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Computer education: new perspectives

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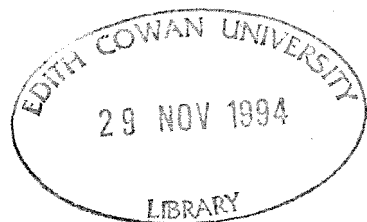
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Computer Education: new perspectives

Martyn Wild and Denise Kirkpatrick



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Foreword

Neil Tuckwell, Dean of Education, Edith Cowan University

Computer technologies were introduced into educational contexts over two decades ago and while there is some argument about the extent to which computers have realised their potential, they have undoubtedly had a significant impact on education. A look into any school will reveal computers being used widely by clerical staff, teachers and children.

It is clear that computers are here to stay, but it is less clear as to how effectively they are being used in the learning process. Teachers not only need to use computers but they need to use them well, and in order to do this they must understand what computer technology can offer and the ways in which such technology can be used in teaching and learning.

I believe this volume helps teachers reach such understandings.

Preface

Stephen Heppell

Computers and education: new perspectives, new technology, new learners

When someone finally gets around to writing the definitive 'History of the Future of Education' much will be made of the mismatch between reality and rhetoric. With learning technology we are so often told that 'this time, we've got it right' that our shared conviction is rarely deflected by the certain knowledge that we continually got it wrong in the past.

Why are we so confident in predicting future trends? There are good reasons not to be. History shows us that new ideas are rarely harnessed in a way that their inventors anticipated: reading through Bell's early papers we find that he thought he was working on something rather more akin to a radio than a telephone. Bell imagined people sitting around the 'receiver' collectively enjoying broadcast plays or listening in on interesting debates. Indeed in Budapest from the 1890s Telephon Hiromonu offered just this form of broadcasting down the 'phone lines. Clearly Bell was mistaken about the future use of his technology and the synchronous, participative, personal media that the telephone became, engendered very different social revolutions from the ones anticipated. But, as the wheel of technology turns, we now find 'Video on Demand' services broadcasting down those same telephone lines. Per-

haps Bell was only wrong with the timing of his predictions. Today the computer games industry, microcomputer manufacturers, cable operators, telecommunication companies, multimedia publishers and a host of other major players all see themselves as being the key element at the heart of our domestic information systems. They can't all be right and we have no way of predicting which are wrong.

On the other hand we can look back on the collected experience from a millennium or two of learning. We know what has worked and we know what hasn't. Crucially, we need to keep this knowledge in sight as we prepare for the new perspectives that computers and education are facing. It is easy to find vast areas of computer resourced learning where this reservoir of sound potential advice has been ignored. For example, much successful learning involves a participative role for learners: collecting, selecting, originating, organising and presenting, and all this in a way that is appropriate to the individual, institutional, local and regional needs of the learner. Sadly, many of the recent developments in multimedia offer few if any opportunities for participation. Support for origination and presentation is sketchy. Support for any individual, institutional, local or regional versioning is rare. The idea of symmetry is important here. When learners study poetry, they create their own, early on, using the same tools and presentation opportunities that the poets they studied used — text, paper, printing. Their work stands alongside the 'experts' in a way that lifts the self esteem of the learners and convinces them that they have an active role in poetry.

With so many learning professionals ready, willing and able to offer advice these mistakes are unforgivable, but they continue: as the 'cutting edge' moves forward from multimedia towards telecommunications and the information superhighway we find that, once again, their wisdom is lost amongst the technology. For example, we know the important role that teachers offer; they don't simply act as a source of all knowledge, rather they provide a filtering and interpretive framework within which learners may investigate the breadth and depth of information and become critically aware. In later life many report their memories of learning with a fondness which recalls not factual material but the unique, even eccentric, perspective of a particular teacher. Perhaps it was seeing Shakespeare's work through one teacher's eyes that brought it to life. Yet instead of offering that filtering and interpretive layer the information superhighway largely offers metaphors of place and structure whilst learners are hungry to know about presence, purpose, interpretation and controversy. Personally, if I have to pick between an intelligent agent that knows what I want and a good teacher who will challenge me with things I didn't know I wanted but am delighted to discover, I know which I'd pick most days. Why is this so readily forgotten?

This book is full of thoughtful descriptions of learning and the computer's role in that process, written by learning professionals who know good learning when they see it. That makes it a valuable contribution to the debate.

As computers and education face up to new perspectives it is important to remember that, although rapid technological development and the accumulated wisdom of our past learning experiences offer a prospect for real change, the real revolution we face comes probably from the technologically-confident young learners currently storming through our learning institutions. Whatever our knowledge, whatever we anticipate, whatever we plan, whatever we embrace, it will be the imperative of their expectations and capability that will revolutionise our pedagogy and curricular.

¶ The close of this millennium promises to be interesting for us all.

Introduction

Denise Kirkpatrick and Martyn Wild

But he's wearing no clothes!

The emergence of new technologies including the personal computer, CD-ROM, e-mail and interactive multimedia have been greeted with claims regarding their potential use in education and the changes which will result in teaching and learning. However, there are many who would see these claims as being like the Emperor's new clothes — without substance. Where is the evidence that supports the claims?

There is a commonly expressed sentiment that information technology (IT) has failed to deliver its promises. The introduction of television and video in education and the claims for the revolutionary changes which would occur as a result of that new technology are cited as parallels to the introduction of computer technologies. A review of classroom practice will show us that while television and video is common in schools and homes, little has changed in teaching as a result. Learners were seldom taught the skills to deal with television and video as a medium of information delivery and many will argue that computer technology will suffer the same fate, that its potential will never be realised. If these new technologies can offer so much in enhancing the quality of teaching and learning, why are teachers so reluctant to make use of them? Why, when computers have pervaded almost every other aspect of day-to-day life and left almost no-one untouched, have they had so little

impact on what takes place in classrooms? Why are teachers not using them effectively and why is there so much software that fails to acknowledge the principles of effective learning?

There is no simple or conclusive answer to these questions. There is no guaranteed way to encourage people to integrate change into their repertoire of behaviours. To address the question of why it appears that the promises of these new technologies are the Emperor, it is necessary to consider a number of issues that emerge from the previous scenario. If we are to establish a firm foundation for the use of new technologies in teaching and learning then we need to have a clear idea of what we want to achieve. What do we want the Emperor to wear and why do we want him to look the way he does?

It cannot be argued that computers have not had some impact on schools. Over the past two decades computers have become increasingly common in school settings. The introduction of computers and associated technologies has presented individual classroom teachers with an array of challenges. Not only must teachers become familiar with the technology themselves but they must find ways in which they can use these technologies effectively in their teaching. Never before has an innovation placed so many demands upon the user. Indeed, the speed with which new technologies develop and change accentuates these demands, where newly-learned skills quickly become obsolete. As new developments occur the demands on the teacher increase: teachers must build a range of technology skills themselves and also develop ways of using new technologies that are educationally effective. In this light, perhaps it is not surprising that the rhetoric about the potential of IT in education has seldom been realised.

In addition to becoming competent users of the technology — or at least accepting the technology — teachers must decide on the role that it will play in the learning process. Should IT be viewed as another resource to be utilised by the teacher as an instructional aide? Or should IT be treated as an integral part of the teaching-learning process? Subsequent issues relate to the management of resources and to ways of teaching and evaluating using IT. For example, where should a school place its technology resources — should they be based in individual classrooms or in a central computer-lab? What types of skills do learners need in order to use these technologies effectively and how are they best developed? How can teachers be encouraged to utilise the technologies in their own teaching? This volume concentrates on the range of technologies available and provides descriptions of successful applications for teaching in classrooms, particularly but not exclusively in Western Australian school contexts.

The range of technologies available

A number of the contributions to this collection focus on the use of the personal computer with software such as word processors, spreadsheets, databases, simulations, games, e-mail and computer-assisted learning packages of various types. In addition to this, Oliver describes the opportunities offered by interactive multimedia. Other technologies discussed include electronic communications tools, such as telematics, Minitel and videoconferencing. All of the technological applications mentioned have potential uses in the classroom, both as a support for the learning process and as a part of the learning process.

The role of technology in the learning process

Computer technologies provide the means to involve the learner meaningfully in the learning process, developing in learners the ability to learn alongside the technologies, rather than simply learn about them. This view extends the role of computer technologies beyond that of resource or instructional support to become an integral part of the learning process, providing learners with the cognitive tools they need to operate at higher cognitive levels; for example, Rowe explores the effect of computer applications on the learner's cognitive processes and the strategies children use when working on computer-related tasks. This approach requires teacher re-conceptualisation of what learning is about, aligning itself with the more recent cognitive views of learning which see the learner as actively involved in the process of constructing knowledge. There is considerable debate about the relative importance of teaching learners the skills to be able to use computer technologies and using software applications to develop particular cognitive and psychomotor skills in the learner. Teachers must be aware of those skills that learners need to be able to use technologies effectively and make decisions about whether to teach these skills implicitly or explicitly. The important thing is that teachers and learners are informed about the processes involved in using technological applications.

It must be remembered that computer applications are only as effective as the teaching-learning environment in which they are used. The selection of software, and particularly computer-assisted learning programs, should be influenced by the philosophy of teaching espoused by individual teachers. For instance, if teaching is embedded in behaviourist principles then the teacher is more likely to adopt programs based on similar principles, such as drill-and-practice or programmed learning software. In selecting applications and programs it is important to consider technical features, appropriateness of subject content and the design of the learning experience to ensure that the software is used in a meaningful manner. Ellerton explores many of the issues relating to classroom use of computer technology,

including organisational and pedagogical dimensions. Using the specific example of mathematics education she highlights the importance of teachers having a clear view of the role that they want computers to play in the learning process. Generally the role of computers as mediators of students' learning is seen to be of greatest significance. The role of computer as mediator is also referred to by Rowe and Dench.

While there have been many claims made for computer technologies in education, it has been easy for critics to draw attention to the lack of rigorous evaluation of the use and effectiveness of instructional technology in the classroom. Reeves highlights the importance of developing an effective method of evaluating the effectiveness of these technologies and explores a range of issues which impact on the evaluation process.

Specific applications

As the range of software applications available expands, so too does the variety of teaching-learning situations in which the technologies can be effectively used. There is currently a vast range of software available, at all levels and in all subject areas. Many of the applications such as word processing, databases, electronic books, CD-ROMs are generic and may be applied across curriculum areas. A number of the contributors to this book consider the application of computer technology to specific situations, either to curriculum areas such as maths (Newhouse; Ellerton), science (Cousins), language (Snyder; Ing & Wild) and French (Elder), or to specific contexts such as the early childhood learning environment (Trinidad) and special education (Evans).

Policy and planning considerations

The classroom use of computer technologies has been encouraged by educational policy makers. Current and past policy documents highlight the importance of developing individuals who are 'computer literate'. The public advocacy for new technologies has done much to ensure that teachers who wish to implement some form of computer-use in the classroom receive a degree of support. Additionally, media coverage of the social implications of more recent advances in technology serves to widen the base of this support and also fuels the debate concerning the future role of government in policy-making in the area of IT. Bowden and Clarke each describe the history of policy and practice in the educational use of information technology in Western Australia, highlighting and commenting on this debate. Certainly, planning — at all levels — for the effective implementation and use of technology is crucial.

Conclusion

The exciting range of new technologies challenges us to redefine our roles as teachers and our students' roles as learners. Not only does computer technology provide us with new ways of presenting and working with information, it can create a new teaching-learning environment in which we and our students work. This volume is concerned with the range of technologies available and the findings of some recent research regarding the effective use of computer technology in the classroom. The contributions identify salient factors which must be considered in the effective use of IT; they also explore ways of responding to the challenges presented by new technologies. In light of the issues raised here, perhaps it will be possible to act in ways that provide substance to the claims for the effectiveness of computer technology in education.

Personal computing: a source of powerful cognitive tools

Helga Rowe

Abstract

Computers allow for the development, adaptation and/or delivery of tools which facilitate more effective thinking, problem solving and learning. These tools are different from normal, task-specific tools. We refer to them as *cognitive tools* because they are knowledge construction and facilitation tools which can be applied in most domains. Cognitive tools are defined as mental and/or technological devices which support, guide and extend the thinking processes of their users. Just as a convection oven supports the cooking process, cognitive tools support thinking and learning processes. This chapter considers the role and effectiveness of computer-based tools for thinking, and how they can mediate learning. The importance of appropriate human-computer interface designs to ensure that the cognitive tool simplifies, rather than complicates, the user's tasks, is stressed. Finally, there is a brief discussion of how cognitive tools can aid the construction of knowledge by compensating for three major constraints of the human cognitive system: the limited capacity of human short-term and working memory, the organisation of knowledge in long-term memory, and the learner's use of cognitive strategies.

As the products resulting from the industrial revolution amplified and boosted the physical power of humans, the computer revolution has the potential of increasing

the power of the mind by extending, supplementing and boosting human performance. Moreover, computing can actually change the characteristics of problems and tasks (including learning tasks), and thus lead to a restructuring of the processes of problem solving and learning themselves. This latter attribute of computing might well contribute new visions of the cognitive, and thus educational benefits of the technology.

