta (2002). The aim was to evaluate the progress of the UK "ICT in Schools Programme" between 1999 and 2002 and involving 60 schools. It investigated the "impact of information and communications technology (ICT) on educational attainment" through three strands of investigation: the use of ICT in and out of schools by students and the statistical relationship to performance in standard tests; how students use ICT and what is gained from this; and, an exploration of the nature of teaching and learning involving ICT focusing on the views of students, teachers and parents. It particularly focused on the impact of networked technologies. The study did not set out to develop a framework but had to do so in order to collect appropriate data for the three strands of investigation. This appeared to be based on what was termed the "Socially Contextualised Integrated Model of Learning (SCIM-L)" that portrays School-based learning and Out-of-school learning as being parallel with an overlap of "ICT skills" and "Homework tasks". For School-based learning a sequence is shown beginning with a defined curriculum and culture, followed by the teacher specifying tasks, the learner uses ICT skills on the task, this improves school-related knowledge leading to improved school attainment. Conspicuous by its absence is any mention of the learning environment.

From the first strand of the study there were two overall findings. Firstly, in at least one third of all comparisons greater ICT use was a positive impact on test results. Secondly, on no occasions was lower ICT use a statistically significant advantage in test results. However, they did find that the "proportion of lessons involving ICT" in the sample was low. The report explained that ICT use tended to be an "optional extra" but needed to become "firmly embedded in all aspects of school life". It is perhaps surprising that the study did not build in to its framework a consideration of the learning environment and the school community. They did consider the "quality of ICT provision and usage" in a school including features: adequacy of ICT resources, ethos for learning with ICT, students attitudes to ICT, attainment of ICT skills by students, and quality of ICT teaching. They used a 7-point scale provided by Ofsted to rate the schools.

The report (Becta, 2002) concluded that students had positive attitudes and good skills due to the ICT curriculum and home use of computers but teachers undervalued the potential by considering it to be "just a tool". The report concluded that,

> ***There is evidence that, taken as a whole, ICT can exert a positive influence on learning, though the amount may vary from subject to subject as well as between key stages, no doubt in part reflecting factors such as the expertise of teaching staff, problems of accessing the best material for each subject at the required level, and the quality of ICT materials that are available.***

SchoolNet in Canada

The SchoolNet National Advisory Board of Canada commissions research on the use of ICT in K-12 schooling that began by identifying four 'constituents' likely to be impacted by the use of ICT. These were considered in terms of a continuum to "help determine the role and impact of ICTs in the learning process" (SchoolNet National Advisory Board, 1998). The four constituents and continua are shown in the Table 8 below.

Table 8

The four constituents and continua developed for SchoolNet in Canada.

	Continua ◄——►		
Teacher	Transmitter	Facilitator	The teacher may be primarily concerned with transmitting content information or with being a facilitator of activities that will engage the learner more actively.
Content	Pre-organized	Constructed	With advanced pedagogies , the content becomes a scientific experience where investigation, research and evolution takes place, often in a collaborative and participative manner.
Learner	Limited Access	High or Free Access	The learner might be in a highly computerized environment where he/she has access to a computer networked to a server which provides intranet – and Internet – connectivity.
Context	Low external support	Extensive external support	Policies and administrative practices have been developed, teachers have had access to professional development, and support programs have been implemented.

This research identified four areas of gaps in knowledge about the use of ICT:

- Connectivity and access;
- Professional development on the use of ICT;
- Better balance between stable and dynamic content; and,
- Performance indicators for evaluating the use and impact of ICT.

As a result research was commissioned to investigate these areas with a number of reports being produced such as that by K&V Stief Associates in 2001. That report considered three areas of focus: connectivity, content and competencies. In order to collect data the researchers developed a framework that considered the impact of ICT for districts in these three areas.

Connectivity

- Level of connectivity - Plan to increase connectivity - Efforts of schools to increase student and teacher access to networked computers - Vision for future developments	Access to Internet connected devices in all learning areas. Two-way multimedia applications such as videoconferencing and videostreaming. Sufficient bandwidth to support simultaneous use of most of a school's computers as ICT is integrated across the curriculum (100 in a school of 500 students).