Cognitive tools

During the past two decades, methods of teaching and learning objectives have become increasingly cognitively oriented; that is, more responsibility for learning and motivation is invested in the students. Teachers and curriculum developers are trying to engage learners in more meaningful tasks and hence more meaningful mental processing. It seems ironic, therefore, that few tools have ever been designed specifically to facilitate learning. The chalk board is one of the notable exceptions, particularly in the light of its popularity and longevity. Other tools, such as paper, pencils, rulers and calculators have become important to education. Many tools and media, such as projectors, transmitters and computers have been retroactively adapted to serve educational purposes. Few have been developed with learning as the primary goal. The availability of computers, particularly personal computers, has changed this drastically. They allow for the adaptation and/or development of tools with only one purpose in mind: to support learning. These tools are different from normal, task-specific tools, in that they can facilitate cognitive processes such as thinking, problem solving and learning. This is why one might refer to them as cognitive tools. Just as a convection oven supports the cooking process, cognitive tools support the learning process.

We define cognitive tools as mental and/or technological devices which support, guide and extend the thinking processes of their users (cf. Rowe, 1988, 1989). Many cognitive tools, such as cognitive and metacognitive strategies, are internal to the learner. However, the tools being discussed here are external, computer-based procedures and environments which extend the thinking processes of learners. These tools engage learners in more meaningful cognitive processing. They are tools which can be used for the construction and facilitation of knowledge and can be applied to mediate learning in most subjects. The cognitive tools preceding computer technology that have tended to receive most attention in this respect are writing systems, systems of mathematical notation and systems of visual/spatial representation.

Cognitive tools, such as written languages, are commonly thought of as cultural amplifiers of the intellect, to use Jerome Bruner's influential phrase (1966, p. xii). They are cultural means of empowering human cognitive capacities. The research literature suggests that cultures with technologies such as written language push intellectual growth better, earlier and longer than cultures without such tools. We find similar predictions for computer technologies based on the widespread belief that computers will inevitably and profoundly amplify human mental power, and alter both what we do and how we do it.

The mediation of learning

Technologies do not directly produce learning. In other words, people do not learn from computers, books, videos, or the other devices which have been developed to transmit information. Rather, learning requires thinking on the part of the learner. Thinking processes are activated by instructional tasks and other learning activities (Rowe, 1989, 1993). Learning processes are mediated by instructional interventions, including technologies. In order to improve learning outcomes, we thus ought to focus on finding ways of teaching students how to think and learn more effectively. The emphasis should be less on the make-up of available sophisticated multimedia delivery technologies, and more on thinking technologies. It is my belief that the role of personal computers and other delivery technologies in learning and teaching is to display thinking tools; i.e. tools that activate and engage cognitive and metacognitive strategies, and thus facilitate students' thinking, problem solving and learning.

During the past two decades designers of learning environments and instructional systems have aimed to invest more responsibility for learning in the students themselves, by engaging learners in more meaningful mental processing. The next logical step in this revolution is to invest additional responsibility in the learner for personally constructing knowledge where appropriate. When this step is taken, learners become more self-reliant thinkers, better able to relate new information to existing knowledge and better able to apply that new knowledge in novel situations.

Cognitive tools lead to students learning with technologies as opposed to learning about them. Learning with technologies empowers the learner. Computer-based cognitive tools are intelligent resources, which learners can adapt to their individual needs and which collaborate with them in constructing personal knowledge. They enable individuals to engage in higher order thinking that helps them to muster cog-

nitive processes that would normally not be available to them without that cognitive tool (Rowe, 1993).

Areas of application

Currently, cognitive tools are being found to assist students in at least three major contexts: (i) in direct problem solving; (ii) in creating something; i.e. a product, idea or procedure; and, (iii) in finding new uses for computing. The most common software includes word processors, spreadsheets, graphics, adventure games and simulations. The curriculum areas most frequently targeted tend to be the enhancement of reading comprehension and all kinds of writing skills, mathematics and science, social studies, foreign language learning, technology subjects and the arts. Important generic skills which are being acquired by the students tend to relate to the development of knowledge representation skills, problem solving, planning and management of study, and students' self-monitoring and evaluation.

User attitudes determine effectiveness

What we will achieve with computing and how it will assist us in our endeavours will be determined by the uses which we can imagine for it. More importantly, our personal attitude to and philosophy of computers and computing directly influences the uses we can think of.

If we view the computer as we view, for example, a pencil; i.e. as a tool with which to produce a piece of writing, we will use computing differently and achieve different results than if we view it in the way we view a wristwatch. Here I am making a distinction between the machines which work for us (e.g. motor cars, washing machines, lawn mowers, watches, torches and drill and practice computer programs) and those that work with us (technology with which we work, e.g. pencils, scissors, garden tools and word processors). We adapt to the technology and machines which work for us, but we adapt the tools we work with so they best serve our purposes (e.g. you may write best with a very sharp pencil, and I prefer a blunt one — Your 'personal planner' might be structured differently from mine!).

Neither pencils nor computers can be regarded as independent variables which are introduced into a particular context, and the effects of which can then be controlled and observed directly. A pencil does not cause better or worse writing, nor does a

computer cause better or worse planning, decision making or learning. It does not cause more or less social interaction among students. Computers, like pencils and other tools are not agents, but something that becomes part of the user and the learning or work environment in many different and complex ways. No wonder that computers are being used in support of the most diametrically opposed theoretical approaches to learning and teaching. Computers can be used to make highly structured methods of instruction even more structured, and they can be used to make open, democratic learning situations more open; i.e. to increase the students' self-directed learning.

The introduction of a new tool can be expected to change the intellectual demands of the tasks for which it is being used. The nature of these new intellectual demands cannot simply be projected from a study of the tools themselves. Many of them stem from the way the new tools are utilised, the functional purposes they fulfil and the way tasks involving them are structured and socially distributed.

What are tools for thinking?

Are there basic tools that give one a certain intellectual leverage? What about powerful individual metaphors for thinking versus general skills or principles which might apply across individuals? The concept of a cognitive tool as used in this context refers to a device or technique for focusing the learner's analytical processes. A cognitive tool can be regarded as an instructional technique in so far as it involves a task or procedure, the explicit purpose of which is to lead to active and durable learning of the information or skills manipulated or organised in some way by the task or procedure. To instruct someone to learn is in effect to say: perform some activities which result in your understanding of, and durable memory for, this material. A cognitive tool gives the learner just such a ready-made set of activities.

Computing can provide a more personal relationship with many aspects of knowledge and thinking, because it can represent a rich source of diverse reference points for so many otherwise abstract ideas. Obviously, familiarity with computing can play a role in learning and instruction even when the computer is not physically present.

The computer in the head can often be a more effective aid to instruction than the computer on the desk. (Papert, 1987, p. 182)

Cognitive tools to simplify tasks

The cognitive tool metaphor should exhort software designers to ensure that the tool simplifies, rather than complicates the user's tasks. A tool which requires more time, effort and training to use than the task requires without the tool, is not likely to be a successful product.

In human-computer interface design, the computer as a tool philosophy implies that designers must actively pursue techniques to reduce the mental processing operations required just to be able to use the tool. Mental processing operations include requirements for the user to learn complex commands and syntax, memorise encrypted codes and abbreviations, or translate data into other units or formats before they can be applied to the problem at hand.

A well designed computer system permits the use of the tools it offers without requiring users to dedicate extensive mental processing to operations inherent in the system design rather than the task. Furthermore, its tools are designed to also reduce task-specific mental processing, especially those types of processing that are performed more effectively by computers than by people, such as calculations and accurate storage and recall of large amounts of pre-specified information. Many of the techniques that have proven useful in achieving these goals are discussed in the human-computer interface design literature.

In the design of an effective human-computer interface, allocating functions to be performed by either the user or the system should be based on an understanding of the capabilities and limitations of both the system and the users: the computer should do what computers do better, and the user should do the things that people do better. Unfortunately, these decisions are often either based exclusively on hardware, software and/or cost concerns, or they are made without any explicit analysis of the allocation of functions.

Constructing knowledge

We learn as a by-product of understanding. Yet we can normally get by with understanding less than we may like to think. Much successful performance can be based on the interaction of the learner with information in the environment. Only by requiring the learner to perform explicit comprehension tasks, when deep processing is necessary to complete the task, can we be sure that the learner is not constrained by the context of the particular learning experience.

Presumably the learner will also become aware of the effectiveness for learning of the pursuit of the kind of thought processes stimulated by a cognitive tool, and will start to apply them even without the tool. This is the learning how to learn argument.

For more than a decade educationalists have stressed the merit of creating one's own ideas in a flexible information environment. Consuming the ideas of others in combination with reconstructing one's own prior concepts about key issues in a new domain can generate new and powerful learning. This led to an interest in flexible, personalised information tools and was the main reason that cognitive tools became a topic of interest for learning. Allowing the student to reflect on his/her personal knowledge or the information presented during instruction allows for cognitive amplification.

Computing as a compensatory tool

Human information processing processes have their limitations. How might the computer compensate for these? Three aspects of human cognition underline the attractiveness of human-computer collaboration:

- the limited capacity of human short-term or working memory;
- the organisation of knowledge in long-term memory;
- the learner's use of cognitive strategies.

Memory The limited capacity of short-term memory is, of course, the primary constraint on the human cognitive system. The capacity of short-term memory has been estimated at approximately seven chunks (plus or minus two) by Miller (1956), and approximately five chunks by Simon (1974). A chunk is a semi-elastic unit whose size depends on the familiarity and meaningfulness of the information to the individual. This, in turn, is dependent on relevant prior knowledge (knowledge structures) in long-term memory.

Organisation of knowledge To remain immediately available, information in short-term memory must be continually refreshed and rehearsed. But this rehearsal of information competes for limited memory capacity with new information that comes along and with information retrieved for current use from long-term memory. As a result, information in short-term memory is lost or distorted as new information is obtained and capacity is reached. If all the information needed at a particular time is not available in accurate form or cannot be obtained from the

environment or from long-term memory, learning will not take place, or, worse, 'mislearning' might occur.

Not all information that passes through short-term memory is stored in long-term memory. This is time-dependent: Simon (1974) estimates that it takes between five and 10 seconds to fixate each chunk in long-term memory. Once fixated, the retrieval or activation of information in long-term memory is dependent on its structure and organisation; i.e. its interconnection with other information. Information stored in computer memory is not subject to any of these restrictions.

Strategies Much of what goes on during learning is determined by the cognitive strategies the learner uses. These are the actions of the learner that obtain additional information (either from environmental cues or associations, or from long-term memory), manipulate it, and organise and structure it so that it enters long-term memory in a retrievable form. Cognitive strategies include scanning, searching, questioning, 'chunking', hypothesis generation, decision making etc. The use of these strategies is based on the learners' perceptions of the task, the value they place on it, and the assessment of their own performance. These processes are automatic for some people, but they are not automatic for less efficient or less experienced students. For the latter, decisions about processing of information occupy and compete for limited space in short-term memory.

In summary, the elements of the processes which most inhibit human thinking and learning are limited short-term memory capacity, difficulty in retrieving needed information from long-term memory, and the ineffective use of cognitive strategies to obtain, manipulate and restructure information. These factors are compounded, so that experts and very efficient learners have more automated cognitive strategies, use less capacity for their strategies, and thus have more space available for information needed to interconnect with knowledge in long-term memory. Those who are less efficient with cognitive strategies must use more of their limited short-term memory, thus less information is immediately available to achieve problem solving or learning, and to transform and interconnect new information with existing long-term memory structures. With less information in long-term memory, and that information poorly structured, less is readily available for use.

Computer support Given these requirements and the limitations of the mind, how can computers be used to facilitate human information processing? Much of what we do with traditional, well designed instruction, including computer-based tutorials, is to support learning by actually performing necessary cognitive strategies for the learner. Instructional strategies such as specifying objectives, giving rules, providing examples, asking questions and evaluating answers (Gagné, Briggs and

Wager, 1988), correspond to and replace cognitive strategies such as determining a goal, inferring a rule, identifying an instance, posing a hypothesis, and testing it. Experienced learners, such as senior high school and university students, may already have these strategies in their repertoire, although they may not use them regularly, appropriately or efficiently. Rather than short-circuit the learning process by performing these strategies for learners, as is the case also with computer-based tutorials, computer-based cognitive tools use a different approach to support learning. They activate and perhaps model cognitive operations and they provide external resources that compensate for the limited capacity of human memory. They can aid thinking, problem solving and learning by:

- making large amounts of information immediately available for the learner's use, thus supplementing limited memory;
- making it easy to retrieve relevant, previously learnt information and making it simultaneously available along with current information;
- prompting the learner to structure, integrate and to interconnect new ideas with previously acquired ones;
- providing for self-testing, thus rehearsing the recall of previously learned information and thus increasing its retrievability;
- enabling the learner to represent ideas verbally, pictorially and graphically;
- providing for the easy movement, consolidation and restructuring of information needed by individuals as their knowledge base grows.

By supporting processing and compensating for limitations in the processing system, a cognitive tool can amplify cognition and at the same time minimise the amounts of mental effort required. Developing new cognitive tools is an important aim in the context of instructional design, for education and for the accomplishment of intellectual tasks more generally.

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Using the computer for mental modelling

Martyn Wild

Abstract

This chapter is concerned with the place of mental models in the process of knowledge construction and in particular the part that can be played by technology in helping learners build and manipulate mental models. It identifies what is meant by the term 'mental model' and outlines why building models is central to the process of acquiring knowledge. The second part of the chapter describes how computer technology can, (i) present models to the learner in a specific domain, for example, in history and (ii), allow learners to build their own models, representing what they already understand about that particular domain. It is argued that computers, in various domains, can play supportive and significant roles in enhancing what is an essential cognitive process: the building, exploration and representation of mental models. In particular, the chapter draws attention to the use of spreadsheets in the process of building models and provides an example of spreadsheet use relevant to children aged 9–10 years.

Introduction

Models are often used in education to present the correct or expert way of doing something: the correct answer in maths; the most effective method of writing a report in science. In other cases, models are used to provide a representation of something complex: how plants breathe (biology); the reasons for human conflict in Northern Ireland (history). As such, there are probably two important kinds of modelling in education: the modelling of expert performance and the modelling of processes (Collins, 1989). Most educationalists would agree that it is vital for learners to be presented with expert models in order to learn new knowledge; furthermore, many would argue that learners need to be given opportunities to interact with these and other models in order to learn effectively. The role of technology is important in both cases; for example, it is important in the presentation of models of processes:

The computer makes it possible to represent processes in ways books never could and even in ways people cannot. Computers can make the invisible visible: they let you see inside pipes or inside the body, how current changes in circuits based on electron flow, where the centre of mass for a group of bodies is, how microscopic processes unfold. (Collins, 1989, p. 3)

In addition, computer technology is possibly more important for the opportunities it provides for learners to manipulate expert models and even to build their own models of knowledge.

Mental models

Models at one level mean much the same thing to most people. When we think of models we might identify a hobbyist's model of a jet fighter aeroplane; or an architect's model of a high-rise apartment block; or even an engineer's model of a new form of motor vehicle. These are all models. Some models are intended to be replicas of real objects and are usually created for demonstration purposes. For example, a model of a new house, as yet not built, might be used to provide a visual aspect for potential buyers. In other cases, models are not necessarily intended to visually compare to the real thing. For example, a model of a molecular structure might be created in science to facilitate study of the relationships between atoms. In this case, the model might comprise a series of small spheres connected by rods.

In the examples above, each of the models is a physical construct intended to represent objects or phenomena. However, it is also possible to create models of processes, procedures or functions. For example, we might build a model of the process of making a cup of tea:

- | | |
|-------------|--|
| Step one: | Fill kettle with water. |
| Step two: | Connect kettle to power supply. |
| Step three: | Turn power on to kettle. |
| Step four: | Place teabag into cup. |
| Step five: | Upon boiling, pour water from kettle into cup. |
| Step six: | After two minutes, take teabag from cup. |

In the same way, it is possible to make models of social systems; for example, an historian might build a model of a medieval parliament in order to study interactive roles of particular officers of that political body; a sociologist might build a model of juvenile delinquency in a particular society; and a geographer might model climatic behaviours as a result of ozone depletion.

In all these examples, models are used as representations. In cases where the model is not a representation of a phenomenon but rather a representation of an abstraction or concept, then the physical model is a representation of a mental one (Carey, 1985). In this sense, although the mental model does not need to be precise or definitive, it does need to be functional. That is, it should provide explanations and it should allow predictions (Bliss and Ogborn, 1989). Piaget was perhaps one of the first to show that mental models are important in the development of knowledge and that learners construct mental models in order to learn (Mandler, 1985).

Knowledge acquisition

The process of knowledge acquisition, or learning, involves, at one level at least, the restructuring of existing or prior knowledge to accommodate new knowledge. In the past, learning was largely conceptualised as the addition of new knowledge to an existing knowledge base, with some resulting differentiation, or hierarchical integration, of the existing knowledge structures as and when needed (Kelly, 1955; Osborne and Wittrock, 1985). More recent research findings in the area of cognitive science have demonstrated that such enrichment or accretion models of the learning

process do not reveal the whole story and that in some cases, knowledge is acquired alongside a radical reorganisation of existing knowledge structures (Vosniadou, 1992).

This is particularly true in the area of science where it is known that children develop naive ideas about natural phenomena before they are taught about science at school (Driver, Guesne and Tiberghien, 1985; Driver 1988a). These naive or informal theories appear to derive from children's direct experiences with phenomena and are supported by both everyday discourse and the popular media (Driver, 1988b). In some cases, children's naive conceptions differ in the extreme from widely accepted scientific ideas of the same phenomena. In these contexts, knowledge acquisition cannot be explained in terms of the enrichment of existing knowledge structures, since these structures themselves are so radically different from the ones necessary to be acquired for learning to occur (Vosniadou, 1992). More importantly, research has shown that where naive and expert conceptions of the same phenomena differ structurally, then the naive conception often proves resilient to change and may well persist beyond childhood, despite considerable amounts of formal instruction (Novak, 1988; Viennot, 1979). In line with this, it has been shown that some non-scientific (i.e. naive) ideas are more prevalent in older children or adults than in younger children (Strauss, 1981; Osborne and Cosgrove, 1983).

Mental models and learning

Models have been used for some time in education. They are most often used to present new concepts to children and in this sense provide a means of communicating definitions and meanings. Used in this way, the models provided are the teacher's: such models are always 'correct' and usually complete. In addition, teachers often expect children to have their own cognitive models already in place and expect those models to conform to the 'correct' ones (i.e. those held by the teacher). Consequently, teachers expend little effort in helping learners to develop their individual and personalised models and even less in supporting learners towards making conceptual changes to those models.

However, if one accepts that education involves both the shaping and restructuring of learners' conceptions, it remains necessary to identify how to go about this; that is, how to move the learner towards the formation of mental models required for understanding in a range of domains. A Piagetian perspective on this problem suggests that knowledge is created via the learner's spontaneous interaction with the

environment and by the social transmission of learning (Ginsberg, 1985). Accordingly, it would appear necessary for learners to build their own models and also for teachers to provide incomplete models for learners to interact with: an incomplete model might possibly challenge the structure of the mental model a learner already has, involving that learner in totally reconstructing her own conceptualisation. Equally, for other learners, providing an incomplete model may allow them to confirm various attributes of their own mental model and provide the means and motivation to extend it.

In the context of science education, a number of researchers have suggested various instructional strategies that help to identify learners' mental models and to promote conceptual change in learners (Champange, et al., 1982; Cosgrove and Osborne, 1985; Driver and Oldham, 1986; Driver, 1988a; Hameed, 1990; Hameed, et al., 1993). In general, these strategies conform to the notion that learners should both build and experiment with their own models as well as with those of their peers and with models provided by experts; the strategies suggested are also relevant to domains other than science. They include:

- providing opportunities for learners to make their own mental models explicit;
- presenting conflicting models to challenge learners' own models;
- providing opportunities for learners to explore correct models, provided by experts;
- providing opportunities for learners to apply mental models to a variety of related learning environments in order to promote their usefulness;
- providing opportunities for learners to become aware of their own mental models and how their conceptualisations are subject to change; i.e. promoting learners' metacognitive skills by, for example, encouraging reflection.

However, it should be stated that some science education theorists (e.g. Claxton, 1982) have suggested that conflict strategies may not always be effective. For example, in Claxton's eyes, learners have a range of available conceptions or models which are selected as they appear appropriate; accordingly, instruction should place an emphasis on developing awareness of the context in which certain models are appropriate rather than on challenging a learner's errant model. For another domain, Bryant (1982) echoes Claxton's reservations about the value of conflict strategies in promoting learning and suggests that to learn from contradiction requires considerably more than simply being made aware of such conflict.

Furthermore, others have identified additional instructional strategies and approaches to facilitating conceptual change in a range of domains; these include

the use of analogy (Gilbert, et al., 1982), scaffolding (Vygotsky, 1975) and various social processes (Edwards and Mercer, 1987). However, the use of such strategies in certain domains might be problematic. For example, Hameed (1990) reveals that the instructional use of analogy and metaphor in science might compound a learner's misconceptions rather than support them in building appropriate mental models to understand a phenomenon. It would seem sensible to suggest that the use of any one instructional strategy needs to take account of the level and type of mental model a learner has already formed in a given domain; that is, it is important to account for the characteristics of learners' mental models.

Characteristics of mental models

It would appear that all learners, whether children or adults, develop conceptions or mental models independently and often prior to formal instruction (Driver, 1988a). Further, mental models are domain-specific representations, in that they are constructed by learners as they acquire understanding or competence in a particular domain (Royer, et al., 1993; Gentner and Stevens, 1983).

Glaser, et al., (1985) suggest that there exist three types of representations or models constructed by learners for a given domain. The first they call a *qualitative process* model, which is an internal representation of a device, system or phenomenon and a set of procedures relating to it. Such a model allows the learner to mentally simulate the performance of that device etc. under various parameter changes. This type of model would typify that of a domain expert, where manipulation of the model is necessary to facilitate problem solving. A second type of model Glaser, et al. call an *appearance* model. This is similar to a qualitative process model but only provides a static representation. The final type of model is a *relational* model; this is a representation that is constructed by the learner according to the features of known models. The relational model is arguably the type of model formed in the initial stages of learning in a given domain. For science education, for example, Rowell, et al. (1990), have argued that scientific misconceptions are, in part, a function of learners possessing only relational models of scientific phenomena.

Glaser, et al. have here conceptualised a hierarchical schema of mental models, whereby a learner, in constructing understanding of a particular device, system or phenomenon, may progressively move from building a relational model, through to an appearance and then a qualitative process model. Others have described mental models differently. For example, in physics, Anzai and Yokoyama (1984), have

classified learners' models as being experiential, correct scientific or incorrect scientific. According to Royer, et al. (1993):

Experiential models are derived from individual experience and do not include scientific entities or relations. A correct scientific model is a set of scientific concepts and relations that are correct and sufficient to capture problem information. A false scientific model is a model that contains scientific concepts and relations but the model incorrectly characterises problem information.

In Anzai and Yokohama's conceptualisation of mental models, a learner's model may not only be qualitatively different from that of an expert (as inferred by Glaser, et al., 1985) but it can also be classified as correct or incorrect.

Being able to identify and classify the type of mental model that is held by a learner at any one point is important as a precursor to developing appropriate instruction and as a means of evaluating a learner's cognitive performance and potential as well as a means of cognitive error diagnosis.

Computers and modelling

Computer technology offers a medium via which learners can make modelling explicit: computers allow the creation, exploration and representation of mental models, facilitating and enhancing an essential cognitive process. For Bliss and Ogborn (1989), the value of the computer is seen in the support it can provide to children in representing and exploring the consequences of their own models. For Vosniadou (1992), computer modelling, particularly in the domain of science, can not only help children extend their observations beyond what is available to them through everyday experience (i.e. computers can model highly abstract and unobservable processes, such as the operation of the solar system or the passage of food through the body), but the process of constructing models can help them understand the limitations of their own beliefs (i.e. about a device, system or phenomenon) and help them become aware of the existence of alternative beliefs and explanations (i.e. what Vosniadou (1992, p. 160) terms 'metaconceptual awareness'). In a similar way, Blow, Francis and others would argue comparable benefits of modelling in a social science domain, such as history: here, the computer can provide a means for visualising what cannot be directly observed, enable children to construct and interact with models based on belief systems about the past and engage children in the historical process of interpreting and accounting for the past (Blow, 1987; Francis, 1983).

Computer modelling can be classified according to a number of criteria; Webb and Hassell (1988) suggest a classification based on the behaviour of the model and methods of modelling and outline five families of models. The following classification is based closely on that offered by Webb and Hassell (1988):

- dynamic systems models;
- spatial models;
- qualitative models;
- probabilistic event models;
- data analysis models.

Dynamic systems models These are models that relate and describe change over time; for example, in geographical terms, a model might be built demonstrating a meteorological phenomenon such as precipitation.

Spatial models These models involve related entities positioned statically or dynamically in space and qualitatively might include at least four distinct sub-types:

- *static spatial models*: such models are typified by maps, showing, for example, a distribution of soil types over a given area. This model would allow prediction of where a particular plant is most likely to flourish;
- *animated sequence models*: such models represent a sequence of related events in which items move over space and perhaps over time. For example, a model might be built demonstrating a biological process such as conception;
- *dynamic spatial models*: such models can describe, for example, land formations such as mountains; they are characterised by changes in the positions of objects in space over time;
- *dimensional models*: these models are usually of a structural type and often multi-dimensional: for example, a three-dimensional model of a bridge or a car.

Qualitative models A large range of models in the fields of sociology, history, psychology and other domains need to represent concepts such as causation, kinship, morality etc. Such models are based on heuristics and are characterised by qualitative, conditional and logical statements often relating to people and events. For example, a model might be built representing the concept of exploration in history; another might be constructed to facilitate diagnosis of an illness or other psychological or medical condition.

Probabilistic event models Such models, for example, might be used for purposes of genetic engineering, where that model is based upon the probability of occurrences of an event(s).

Data analysis models These models are constructed from analysis of large-scale data sets and typically allow identification of patterns in data. For example, population growth trends can be revealed by the representation and analysis of population counts. Such models might be accompanied by graphical data representations.

There already exists some software necessary for modelling activities using the computer. For example:

- spreadsheets allow the representation of numerical data, providing for the building of data analysis models (e.g. in science, maths and geography);
- graphing software similarly facilitates the construction of data analysis models; Logo provides for the building of static and dynamic spatial models (e.g. in maths and design technology);
- expert and knowledge-based systems software allow construction of qualitative models (e.g. in history and social studies);
- animation software allows the building of animation sequence models (e.g. in science, human movement, dance and design technology).