Content

- Provision of online content - Processes for online content development - ICT content requirements in K-12 curriculum - Curriculum management tools for teachers	Learning resources that might be used by students to support inquiry and problem solving in all subject areas. Learning resources for teachers to use in planning programs for their students (lessons, units, learning objects etc.) Online courses, particularly at the secondary level, or online modules that could be combined with classroom activities in all subject areas. Specialized courses to prepare students for related further study and careers.

Competencies

- ICT professional development initiatives for teachers and leaders	Variety of approaches including: mentoring, workshops, summer institutes, and virtual teachers centre. Strong and informed leaders are essential.
- Standards of practice for teachers to integrate ICT as part of teaching and learning	Three areas of focus are: technical skills, integrating ICT with subjects, advanced pedagogies.
- Expected student outcomes related to ICT (ICT skills, information literacy)	Curricula that focus on developing the competencies that if learned would prepare students for both working and lifelong learning in a knowledge society.
- Assessing ICT student competencies	Expected outcomes at key stages at include technical skills as well as using ICT for inquiry and problem solving, making choices about appropriate technology, and understanding the personal and societal impact of technology.
- Research and development of new pedagogical approaches	Best practice studies.

While this framework provides some useful measures on three constructs it is clearly not adequately comprehensive to consider the impact of ICT on schools and schooling. These three constructs need to be incorporated as aspects of a more comprehensive framework that, for example, considers more than just connectivity in the provision of ICT capacity, and more than just online content in the provision of digital resources.

One of the objectives for the Working Group on Research and Measurement is to "Develop for SchoolNet consideration, a set of recommendations on the three different types of research that need to be done, i.e. baseline, assessment and innovation." (http://www.schoolnet.ca/snab/e/working_groups/members/rm.asp)

Framework for Implementation of LTs in WA Govt Schools

In 1998 the Education Department of WA released the "Framework for the Implementation of Learning Technologies in WA Government Schools" to support schools in the development of a learning technologies plan that was required to receive a government infrastructure grant. A copy of the framework is provided in Appendix C. The framework has six dimensions: ***Planning, Integration and Use, Staff Capabilities, Electronic Educational Resources, Hardware, and Connectivity***. These are all related to the impact of ICT but the ***Integration and Use*** and ***Staff Capabilities*** dimensions are being developed in another project. Therefore it is appropriate to start with the other dimensions and build on other dimensions identified in the review. Each dimension has a descriptor and pointers at four levels: Low, Mid, Target 2002, and High.

Planning

This dimension involves concerns for school planning for the integration of ICT use. It is stated that planning should integrate the use of ICT, link to student outcomes, and prepare for changing technology. At the HIGH level this is stated as,

> ***Learning technologies planning is embedded in school curriculum plans, is well monitored and responsive to changing technology and emerging needs with the school.***

The pointers at this level state that, Learning technologies planning is …

> ***… integrated in all learning areas and is embedded within curriculum and school planning processes.***
>
> ***… embedded in planning to improve student outcomes.***
>
> ***… monitored and flexible to take account of changing technology and emerging needs.***

Aspects of this dimension are clearly related to the impact of ICT on schools, curriculum and thereby teachers.

Electronic Educational Resources

This dimension involves concerns for the review and management of software resources, including Internet sites. At the HIGH level this is stated as,

> ***Planned approach to management and use of electronic educational resources appropriate to the teaching and learning program.***

The pointers at this level state that,

> ***Selection of electronic resources is coordinated throughout the school and strongly linked to the curriculum needs of students and staff for all learning areas.***
>
> ***There is management and coordination of all electronic resources across all learning areas.***
>
> ***All staff are confident in their selection and appraisal of electronic resources for the teaching and learning program.***

Clearly this dimension is related to the impact of ICT on schools, curriculum and thereby teachers.

Hardware

This dimension involves concerns for the provision and management of hardware resources. At the HIGH level this is stated as,

> ***The school has excellent facilities which allow for varied modes of usage to maximise improvement in student learning. Effective policies and procedures for the management of hardware resources are evident.***

The pointers at this level state that,

> ***Computer to student ration: primary 1:1, secondary 1:1.***
>
> ***Extensive variety of learning technologies for different curriculum needs in all learning areas.***
>
> ***Students have unlimited access to select and use learning technologies.***
>
> ***Technical support and maintenance is well managed by skilled experts from a technical support contract or school appointed technician.***
>
> ***A planned and dynamic learning technologies repair and replacement program is in place.***

Clearly this dimension is related to the impact of ICT on schools and educational systems.