Furthermore, over recent years we have begun to see the use of multimedia software to build both sophisticated quantitative and qualitative models, usually by combining data generated from a range of different software.

However, there does not exist a comprehensive modelling environment on the computer, enabling learners to involve themselves in a range of modelling activities. This is despite several educationalists outlining the desirability of such a software environment (e.g. Webb and Hassell, 1988; Webb, 1994). Indeed, the engineering of a modelling program, with which a learner may both create and manipulate models of various types, is not a trivial task. The Tools for Exploratory Learning Research Programme, funded by the Economic and Social Research Council (United Kingdom) and coordinated by the London Mental Models Group, has indicated that it is more feasible to consider the production of specific domain-related software tools, to allow for modelling activity within a particular domain; i.e. they have chosen to consider the production of software tools for 'two contrasting domains — technology and social situations' (Bliss and Ogborn, 1988; Bliss and Ogborn, 1989).

Bliss and Ogborn (1989), suggest there are two categories of software tools necessary for modelling: exploratory and expressive tools. Exploratory tools allow learners to investigate models which might be different from theirs; expressive tools permit learners to explore their own representations. They suggest (p. 41):

In the former, learners are developing models based on the assumptions of others, and in the latter, they are modelling their own assumptions. Each permits the learner to explore different but complementary modes of learning and as such both can help to facilitate the move from the pupil's mental model of a domain to the different or more complex conceptual (*expert*) model necessary for a deeper understanding.

Furthermore, they suggest that in designing the types of software tools necessary to engage learners in modelling activities, it is important to address a fundamental difference between quantitative, semi-quantitative and qualitative modelling (Bliss and Ogborn, 1988), (a distinction that approximates to, and simplifies, the modelling classification provided by Webb and Hassell (1988), described above).

The application of computer-assisted modelling

Much of what occurs in classrooms, both primary and secondary, in the name of computer-assisted learning (CAL) often involves the use of simulation and decision-making 'adventure' games. Such CAL occurs frequently in humanities' domains, such as history and social studies (Watson, 1984; Nichol, 1988). The software simulations and games that are commercially available incorporate models that are usually qualitative in nature. Bliss and Ogborn (1989) would suggest that this CAL provides for modelling in an *exploratory* environment; that is, learners are able to explore a model built by someone else within a given domain but not able to alter this model or, indeed, to build a model representative of their own thinking within that domain.

A classic example of an exploratory software model is provided in the simulation *Palestine 1947* (CET, 1986). This simulation allows children to explore the effects of a range of policies available to the five major powers concerned (e.g. USA, USSR, Jews, Arabs, United Nations) with a United Nations' plan for the partition of Palestine in 1947. The aim of the software is for children to find out, in as few moves as possible, which combination of policies implements the United Nations' plan. The outcomes generated by the software, reflecting the effects of various policies chosen by the user, range from outbreak of war to successful implementation of the United Nations' plan.

The actual model upon which the simulation is based is overly-simplistic; for example, whereas a learner could choose over 700 possible combinations of policies for the five powers represented, there are only four outcomes generated by the software. Furthermore, children can neither alter the existing model (perhaps adding to the possible outcomes) or use the software to express their own knowledge within this domain. Children can readily see the (simplified) effects of their choices but they cannot determine why these effects occur (i.e. they cannot observe the model on which the program outcomes are based since the model is made inaccessible to the user of the software).

The author, Blow (1987), has deliberately limited children's interactions to exploration of the model in *Palestine 1947* and in doing so follows the line of thinking that in a complex domain, where the acquisition of domain knowledge is the goal, children should:

analyse the patterns and relationships in a computer model to establish how its rules operate; change the rules and predict the effect. (National Curriculum, United Kingdom, statement, quoted in Webb, 1994, p. 143)

Indeed, for both Blow and the UK National Curriculum, the process of children exploring models is thought to necessarily precede that of children constructing their own models. However, from the results of studies conducted by both Webb and Nichol it may be that the view described in Blow (1987) and elsewhere is flawed (Webb, 1994; Nichol, 1988). It would be easier for children to understand patterns and relationships in a computer model if it were one they had designed and constructed themselves, 'rather than trying to guess the basis of a model that is built into a simulation program by examining the output under different circumstances...' (Webb, 1994, p. 143). Thus children are more likely to learn domain knowledge as well as the process skills necessary to building and exploring models within that domain if they are engaged in constructing their own models at a very early stage in their learning.

It is of value to extrapolate three points of significance from this finding:

- There is a need for software environments to be developed that enable young children to build their own qualitative models. To date, it would appear that knowledge-based and expert systems tools are likely to provide a foundation for any software modelling tools to be designed for children to develop their own qualitative models (Nichol, et al., 1988; Bliss and Ogborn, 1988; Bliss and Ogborn, 1989; Webb, 1992; Webb, 1994).

- That since modelling is recognised to be a domain-specific activity, software tools are necessary to facilitate modelling activities in a range of different domains (Royer, et al., 1993; Gentner and Stevens, 1983).
- That young children should be encouraged to build their own models in domains, such as maths, where there already exists software tools with which children can develop models (i.e. *expressive* software tools). For example, both spreadsheets and graphing software allow for building models of a quantitative type, where numerical relationships between data items can be represented (Heppell, 1986). Indeed, Heppell (1986), makes a sound argument for the use of spreadsheet software such as Microsoft Excel, with children aged as young as 6–7 years. But whatever software is used, it is important that a young child's cognitive capacity is not expended in trying to master the interface of the modelling software itself but rather on developing the model(s).

Using existing software for modelling

The following is a brief outline of an activity which is appropriate to children of 9–10 years. It makes use of a spreadsheet and associated graphing software for a modelling activity in maths. The task set for the children is to generate a set amount of money (i.e. at least \$80.00) to help purchase a computer for their classroom. It involves them in a fund raising-activity where all children in the class will make and sell mince pies. The children, probably working within a number of smaller groups, need to manage the task and complete it successfully. The management tool is the spreadsheet; using that tool, children can model some of the processes necessary for (i) the making of the mince pies; and, (ii) their sale.

Figure 1 illustrates the raw data sourced by the children concerning the cost of ingredients for the mince pies; this data has been placed within a model for costing the making of the mince pies. The model has a number of components: ingredients, weights, costs. These components are linked within the model to enable the children to find out how much it will cost to use the amounts of ingredients suggested in the recipe (which will make a total of 35 pies). They do this by carrying out a number of calculations using inherent functions of the spreadsheet; for example, firstly finding out the cost of the various ingredients per 100 grams (g) and then using these findings to calculate the cost of the recipe for making 35 pies. The question-marks (?) in Figure 1 indicate the costs that are yet to be calculated in order to complete the model. Figure 2 is an extension of this same model, using graphing software (in this case, provided within the spreadsheet program) to illustrate and analyse relative costs of ingredients.

	A	B	C	D	E	F
1	<div>Task: to make at least \$80 from making and selling mincepies</div>					
2						
3						
4						
5						
6		Weight			Recipe to	Recipe
7	Ingredients	(g)	Unit cost	per 100 (g)	make 35 pies	Cost
8						
9	Flour	500	\$0.60	?	450	?
10	Margarine	250	\$0.75	?	250	?
11	Mincemeat	500	\$1.20	?	675	?
12	Eggs	6	\$1.60	?	1	?
13						
14	Total costs		\$4.15			?
15						

FIGURE 1. Modelling the cost of making the mince pies (1)

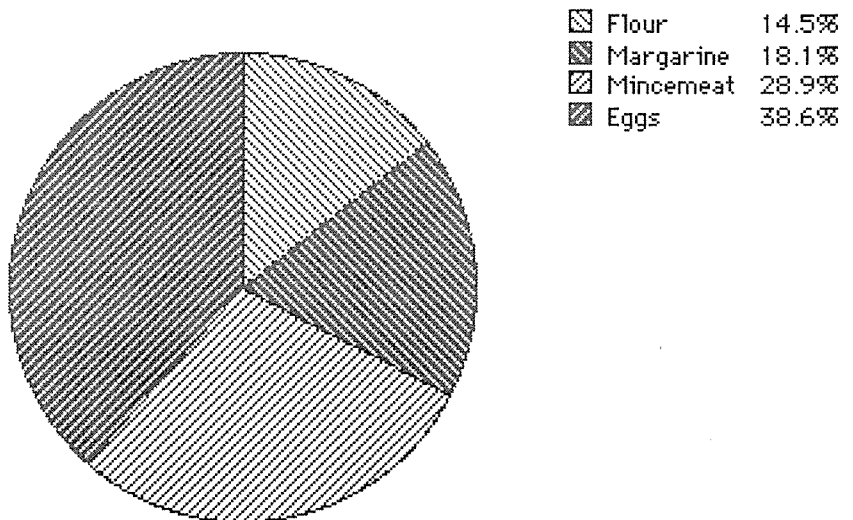


FIGURE 2. Modelling the cost of making the mince pies (2)

Figures 3 and 4 are illustrations of other models that have been built by the children to help them complete the original task. Figure 3 illustrates an expanded model of that described in Figure 1: it now demonstrates all costs of making the mince pies. In addition it describes how much it will cost to make one or more mince pies and predicts a range of selling prices for the mince pies in relation to the numbers that might be sold. That part of the model formatted as bold text (i.e. at the lower-right of the figure), shows the predictions necessary to provide for a net profit of at least \$80.00. Figure 4 is a graphical model based on the data shown in Figure 3. Here, the prediction data is illustrated as trends by use of a line graph; the dotted line demonstrates the critical point when a net profit of \$80.00 has been reached.

What cannot be illustrated here is the dynamic nature of the models shown in Figures 1-4. Each of the models shown has been designed by the children to enable them to analyse new data and make further predictions based on, for example, changing costs of ingredients (i.e. due to inflation or some other extraneous factors).

	A	B	C	D	E	F
1	Mince Pies Problem Solving Activity					
2						
3						
4	Ingredients	Weight (g)	Unit cost	Costs per 100 (g)	Recipe to make 35 pies	Recipe Cost
5	Flour	500	\$0.60	\$0.12	450	\$0.54
6	Margarine	250	\$0.75	\$0.30	250	\$0.75
7	Mincemeat	500	\$1.20	\$0.24	675	\$1.62
8	Eggs	6	\$1.60	\$0.27	1	\$0.27
9						
10	Total		\$4.15	\$0.93		\$3.18
11						
12	To make:	1 pie	10 pies	100 pies		
13	Cost:	\$0.09	\$0.91	\$9.08		
14						
15	To sell at: →	\$0.10	\$0.20	\$0.30	\$0.40	\$0.50
16	No. pies ↓					
17	10	\$0.09	\$1.09	\$2.09	\$3.09	\$4.09
18	32	\$0.30	\$3.50	\$6.70	\$9.90	\$13.10
19	64	\$0.59	\$6.99	\$13.39	\$19.79	\$26.19
20	100	\$0.92	\$10.92	\$20.92	\$30.92	\$40.92
21	200	\$1.85	\$21.85	\$41.85	\$61.85	\$81.85
22	300	\$2.77	\$32.77	\$62.77	\$92.77	\$122.77
23	400	\$3.70	\$43.70	\$83.70	\$123.70	\$163.70
24						
25						

FIGURE 3. Completing the model: the output and selling price of the mince pies

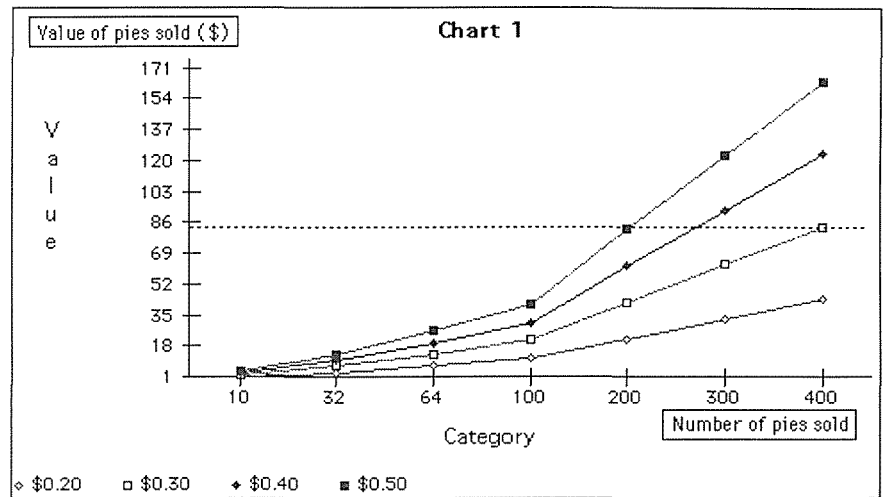


FIGURE 4. Modelling trends in the output and selling price of the mince pies

This activity has been described in terms of the models that might be built by children in order to successfully complete a task. In the classification of modelling offered by Webb and Hassell (1988), each of the models illustrated here possesses characteristics of *probabilistic*, *dynamic spatial* and *data analysis* model types; when placed within the classification provided by Bliss and Ogborn (1988), the models are clearly of a *quantitative* type.

What is shown in Figures 1–4, are examples of conceptual or expert models (Norman, 1983); what is not shown are models that demonstrate misconceptions or ones that are incomplete, although children should be expected to build such models in their attempts to complete the task. Also, this example does not refer to the learning environment in which children are engaged in building their models. Indeed, learning is not a simple function of the learner's interaction with the software but is rather a product of a very complex classroom system (Biggs and Moore, 1993). Both Brown (1994) and Webb (1994) outline classroom system characteristics necessary for successful modelling activities, particularly in relation to *teaching context* (Biggs and Moore, 1993). They point out that:

- students should possess ownership of the task to be completed (i.e. to support a high level of intrinsic task motivation);

- the teacher should be prepared to closely monitor and intervene in students' modelling (i.e. to prevent students working inefficiently with the software as well as to promote students' modelling skills and dispositions);
- students should be encouraged to interact with others whilst engaged in the modelling task (i.e. maximising, for example, peer learning and on-task verbal interaction);
- appropriate amounts of time need to be provided for task completion (i.e. modelling activities are recognised to consume more time than is often allowed for in a given learning experience in schools);
- students should be encouraged to reflect on their modelling experiences (i.e. thereby engaging students in applying what Biggs and Moore (1993) have termed, *deep* and *achieving* approaches to the completion of the task, rather than a *surface* approach).

Pintrich, et al. (1993) have also recently pointed to the importance of what they term *contextual factors* and in particular, student motivation, as pivotal in determining knowledge acquisition in students as a result of modelling activities. In this sense, they argue for the primacy of contextual factors over purely cognitive strategies, in providing for conceptual change in students.

To conclude the comments made in respect to the example of model building provided above, it is as well to draw attention to the benefits of using the spreadsheet in this case. Essentially, building the models shown here engaged the children in forming and exploring their own cognitive models of the domain, the spreadsheet software allowing children to give concrete form to their abstractions. Here, it is likely that the process of building models using the computer enhances the children's understanding of the domain by:

- raising their level of cognitive processing (i.e. they are encouraged to think at a higher level; for example, to generalise about concepts and relationships);
- encouraging them to define their ideas more precisely and accurately;
- providing them with means and opportunities to test their own cognitive models and, by doing so, to detect and correct inconsistencies.

Conclusion

This chapter has attempted to draw attention to the importance of the computer in providing a means by which children can build and represent their own models in particular domains. There is undoubtedly a need for software to be provided so that model building of different types is facilitated in a range of domains: this is the goal, for example, of the London Mental Models Group (Bliss and Ogborn, 1988). It is also important for educational researchers to identify what specific strategies can be applied to enhance the benefits of modelling using the computer; for example, both cognitive (e.g. the provision of conflicting models; the opportunity to apply models to a variety of contexts) and environmental or contextual strategies (e.g. providing for learner ownership of task). In these ways, it might be possible to plan for and maximise conceptual change in learners; that is, to use technology to provide the optimum conditions for modelling so that learners might build understanding in various domains.

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Making powerful software tools available to children: Logo and other examples

Paul Dench

Abstract

Modern personal computers give access to many powerful tools with increasingly user-friendly interfaces. These tools present opportunities for use by young children but also the dilemma as to what nature of access and what level of instruction are necessary and appropriate. One of the first of these powerful tools was lookout was embedded in an educational philosophy which many teachers believed, and still believe, meant total freedom for children to explore and experiment, free from teacher restraint or influence. This is a gross misunderstanding of the philosophy of Logo's developers; their intention was always that the teacher should intervene at the appropriate time and in the appropriate manner.

This chapter places the ideals implicit in Logo in the context of modern philosophy about the nature of a 'disciplined activity'. It will argue that empowerment of students working with any powerful tool will only occur if they have access to the more powerful features of that tool. This 'knowing' can only be achieved as a disciplined activity under the guidance of an 'expert' teacher who ensures that certain basic skills are acquired and that certain criteria of success are established. Teachers become expert by collecting ideas, tool-boxes, procedures and programs; learning about them by using them themselves; adapting them to suit the individually-expressed needs and purposes of their students; and intervening in their students'

use of the tool with assistance suited to their needs, individual learning styles and levels of development. A praxis for guiding students to become powerful users of Logo is then presented showing how various classes of tools suit different needs and different development levels. It is argued that the same approach is equally effective and equally necessary to becoming powerful users of any other powerful tool.

Introduction

Logo is often described as only a children's programming language; it is given little consideration beyond its ability to enable children to program computers to draw pictures. This is a superficial viewpoint which masks the real power of Logo and often leads computer experts with a narrow knowledge of computing to dismiss it as a trivial language. In reality, Logo has its origins in LISP, a powerful artificial intelligence language. Papert (1980) and his colleagues borrowed the list-handling commands of LISP and added the set of graphics commands which are the most familiar part of Logo. Their efforts resulted in a programming language designed to be more accessible to children, not only a children's programming language. It was also a language that had its roots in educational philosophy. The attraction for young children is the immediate visual feedback provided by working with Logo's graphic commands and the egocentric nature of the Logo 'turtle' which wanders around the screen drawing lines as a result of a child's instructions. It is our challenge to introduce Logo to children in such a way that access to the more powerful parts of Logo is facilitated.

I first heard about a new computer language called Logo while working at the Carnarvon Tracking Station in 1974. To while away the hours between manned space flights we wrote a primitive version of Logo in FORTRAN. I remember a few years later during my early years of primary teaching wishing I still had my primitive Logo when my Year 7 students who had been doing some elementary MINIWAFT programming using punched cards were impatiently awaiting the computer's postal response. Then in the early 1980s the BBC Acorn microcomputer appeared in primary schools and soon a definitive version of Logo had arrived: in 1982 my voyage of discovery working with Logo with children began. Like many others at that time, I had heard that Logo was synonymous with the idea of a student's complete freedom to experiment. I recall the horror I experienced when the computing teacher at the local secondary school presented me with a Logo worksheet for a Year 8 Computer Literacy class. It read something like this:

1. Type the following:
2. TO SQUARE
3. REPEAT 4 [FD 100 RT 90]
4. END
5. Now type SQUARE. What happened?

While my approach to using Logo then was not entirely *laissez faire*, it was then much less structured than it is today and never as highly structured as that secondary school example.

I do not intend to argue the merits of Logo, or to what degree transfer of learning or thinking strategies to other areas of school work occurs from working with Logo; the jury is still out on these issues. For me, many of the studies that seek to decide these issues lack detail about the methods of teaching; or are too short in duration for any significant learning to have taken place; or lack substance about what knowledge of Logo as a discipline has been, or ought to have been, achieved. To talk of the development of other learning attributes without these parameters being considered is inappropriate.

What I intend to do is to present a guided discovery approach in which the teacher has the responsibility of ensuring that a child's discoveries in Logo are achieved within a disciplinary setting. In such a setting, 'knowing' is real because it has been personally acquired and because it can be shared with and understood by co-users of Logo. The approach I suggest has been nurtured by certain key papers on teaching and learning styles in Logo. It is an approach which I have adapted to working with students with Genesis, a hypertext/multimedia application with a scripting language not unlike Logo and with Vector, a vector-style drawing application. I will illustrate the following discussion mainly with examples from Logo but also from these other two applications.

Misconceptions about Logo

Logo was the first of many powerful tools whose intent is empowerment of young children through ease of access to its features. Too often, however, only a small part of that power is released because of teachers' misconceptions that empowerment in Logo means total freedom to experiment. At the other extreme, many teachers use published teaching materials and workbooks which take a very structured approach to using Logo; one which may provide skills in using Logo but little empower-

ment. Neither of these approaches places much demand on teachers. Both are relatively easy to implement; either 'no structure and no input' or 'high structure and no input'. Both equally misunderstand Papert's seminal work (1980) on the role of the teacher with children working in Logo. He is quite convinced that all children, given the right conditions, can acquire proficiency in programming. This would be under conditions very different from what are the norm in a modern-day secondary school computing class or using the more structured teaching materials available. The 'right conditions' include more and freer access to computers, considerable student autonomy and, contrary to much belief about his central thesis, considerable teacher support to the extent of answering questions, providing help when asked and even demonstrating 'something the student can use for an immediate project' (1980, pp. 179–180). Teachers who take either the laissez faire or structured approach will not themselves generally develop the personal knowledge and skills required to support the student development implied by Papert's right approach; an outcome they have more or less prevented by the choice they have made.

'Knowing' Logo

I shall now argue that a disciplinary framework must exist if students are to share and understand each other's work. What is the nature of that discipline? The viewpoints of four modern philosophers are often used to support contrasting points of view in education. Hirst (1974) and Phenix (1964) take a conservative view and regard disciplines as characterised by 'knowing that' knowledge, while Pring (1976) and Schwab (1964) take a more liberal view in which knowledge is characterised as essentially 'knowing how'. Although they all regard a discipline as an 'association of specialised inquirers', the latter viewpoint is more appropriate to our understanding of Logo learning as a disciplined activity.

Pring (1976) lists four characteristics which he suggests determine the structure of a 'disciplined activity' or a 'way of knowing': constellations of central organising concepts, principles of procedure, criteria of success, and a disciplinary framework. The distinctive logical structure of Logo, the modular approach which depends on procedures and functions, how procedures call each other, and the facility with which recursive calls are implemented form the 'constellations of central organising concepts' (p. 30) of the discipline. The 'principles of procedure' (pp. 31–32) may only be distinguished by the questing behaviours which are merely implicit in the group practice; i.e. the acceptance that experimenting, 'playing turtle', or guessing and testing (known technically as debugging) are legitimate ways of programming when you have an interactive environment. Other behaviours would be the

students' use of concepts such as the 'return turtle' or 'total trip' theorem (the turtle must turn 360° to close a path) and the 'reverse path principle' (the reverse path is the mathematical inverse of the outward path); their awareness of turtle-state (control of turtle position between procedures); their use of 'good style' such as the appropriate layout of code to heighten the perception of similarities and patterns; and the meaningful naming of procedures and variables (Dench, 1989). All of these behaviours require 'knowing how' and are demonstrated by practical behaviour without necessarily being able to explain why alternatives are wrong.

'Criteria of success' means performing well or effectively according to standards which are often merely implied such as having a 'good style' to facilitate communication among inquirers. I guide my students' development using criteria from a 'model for assessing learning with Logo' (Dench, 1989, pp. 60–61, adapted from Nolan and Ryba, 1986). 'Disciplinary frameworks', Pring's fourth characteristic, may be provided solely by the set of problems or the shared interests which bring a group of people together; these despite 'any clear rules of procedure or agreed criteria of... success' lead to the growth of a tradition which disciplines a group of people in their chosen interest and which can be learnt by new members of the group. Even Hirst, a more conservative thinker about the nature of knowledge, accepts that disciplines contain elements which can only be learnt tacitly 'from a master on the job' (1974, p. 45); in this case the teacher.

Children learning Logo as a 'disciplined activity', guided by a teacher as expert, will develop sufficient strength in their knowing to give them access to the more powerful features of Logo. Children learning from either a laissez faire or highly-structured approach will emerge knowing Logo of only limited power.

Learning styles and teacher intervention

Solomon (1982), one of Papert's co-workers, discusses three different styles of learning. She suggests that at any one time a child could be using any one of the strategies. What is important is that the teacher is aware which style is currently dominant and then, knowing the child's developmental readiness, chooses the type of support that will empower the student.

In a study of the difficulties children have with structured programming, Leron (1985) suggests a quasi-Piagetian learning approach which requires a more active role for both the teacher and printed learning materials whilst maintaining considerable student autonomy. His three levels of learning — syntactical, semantic, and

expert (1985, p. 29) — give some guidance for the design of an intervention curriculum. Syntactical learning, the lowest level, is the acquisition of a set of syntactical rules such as ‘user defined procedures may call one another’. The actual use of these rules, semantic learning, requires ‘the cognitive ability to conceive of a complex procedure as a hierarchy of sub-procedures with interfaces between them, as well as the technical ability to program in this style’. In expert learning the students show ‘the tendency to use these tools spontaneously and willingly on their own’. Leron envisages a well-planned, modular, spiral course guiding the students through the three levels. He devotes considerable attention to the child’s development of the notion of ‘modules’ and ‘interfaces’ or ‘seams’ (what I call ‘bricks’ and ‘cement’) in which the interface specifically consists of the steps necessary to move the turtle from its state at the end of the first module to its state at the beginning of the next module.

McDougal (1985) has identified four teaching/learning strategies: synthetic, analytic, turtle-humming, and ‘Logo on the run’. They differ in the amount of teacher intervention and student autonomy each requires. She makes no claim that these strategies are mutually exclusive, suggesting that teachers use a blend of them depending on a student’s developmental readiness or phase of development of Logo concepts. Her ‘Logo on the run’ best describes my own approach to working with skilled students; even though the students are autonomous they are encouraged to call upon me at any time for a written procedure to meet a need they are unable to fill. This enables me to encourage good style and structure; however, it is an approach which requires a Logo-expert teacher.

Four levels of progressive involvement for the teacher becoming Logo expert are offered by David (1985, p. 15). His first, colleagues in learning, reflects both teachers and students new to Logo: ‘What you lack in programming skills you can make up for in... a sense of where the power of language lies, an awareness of procedural thinking,... and a recognition of individual problem-solving styles’. His second level, behind the scenes programmer, requires the teacher to develop (or acquire) a repertoire of helpful procedures which are offered to students when they are on the verge of discovery but are threatened by frustration; he believes that students should not need to discover everything for themselves. His third and fourth levels would take students into ‘high school and beyond’ levels of programming. David’s approach ensures considerable student autonomy but still leaves the teacher a clearly defined role as an expert helper and guide.