Connectivity

This dimension involves the provision of Internet and network connections. At the HIGH level this is stated as,

> ***High standard connections and integrated use within the curriculum.***

The pointers at this level state that,

> ***School has clearly articulated and well coordinated management plan for the operation of learning technologies networks across the school.***
>
> ***Extensive range of online services available throughout the school (e.g. email, access from home, shared curriculum resources, intranet, video-conferencing facilities).***
>
> ***A school wide network that includes curriculum and administration with excellent Internet access.***

Clearly this dimension is related to the impact of ICT on schools, educational systems, and curriculum.

This framework provides a useful starting point for developing a ***Schools ICT Capacity*** framework with the need to add a technical support component. The inclusion of the concept of a Target level of implementation would seem to be useful for a school system to promote comparability of capacity across the system.

Implications for WA Government Schools

Internationally, nationally and locally there is widespread support for the use of computers in schools and a belief, supported by an increasing weight of research, that this should have a positive impact on students. There are three clear rationales for the effective implementation of ICT in schools, to:

(1) Improve student achievement of learning outcomes across the curriculum,

(2) Provide students with adequate ICT literacy, and

(3) Increase the efficiency and effectiveness of schools as organizations.

Effective implementation of ICT in schools will involve a large investment in a variety of resources at many levels. Therefore there is a need to address accountability for expenditure on ICT. Unfortunately, while this can be done relatively easily for the latter two rationales, the first and most critical rationale concerning the achievement of learning outcomes can't be readily addressed. Not only is it difficult to accurately measure such achievement, it is not possible to ascribe any gains specifically to the use of ICT since many other factors associated with the learning environment will contribute. However, schools and school systems will still need to address accountability in this area. To do this they will need to address the complex nature of the link between the use of ICT and improvements in student learning. This will need to be addressed in a multifaceted manner taking account of the known requirements, or conditions, to successful implementation of ICT to support learning and teaching processes.

The framework developed out of this literature review attempts to provide a method of addressing accountability in the use of ICT to support students in the achievement of learning outcomes across the curriculum. It also provides a guide for schools, teachers and school systems in how to optimise the potential impact on student learning of using ICT. This has implications for:

- The organization of the curriculum.
- The organization and staffing of schools.
- The culture, policies and procedures of schools.
- The training and support of teachers.
- The provision of hardware and software infrastructure.

In Western Australia curriculum reform has been accelerating over the past decade to support a more student-centred outcomes-focused approach that is clearly well aligned with internationally accepted understandings of learning and the needs of modern society. These changes should also encourage better use of ICT to support learning and teaching processes when they are well implemented in schools. Therefore it is largely at the school and individual teacher level that changes may be required. For some schools this will represent massive change while for others much of the realignment has already occurred. Fundamentally any change is aimed at improving the educational opportunities for all students and not just to make use of ICT. At all times the focus must be on improved outcomes for students and not on how the technology is used. Clearly we can not be satisfied with the current educational outcomes for Western Australian students and the evidence is mounting that we can make significant improvements with the appropriate use of ICT. Large investments have been made in ICT for schools and there is a need to take account of how effective that investment has been and where further investment should be made to maximise the impact of ICT on learning outcomes for students. The companion document to this review develops a framework for addressing some of these issues in a systematic manner.

Definitions of common terminology

The following terminology has been used throughout this document.