The opinions offered above clearly suggest a Logo teacher requires a wide variety of skills. Solomon’s (1982, p. 197) list captures most of these:

- collection of programming projects that make the power of programming techniques and concepts apparent to beginners;
- vocabulary for talking about programming;
- an awareness of different learning styles and strategies for building on them;
- sensitivity to the kinds of resistance that keep many... children from experimenting with mathematics.

To these I would add:

- an awareness of an appropriate developmental sequence of Logo concepts; and,
- a repertoire of procedures that could be provided to students requiring help.

This complete list is consistent with ideas expressed by Leron (1985), McDougal (1985) and David (1985).

The role of tools

In a study of children's learning styles, Lemerise (1992), discusses the importance of tools in developing Logo abilities: 'children cannot use tools until they possess them, nor can they make deliberate choices until they are conscious of alternative tools' (p. 216). She suggests that children need an appropriate selection of assigned tasks so that they have time to become familiar with new tools before becoming able to adapt them to their own purposes. Hillel (1992) also stresses the teacher's role in providing 'a selection of well thought out activities' (p. 34). Teachers working with children learning Logo need to be collectors of such tools and activities; of ideas, procedures and programs. They must use their collection so they understand by 'doing' Logo, and then must adapt it to suit the developing needs of their students. This collection is likely to consist of three different categories of tools: tool-boxes, program shells, and microworlds. I will describe these briefly, with some examples, before further elaboration of the 'disciplined' guided discovery approach.

A toolbox is a set of procedures which extends the set of Logo primitives and which can be used directly without modification. A teacher would provide these to students who have sufficient knowledge of Logo to use them effectively or even to adapt them but who have not yet developed the skills or knowledge to develop them for themselves. A teacher can reasonably expect mid-primary students to develop regular polygon procedures with a 'variable' input (:SIDE, for TRIAN-

GLE, SQUARE, CIRCLE etc., and even :WIDTH and :HEIGHT for RECTANGLE) but to ask them to develop a procedure for ISOTRIANGLE, with the variables :APEXANGLE and :BASE, would require a trigonometrical sophistication beyond some of their teachers. However, having designed simple shapes they have acquired the skills to use a toolbox of more elaborate 'extra shapes' (Dench, 1989, pp. 29, 76). Even experienced Logo users make use of tools; I use a 'language' toolbox offered by Goldenberg and Feurzeig (1987, p. 9) as the basis for many of my language microworlds.

The concept of a toolbox is not peculiar to Logo; it can be applied to other applications with equal facility and for the same reasons. Figure 1 shows a stage design using a teacher-designed toolbox (a Vector library) of pre-scaled furniture. Students master the basic draw package skills of rotation, reflection, scaling, etc., of objects to maintain a sense of perspective in their design but are not presumed to have the skills (or time available) to draw anything but the simplest of objects.

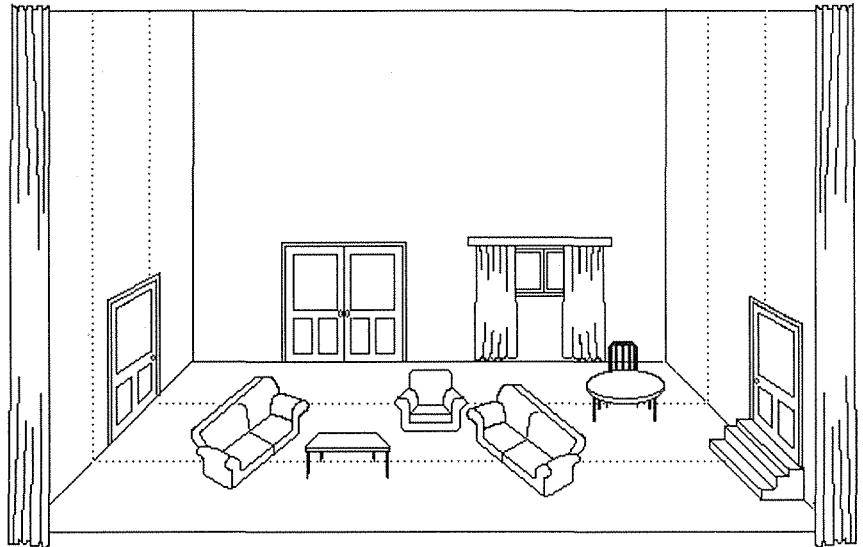


FIGURE 1. Stage design toolbox

One tool I have developed for Genesis inserts a transparent 'button' over a word or picture element that needs to be made active and creates a linked frame into which the student can insert explanatory text or graphics. The tool automatically creates the necessary script, and names and numbers the two frames it creates. It also keeps track of what it has already created so that numbering is correct when the next active area is inserted. This has made a powerful feature of Genesis available to students who are able to design a multimedia application but who would be most unlikely to develop the scripting skills to initiate their ideas.

A program shell is an unfinished (or unfilled) program structure containing procedures and sub-procedures which can be adapted or extended to suit the purposes of the student who applies skills which are already well developed. I have a 'software' shell which is used by skilled students to implement a menu-operated graphics environment which allows the user a choice of graphical elements in building a picture of choice; e.g. the hamburger in Figure 2, originally drawn by two ten-year-old girls, was developed a year later into a colour-filled piece of software in which the user was offered a range of different fillings for the hamburger and then a choice from several examples of canned soft drinks.

Another approach to program shells is to use an extendible procedure such as the 'suffix-s' (plurals) case study presented by Goldenberg and Feurzeig (1987). I have often used this with skilled students starting list-handling, providing them with a small starter program which deals with the general rule and maybe one of the plural exceptions. Students then research special cases of plurals and extend the shell to deal with these extra cases; by no means a trivial task.

In Genesis, menu and sub-menu structures are quite difficult to implement because they must be arranged in reverse hierarchical order in the main script. This provides an ideal opportunity to devise a shell program to make menu features more accessible. A student drags a menu 'button' onto the page to guarantee the correct order. The script elements are then individually opened and modified to suit the special purposes of the student.

A microworld is a closed environment with boundaries and rules determined by an installed Logo program containing procedures which can be used to explore that microworld; a knowledge of Logo may or may not be required. A very limited microworld often found in Logo literature is the single key press (F, B, R, L, etc.) kindergarten Logo. My version, Slow Logo (Dench 1990, p. 6), moves and turns the turtle slowly so that beginning Logo users can 'see' the action and readily perceive the difference between the two types of movement; this helps to change the beginner's mind from 'Cartesian' to 'turtle' thinking.

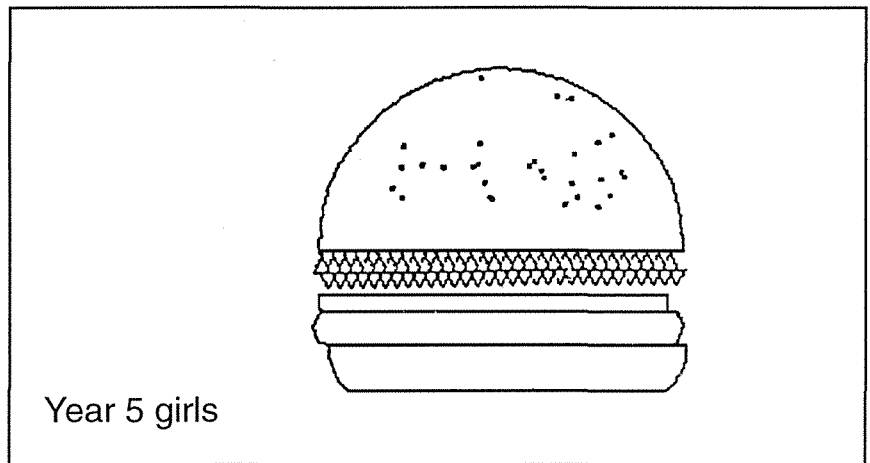


FIGURE 2. Hamburger

A grammar microworld I have developed (Dench, 1991) is capable of generating poetic structures designed by the student exploring its possibilities. This was further developed to give non-Logo students programmed access to an advanced language toolbox only usable by students with good list-handling skills. The ideas of Goldenberg and Feurzeig (1987) were very influential in this development. Another of my language microworlds, still in use in the Geraldton and Meekatharra districts of Western Australia, allows students to discover for themselves the grammar and suffixing structure of simple sentences in Wajarri (the local Aboriginal language).

All of these Logo tools, except perhaps self-contained microworlds, will require the development of Logo skills to take full advantage of them. It is now time to discuss how teachers can develop their students' skills within a disciplinary structure.

Developing 'disciplined' Logo

I must first declare my presumptions about children upon which I base my approach; these are:

- they work best if they feel they have ownership of the problem;

- they have the broader concepts and ideas to develop significant pieces of work, and the motivation and stamina to do so;
- they can only retain ownership of the problem if they have the basic skills needed to accomplish the task they have set themselves, and if their teacher furnishes help and guidance on request at a level suited to their current level of development.

An appropriate developmental sequence for Logo starts with learning basic skills, proceeds with using toolboxes, then with using and adapting program shells, and follows, much later, with designing microworlds. Generally the ability to use a toolbox will precede the ability to design more complex procedures, and the ability to adapt a more complex suite of procedures to suit personal purposes will precede the ability to design microworlds.

The above observations have emerged from my work with children and Logo and have guided the evolution of my approach to both working with Logo and other powerful tools. For me, six elements are critical to the development of a disciplinary approach to Logo: the establishment of the concept of modules (or procedures); the awareness of the ability of modules to call each other; the control of turtle-state within modules (sometimes called state-transparency or state-invariance); the design of the interfaces between modules; the early introduction of variables; and the need for 'good style'. Each powerful tool we introduce will have its own set of critical elements which will need to be identified by the teacher.

Developing the concept of modularity has always been the very first of my aims for 'disciplined' Logo even before the fundamental primitives (FD, BK, RT and LT) have been mastered or even introduced. This is an instructional approach supported by Hillel (p. 34, 1992) who stresses that the 'role of the teacher in introducing and maintaining work with... procedures' is vital to the later development of the concept of variables. I use a Pattern Logo microworld (Dench, 1992) to help develop the concept of modularity. Originally it was developed to give my six- and seven-year-old students keyboard-familiarity skills in a Logo context, blending school policy on keyboarding with my personal philosophy; it now forms a part of their mathematics learning. Every key on the keyboard is associated with a Logo function; e.g. F(orward), B(ack), R(ight), L(eft), H(ome), C(lear), and U and D for penup and pendown, for fundamental primitives; A and J for 90° right and left arcs respectively; and T(riangle), S(quare), O for circle (C is already used), Q(uadrant), K(ite) etc. for shape procedures and so on for the other keys. Children design a pattern by typing in a sequence of letters. Figure 3a is a successful design realised with a repeated 'A A A A J' by a six-year-old child and, a more economical solution, a repeated 'O J' by a seven-year-old child. The disciplinary concept of modularity is

reinforced by my insistence on a string of letters on the same line repeated on subsequent lines, as necessary, to produce a pattern. Success is rewarded with a print-out of the design; a single letter per line or a 'scribble' design does not meet the required 'criteria of success'. In a more recent version of Pattern Logo, I have introduced the notion of repeated patterns more formally; Figure 3b was produced by a nine-year-old student with a '6 K L T R R R' module; i.e. the pattern repeated six times.

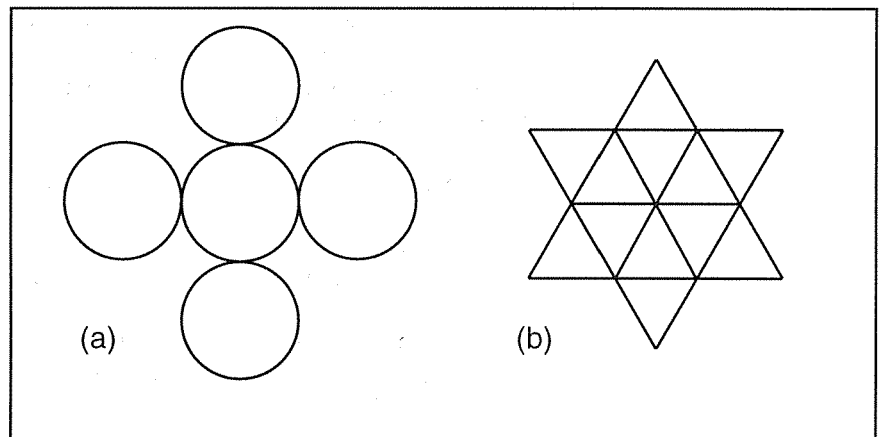


FIGURE 3. Designs generated by *Pattern Logo*

The next step in ensuring a modular approach in a pre-variable, pre-editor environment is to introduce a BUILD microworld (Dench, 1993) and make the shape procedures of Pattern Logo available as a 'toolbox' in a normal Logo environment with full access to all the basic primitives. This microworld emulates the TO.....END programming process and allows children to design and edit procedures while operating in the 'direct mode' of Logo rather than in the 'editor mode'. It is suitable for eight- to nine-year-old students and enables children to acquire the concept of super-procedures which call the toolbox procedures and the modules they have just built and named. As students reach mid-primary age, I introduce a more formal approach to module building as outlined in Dench (1989).

An important step in modular thinking is the realisation that a repeatedly used sequence of commands can be replaced by a sub-procedure that is called up by a single word descriptive of its function; also that procedures may call each other

within their sequence of commands. The elegant way in which recursion can be implemented where a procedure calls itself is a powerful programming aspect of Logo. An effective approach to reinforcing the concept of procedure calling is to use a program shell which consists of procedures that call each other and the procedures that children write themselves and include in the shell; the structure of the program shell can be written to ensure that procedures are relatively small modules rather than long elaborate code sequences. An example of this would be the 'choose your own burger and drink' elaboration of Figure 2.

Probably the most difficult concept to establish in a disciplinary approach to modular thinking is the control of turtle-state. This is necessary to ensure that modules can be readily exchanged or enhanced without the need to modify the interfaces between touching modules. For example, in the classic Logo problem of constructing a HOUSE, a right-rotating SQUARE walls module with a right-rotating TRIANGLE roof requires a different interface (or cement) than a HOUSE with a left-rotating TRIANGLE roof; the roof modules are not interchangeable. Similarly if the houses are to be assembled into a STREET the proper handling of turtle-state would require the interface from base to roof to be reversed after the roof is drawn before another interface is designed to move from one house to the next house. Examine the following HOUSE procedure:

```
TO HOUSE
  SQUARE 100      walls module
  FD 100 RT 30     interface
  TRIANGLE 100    roof module
  LT 30 BK 100    reverse interface
END
```

The first interface is obviously needed because one cannot place the roof at the top of the walls without it. The reverse interface is not so obvious and, more often than not, children will not accept that it is necessary except as part of the interface command to join up the second and subsequent houses in a row of houses. There are various sequences of commands that will reverse the first interface and restore the turtle-state; a common one being 'RT 150 FD 100 LT 180'. I ask my students to list all the possible ways of 'getting back down' and invariably 'LT 30 BK 100' emerges as the most elegant way and leads our community of inquirers to adopt the 'Reverse Path Principle' (Dench, 1989, p. 20): mirror each command of the first interface in an inverse order and in a mathematically inverse sense. Leron and Zakis (1992, pp. 346–349) discuss the concept of 'inverses and conjugates' in the control of turtle state and the design of interfaces, and Clayson (1988, pp. 175–179)

offers a useful alternative method for the more complex turtle-state situations which arise in visual modelling.

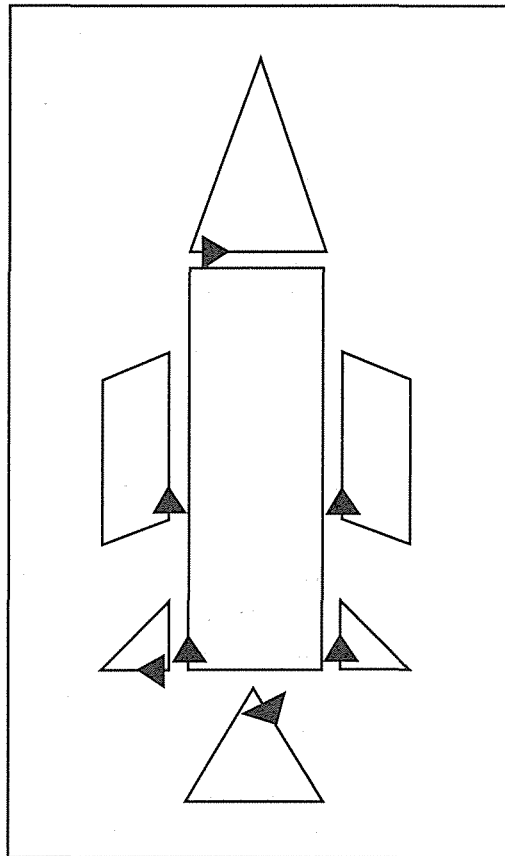


FIGURE 4. Spaceship showing 'turtle-state'

To emphasise the concept of interfaces between modules I introduce a worksheet on 'cementing shapes' (Dench, 1989, p. 28). The appropriate time to do this is when the shapes toolbox is provided. Figure 4 shows a spaceship to be built using the toolbox; it highlights the turtle-state at the beginning and end of each module. The student's task is to design the interface (or cement) between each module and

the next. In a suitably structured procedure the interfaces could be later amended to include pen colour changes and local variables when, for example, spaceships of differing sizes are required.

Variables should be introduced to children very early into the process of designing modules immediately after they have developed a firm understanding of modularity. Children around ten years old are able to use the procedure editor and have no difficulty in replacing a set of numbers with the equivalent variable particularly if it is named appropriately such as "HEIGHT and "WIDTH and not as mysterious algebraic variables such as X, Y and Z. The need to do this will be fostered if they are encouraged to set themselves tasks which require variations in the value of the variable to change the size of the result. Harvey (1985, pp. 36, 45–48) presents two metaphors which deal effectively with overcoming the initial confusion there will be about the difference in notation between "LENGTH and :LENGTH.

The final important element in developing a disciplined approach to Logo is the matter of 'good style'. This is necessary not only so one can read one's own program after a lapse of time but is also vital to the free flow of information between users in the 'association of specialised inquirers' being established. One of Logo's many virtues is its ability to reveal the purpose of a program if full advantage is taken of the ability to name variables and procedures meaningfully and arrange the code in modular chunks on the page. However, the common student tendency is to put all the commands in their program into one huge amorphous 'paragraph': this must be vigorously resisted. Imagine the difficulty in debugging this small example of amorphous coding: RECT 200 50 FD 200 RT 30 TRI 50 LT 30 RT 90 FD 50 RT 90 FD 200 TRI 20 RT 90 FD 50 TRI 20. Equally deplorable is a common solution to this problem where teachers require the 'spaghetti' approach: a single primitive command per line. This also reduces the readability of a program and would extend this chapter to about 40 pages. Consider

this
vertical
sequence
of
words
is
not
as
easy

to

scan

and understand as a horizontally scanned sequence of semantically linked words. I insist on a modular approach even within a procedure definition, grouping each related sequence of commands on a single line to convey a 'phrase of meaning', e.g. the total interface between adjacent modules. Consider this rearrangement of the amorphous example presented above:

RECT 200 50	<i>module</i>
FD 200 RT 30	<i>first interface</i>
TRI 50	<i>module</i>
LT 30 RT 90 FD 50 RT 90 FD 200	<i>second interface</i>
TRI 20	<i>module</i>
RT 90 FD 50	<i>third interface</i>
TRI 20	<i>module</i>

This approach helps to reveal the structure of the program better than a 'spaghetti' or an amorphous approach and makes it easier for students to recognise patterns and similarities within and between similar procedures; it also assists them to clone their own versions.

The other element of 'good style' is the appropriate naming of variables and procedures. Sometimes students are so self-centred they name them after their pets or pop and sports stars and confuse even themselves when their programs get more complex. I will usually decline assistance until they edit their programs so that I can read them. 'Good style' must be enforced right from the beginning before the alternative becomes a bad habit.

Students who have mastered the above six elements of a disciplined approach to Logo will go on to become powerful users who will have little trouble in mastering the most powerful features of Logo: recursion and list handling.

Conclusion

Too often Logo is used in a laissez faire manner which precludes access to its more powerful features. I have argued that this approach is contrary to the educational philosophy implicit in Logo. The full power of Logo can only be made accessible to students if they achieve it within a disciplinary framework. Even liberal defini-

tions of what characteristics determine 'disciplined' activity imply certain standards must exist for there to be communication and growth for the co-members of that discipline.

Teachers have a critical role in establishing associations of disciplined student inquirers. They must be prepared to become proficient users of Logo themselves, learning with their students if necessary, and ensuring their students acquire the foundation skills and criteria of performance necessary to develop into powerful users of Logo. They will collect, use and adapt resources and make them available to their students at times consistent with their level of development, style of learning and need. This is an approach which is equally effective and equally necessary with any other powerful tool we make available to our students.

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Open wide! Computers and communications

Ros Keep

Abstract

The world is getting smaller. It is no longer unusual to find children who have travelled around Australia, even overseas. Television and radio make it possible for our students to see and hear about other countries and other cultures, to see how they look, experience their atmosphere and follow the major events of the moment. Electronic communication can take that knowledge a step further. Not only can they use the extensive databases available on-line to keep in touch with current affairs and explore historical information, but also communicate with students from different backgrounds and cultures. By working together, they begin to see that they have a lot in common with their contemporaries around the world. Students the world over have the same interests, the same hopes, the same fears and the same over-riding goals. By providing opportunities for students to communicate with others, we can foster this collaboration and encourage the development of understanding among young people. Through the distance of electronic discussion, we can help young people to listen to other points of view, to consider them carefully before stating their own opinions in a non-aggressive way and then, most importantly, accept the differences.

This chapter describes how electronic communication can break down the walls of the classroom and broaden the horizons of the students. It goes on to explore some

of the practical implications of using communications technology and discuss future possibilities.

Letting the world into your classroom!

Imagine having access to three or more years of news reports, all on the table at the back of your classroom. Suppose you could contact other teachers all over the world from that same desk. And picture your students chatting with their peers in America, for example, or England.

All this is now possible through electronic communication, a simple link through the telephone system which enables your classroom computer to attach to another. The computer you link to may have a mail-box facility, conferencing software or hold extensive databases, such as the Australian Associated Press database. Alternatively, it might link to other computers, acting as a 'gateway', which offer such resources. Figure 1 illustrates how it works.

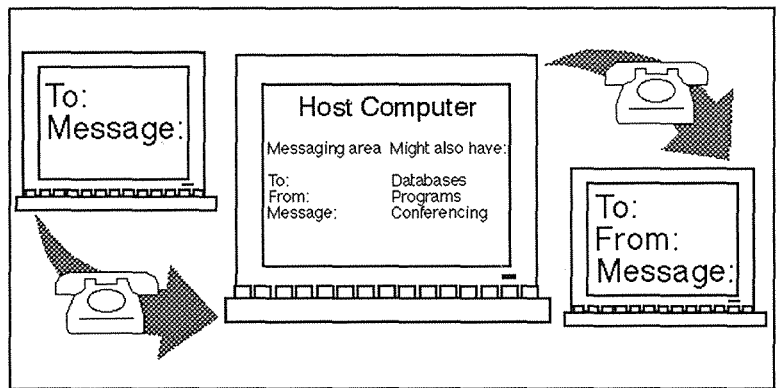


FIGURE 1. Electronic communication

Through your class computer, no matter what type it is, you can connect a modem (if required) and telephone, and link into another computer, the 'host', which may be just down the road or on the other side of the world. Once your computer is acting as a terminal to the other, you can access the software, databases and other

resources which the host machine offers. If the host has an electronic mail facility ('e-mail'), it will allow you to leave a message in an area designated by the computer for another user, that is their 'mail-box'. Your message will stay on the host machine until the addressee connects to the host ('logs on') and reads it.

If the host has a gateway connection, it may be that, quite invisibly to you, when you access some facilities it needs to make a telephone connection to a different computer so you can act as a terminal to that new host. When you finish with that facility, you are returned to your original host and the second connection is closed.

This describes one basic system of electronic communication, but there are variations on the theme, such as the 'collect and forward' e-mail service which actually connects to each individual who has incoming mail and delivers it onto her hard disk and at the same time collects any outgoing mail.

Opening doors

Let's explore now what this kind of technology can mean in schools.

On-line databases Most schools realise the importance of developing information skills in their students and so try to build up a comprehensive library. But much of the information required by students is of a contemporary nature: they want to know about Russia now, or what led up to a current conflict. Historic information and that which is given by books which are more than a couple of years old is useful, of course, but it needs to be complemented by more up-to-date information.

For the most up-to-date information, on-line databases are a must. Access to the Australian Associated Press (AAP) database, for example, provides the very latest news reports coming in from all over the world; that is the raw reports, straight from the journalists, rather than the modified and edited information which appears in the newspapers and news broadcasts.

Imagine what this can do! Quite apart from the excitement of having access to the news even before it has been broadcast on the radio, it also enables a unique study of the media. What information is different when it appears in the papers? How much is edited? How much has been 'pre-masticated' by the news providers, removing the necessity (or opportunity?) for the reader or listener to draw her own conclusions? How do the news providers decide which stories are most important? Encouraging children to create their own newspapers from the AAP reports offers a

wonderful opportunity for them to understand the processes of the news editors, as well as all those writing and design skills necessary to put together the paper.

The AAP is a prime example of the value of on-line databases, because it is a rapidly changing database which is not available in any other format. But there are other volatile databases such as stocks and shares information, currency exchange rates, flight information and bookings and many others. These resources change rapidly and so are expensive to maintain: they may therefore be expensive to access unless special education rates are provided.

There are also more 'static' databases which do not change rapidly, but are nevertheless useful resources. Their availability on-line means that a school does not have to purchase those sources of information which are only used occasionally. For example, information from the last census might be used by one teacher once a year: hardly worth purchasing the document, as it will be outdated in a few years anyway, and it can be more easily searched and manipulated on-line. There are also any number of bibliographic databases, where students can find further resources for study; some magazines make entire articles available in this way; there is the *Macquarie Dictionary*, to check those really elusive words which may not appear in the average classroom dictionary; and information about dangerous chemicals is also available on-line.