Application	May be used to refer to a type of software such as a word processor or generally to the use of computers in a particular situation.
Bulletin Board	The facility of a networked server computer to allow messages to be posted for others to read.
Computer	Electronic machine, operated under the control of instructions stored in its own memory, that can accept data (input), manipulate data according to specified rules (process), produce results (output) and store the results for future use.
Computer Literacy	Concerning the knowledge, skills and attitudes which enable a person to use computer technology to benefit themselves and others in relation to tasks they wish to accomplish.
Computer Awareness	Concerning the understanding of the role of computer technology in society and the social implications associated with the use of computers in society.
Curriculum	The word curriculum comes from Latin meaning to run a race-course. Its meaning in education has come to mean a combination of the learning outcomes, pedagogy, and content that students are to address. The Pennsylvania State Board of Education defines it as: "A series of planned instruction that is coordinated and articulated in a manner designed to result in the achievement by students of specific knowledge and skills and the application of this knowledge."
Curriculum Framework	Documents that describe curriculum goals and objectives for learning, and include direction for specific content areas, benchmarks, activities, and forms of evaluation.
E-mail (electronic mail)	Text messages and computer files exchanged through computer communication, via Internet or intranet networks.
Hardware	The tangible components of computers including processors, input, output, communications and memory.
ICT (Information & Communications Technology)	Typically used to refer to computer technologies but strictly speaking should also include other technologies used for the collection, storage, manipulation and communication of information. In some places the term IT (Information Technology) is used.
Interactive Multimedia	The use of a computer to control and present combinations of media such as text, graphics, video and sound. Sometimes the term is shortened to multimedia.

Internet	The international network of networks of computers using common protocols such as TCP/IP.
Intranet	A communications network, based on the same technologies used for the Internet but only available to authorised users within an organisation or company.
Learning Outcome	That which students may demonstrate from what they have learned. In the Curriculum Framework these are described as sets of outcomes associated with areas of learning.
Online	Usually refers to connection to host/server computers as found on the Internet.
Overarching Outcome	There are 12 overarching outcomes at the beginning of the Curriculum Framework that aim to direct the focus of all learning in Western Australian schools.
Pedagogy	A strict dictionary definition would state that pedagogy concerns the science of teaching children. It concerns what teachers do when they interact with children to support their learning. Most educators would consider that pedagogy encompasses the beliefs and actions of teachers including their teaching strategies, the organization of learning experiences and of the learning environment generally.
Server	A computer used to provide a service over a network. It may be a web server, print server, email server etc.
Software	The sets of instructions and data used by computers, sometimes referred to as computer programs.
TCP/IP (Transmission Control Protocol/ Internet Protocol)	The communications protocol used to define the 'rules' for the transmission of data between computers and networks wishing to be part of the internet.
URL (Universal Resource Locator)	The unique address of any document available for access over the Internet.

Appendices

Appendix Table A

Key Principle	Explanation	Constructivist Attribute
1. Opportunity to learn	Learning experiences should enable students to observe and practise the actual processes, products, skills and values which are expected of them.	Learner Knowledge Assessment Community
2. Connection and challenge	Learning experiences should connect with students' existing knowledge, skills and values while extending and challenging their current ways of thinking and acting.	Learner Knowledge
3. Action and reflection	Learning experiences should be meaningful and encourage both action and reflection on the part of the learner.	Learner Knowledge Assessment
4. Motivation and purpose	Learning experiences should be motivating and their purpose clear to the student.	Learner Knowledge
5. Inclusivity and difference	Learning experiences should respect and accommodate differences between learners.	Learner Community
6. Independence and collaboration	Learning experiences should encourage students to learn both independently and from and with others.	Learner Community
7. Supportive environment	The school and classroom setting should be safe and conducive to effective learning.	Learner Community
A1. Valid	Assessment should provide valid information on the actual ideas, processes, products and values expected of students.	Knowledge Assessment
A2. Educative	Assessment should make a positive contribution to student learning.	Learner Assessment
A3. Explicit	Assessment criteria should be explicit so that the basis for judgements is clear and public.	Assessment Community
A4. Fair	Assessment should be demonstrably fair to all students and not discriminate on grounds that are irrelevant to the achievement of the outcome.	Learner Assessment
A5. Comprehensive	Judgements on student progress should be based on multiple kinds and sources of evidence.	Knowledge Assessment

Appendix Table B

Evidence that a teacher is implementing an outcomes focus	Attribute of Constructivist Environment
Plan and teach to ensure that all students achieve the outcomes	Learner centred Knowledge centred
Incorporate the core shared values in their planning, teaching and monitoring.	Knowledge centred Assessment centred Community centred
Adapt and develop curriculum to meet the needs of all students.	Learner centred Knowledge centred
Make judgements about students' progress in relation to the outcomes	Knowledge centred Assessment centred
Provide learning opportunities to assist students to see relationships among knowledge, skills and values	Learner centred Knowledge centred Community centred
Work collaboratively to achieve integration, breadth and balance in the curriculum.	Knowledge centred Community centred

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