The ability to search the data held on-line is another important attribute. We are now coming to experience the disadvantage of having so much information available: information overload! The AAP database may have literally hundreds of entries each day, from the latest cricket scores to numerous reports on the same top story. It would be impossible to simply 'browse' through all these items. Most on-line databases, therefore, have a very sophisticated query language which enables the user to search for subjects, authors, dates — or run 'free text searches' which can examine every word in every article.

The databases mentioned so far are essentially commercial ones, provided by professional agencies and are 'read only'. There are, however, another range of databases which are generally known as 'bulletin boards', and these are much more flexible, often allowing the user to add her own information. For example, the 'Frogwatch' board¹ is created by schools across Australia entering details of their local frog population. As the information grows, it becomes more valuable. It is difficult to hypothesise about the frog population (and therefore the pollution levels)

1. This is one of the *OzProjects* available via Keylink and Nexus systems.

of Australia from only ten reports, but once there are a hundred or a thousand, the information becomes far more meaningful. The larger the amount of data available, the greater the opportunities for analysis of the data, looking for similarities and differences, making hypotheses and extrapolating information.

Another example of this comes from a project undertaken by ten primary schools in the UK.² Each school surveyed their local river, looking particularly at the living creatures they found. These acted as 'living indicators' to the pollution found in the water. Each school could take only a few readings, and only in the places closest to them. But by linking with other schools living on the same waterway, the children were able to build up a comprehensive view of the purity of the water and were, in fact, able to pinpoint the location where pollution had occurred. The children were proud to report this to the local Water Board and the culprits were later prosecuted.

Electronic mail and messaging Communication skills are at least as important as information handling skills, and electronic communication can be instrumental in developing these in a unique way. Through electronic mail, students have access to an authentic audience and one which is genuinely interested in the writer.

E-mail has been described as a hybrid of telephone call and letter: it is not so formal as a letter, but more succinct than a telephone call. It develops a language all of its own. With electronic mail, there are no 'clues' as to the person, no body gestures, no tone of voice. There are no preconceived ideas about the writer which are usually formed from physical appearance, age, gender and so on. Every bit of information comes from the writing: students soon realise the importance of choosing their words carefully in order to portray the right 'image'. They read incoming mail, and realise how easy it is to misinterpret the writer's meaning. And they will soon learn the 'language' of e-mail, how to use symbols to denote facial expressions or words to indicate humour [:-)].

The invisibility of the medium does more than just encourage more thoughtful writing. The author remains anonymous, except for the name given — which is not necessarily the real name. Their age, sex, colour and physical attributes are hidden unless the author decides to disclose them. So we can happily have a bright 10-year-old discussing the Bosnian crisis with a TEE student, or a 15-year-old chatting about fishing with an 11-year-old. Students with physical disabilities are no longer disadvantaged in conversation. In fact, many with speech problems, who use a computer anyway for communication, may find it easier to communicate elec-

2. Further details of this and other curriculum projects are given in Keep (1991).

tronically than in person. E-mail can therefore be used to explore a number of issues such as sexism, racism, ageism or discrimination towards handicapped people.

Because of this invisibility, the medium has great potential for role play and simulation. Role play in a classroom situation is no less valid, of course, but it is sometimes quite difficult for students to maintain a role play in which they can clearly see the characters are not what they are supposed to be. A simulated parent-child conflict, for example, may be easier to sustain on-line where the students are not put off by the fact that the 'parents' are actually younger than themselves!

One of the most exciting aspects of electronic communication is the ability for students to work collaboratively with others from different backgrounds and cultures. A message can be sent as quickly and easily to someone in a school down the road as on the other side of the world, and no matter what the reason for the communication, once the link is established, the sky is the limit! The students can compare lifestyles or views about topical issues. From such a link they can learn not only the differences between themselves and others but also the similarities. If ever there was a device to encourage international understanding, e-mail is it!

While the most interesting exchanges seem to come unbidden, there needs to be a reason for the first communication. In general, pen pals is not enough. In the same way that traditional pen-pal relationships fizzle out, so do electronic ones. They may fizzle more quickly, because communication is faster, or it may hold the students interest a little longer because of the speed or the use of the technology, but in the end the result is the same. However, if the students have a real need for the link, the social exchanges will tend to grow.

Using e-mail to collect information from others, be it empirical data or information on individual lifestyles or points of view, can be useful in every area of the curriculum. Young children can compare details of the kinds of birds they see in the school grounds; or collect information about the kinds of homes other children live in. Older students might conduct a survey into the dietary habits of students in different parts of Australia. More sophisticated students might link to debate a topical issue, simply sharing their views with others and 'listening' to alternative viewpoints.

Collaborative writing can also be exciting, whether students are developing a continuing story, with different schools contributing instalments, or working on a more complex scenario which requires the students to contribute ideas and text throughout the project. An example of this took place in the UK in 1988 when a group of

six schools worked with novelist Martin Booth in a fantasy scenario in which the professional writer took the role of an aging archaeologist, too old and infirm to travel, who advertised for groups of young people to travel the world, collecting artefacts for him. Each class became an expedition team, each member of that team was 'created' by three or four students, some of whom were only nine and ten years of age, projecting themselves into the minds of university graduates, doctors and budding explorers. In writing the story of their 'travels', the students had to link fact and fantasy to achieve a realistic tale. And if the students' writing wasn't vivid enough, Martin would write back to them with questions designed to send them scurrying back to the textbook to enliven their writing.

Open learning Real open learning means allowing the students to study what they want, when they want and to a level which is appropriate. This concept does not suit 'traditional' classrooms; students are supposed to study, say, English at nine o'clock on a Monday morning, then swap to mathematics at 10 o'clock. They study an area designated by the teacher, probably with the teacher leading the lesson. And when they have done what the teacher required of them, that's it.

Happily, things are changing, and primary schools particularly have adopted a more flexible approach. Project work is much more popular, allowing students to concentrate on a specific topic, often one of particular interest to them, and follow it to an appropriate level, with high achievers, for example, expected to do more and at a deeper level than others.

But the students have been hampered by lack of resources. The teacher may know little about the chosen topic; the school library perhaps has little information to offer. Even the local library — if there is one — might be lacking. So how can the students study their chosen area?

It is in this aspect that e-mail and on-line databases can excel. No information in the school library on Mabo? Then go on-line and do a 'chronology' search in AAP. This will pull up all the major events leading up to today and provide many pointers as to where to go for further information. Want to know what other young people think about the issue? Well, why not ask them through e-mail, or set up a bulletin board for more open discussion? Communicate with students all over Australia, those from rural backgrounds as well as 'townies'. Never before have students had such easy access to such a powerful research tool.

On another level, there has been a great deal of work in Australia with the idea of teaching through telematics (Elliott, 1990). Through telephone, fax and a computer link, students in one or more schools can work with the same teacher who may not

be based in any one of the schools. This means that students in remote or small schools, or schools where there are no teachers with a particular specialism, are no longer disadvantaged.

The telematics projects here in WA use Apple Macintosh computers running a specially developed package called the Electronic Classroom. The students link through a modem to a distant teacher (who may or may not have a class in front of her), and the computer is used like an electronic blackboard. Whatever the teacher writes or draws on the screen can be seen by the students, and, when the teacher passes command to a student, their additions to the screen are also seen by all. Alongside this is a telephone link, usually using a hands-free phone and a conference link, enabling a number of schools and the teacher to talk together. The fax machine is often used before, after, or at the same time as the lesson to exchange written work or graphics.

Practical considerations

There are a number of electronic information and mail services available in Australia (and beyond), although NEXUS is the most common here in WA. However, services change and it may be that more than one service is used, so the following information is generic rather than specific.

What you need Almost any computer is suitable for communications, but as information from the system will need to be 'down-loaded' into a word processor, it makes sense to use a compatible computer. There are three things you need:

- a modem to link the computer with the telephone system;
- access to a telephone socket;
- communications software for your chosen machine. Some integrated packages such as Microsoft Works and ClarisWorks have a communications component. Or there may be some suitable public domain (i.e. free of copyright and purchase costs) software.

Access The positioning of the communications workstation will vary from one school to another, but it is important to realise that this is a whole-school resource. Putting it in the computer room may be fine for those students studying the technical side of communications, but what happens when the English class need access, or a history group? One of the best locations for the system is probably the library.

It is equally important to have access to other computers to manipulate the information, files or messages which have been down-loaded. To keep on-line costs to the minimum, students need to be encouraged to do as much as possible off-line. So, when looking for information they prepare their query away from the computer, go on-line, run their search and save the results as they go, then log-off. The saved file can then be opened in a word processor where the extraneous and irrelevant information can be edited out and the text can be manipulated into the required format.

The same method applies to users of electronic mail. Students should down-load incoming messages if necessary, use a word processor to prepare their response and then go on-line to send it. Occasionally there is a need for an immediate response, or a very short reply which is best handled immediately, but for the most part, it is better to work off-line.

Classroom organisation There are almost as many strategies for using electronic communications in the classroom as there are users and most teachers try a number before they hit on the one that's right for their particular situation. Here are a few which have been used successfully:

- Introduce the whole class to e-mail with a demonstration, show them what is possible but don't go into detail. If they know what is possible, they can always find out how to do it later.
- Train a couple of students as 'experts' and allow them to train the others and to work with them while they are on-line.
- Have one small group go on-line each morning to down-load incoming messages and distribute them to the appropriate people.
- Some teachers have found the most practical way is to have a computer system at home and do all the on-line work after hours (when the system is cheaper to use).
- Have one of the staff allow half an hour a day to check incoming messages and send outgoing ones.
- Show the library staff how to use the system both for on-line searching and checking incoming mail.
- Co-opt a willing parent to help out whenever there is a need to send large amounts of data.

Planning a project

There are so many exciting projects which can happen using e-mail, and although we have seen many serendipitous 'asides', such projects always begin with planning. There is little point in your class deciding they want to write a joint novel, doing lots of preparation and then just expecting another school to leap in and take it on. Sometimes that can happen: but it is so disappointing when it doesn't.

Far better to have a plan. Work with a teacher in another school: it has been found that projects between friends have a greater chance of success than those between people who have never met. Discuss the project, decide on the desired outcomes both in terms of final product (if any) and the learning process. Set deadlines — and stick to them. Don't forget to give a reasonable period of time for getting used to the chosen system and finding a strategy that works.

If the project needs to be wider than two schools, perhaps a more general survey, try and get assurances of response from a number of other teachers. There is nothing worse than having the students prepare a beautiful questionnaire if they receive no response. And just in case no response is forthcoming, ensure that the on-line work is only a part of the project and there is plenty of other exciting work for the students.

When planning projects, don't forget that other teachers are planning too. Give as much notice of the project as possible, at least a Term. There are a number of factors which have been found to affect the success of on-line projects. A project needs:

- a reliable and enthusiastic 'coordinator' to drive the project;
- good relationships between teacher-partners, coordinator and supporters;
- the enthusiasm of the teachers for the project in hand;
- all participants to have easy access to the necessary equipment;
- support from senior staff in the school;
- time to plan, develop and evaluate the project;
- a carefully considered time-schedule to which participants adhere.

Cost

No matter what system is being used, there are a number of strategies which will keep costs to a minimum:

- Create a 'Search Request' form for the students to complete before they go anywhere near the computer. They need to know precisely what information they require, where they might find it, what key words might be appropriate, what query they will type in and have a back up of other key words in case the early ones don't have the desired result.
- Where possible, go on-line after 'business hours' (Melbourne business hours that is).
- The first time you log-on, and then when you log-on with your students, you will need to explore the system. Early calls will inevitably cost more than later calls.
- Some of the databases (e.g. AAP) make an additional charge for access to their data (because of the work involved in keeping them up-to-date). You will always be warned of this before you see the database.
- Try not to write anything but the shortest messages on-line. Use a word processor, then 'up-load' the text using the communications software or copy and paste from a word processor.
- If you do get involved with typing on-line (either when someone starts to 'chat' to you or because you need to get a quick response to someone immediately), then don't worry about typing mistakes! We all make them, and on-line people understand that time is money. It's much quicker to ignore them.
- Rather than printing while you are on-line, open a file before you start searching to 'capture' all data, both what is coming in and what you type. This file can then be accessed from a word processor and you can print what you need or transfer it to another file.
- Most systems allow you to keep track of costs. Make a note of these (or print them out) so you always know how much is being used.

Crystal Ball Gazing

While electronic communications services are not difficult to use now, there is no doubt they will get easier, more intuitive, more comprehensive and more invisible. Already we have computers that can be voice activated, incorporate speech output, link with video cameras and recorders and, of course, CD-ROM.

In a very short time there is no doubt that we will have a much more intuitive system. You will be able to sit at your desk and ask the computer — verbally — to find, say, all recent articles on the Australian rabbit population. You will be able to read

them from the screen — or have them read to you — edit them, by voice or keyboard, and then send the result, along with an accompanying note, to a school in England which has asked for that information.

The whole process will be seamless: you'll turn on the computer in the morning and see an 'in tray' which holds all new mail messages, perhaps from a number of different services, along with notification on new items which may be of interest. These messages can be read to you if they are text, with photographs of the sender if required and perhaps including video clips. Or maybe they will be audio or video clips of the sender. You will be able to reply to them verbally, if you choose, the computer taking dictation. Or you could activate the video or audio recorder and record a message. On request the computer will then add the electronic addresses to your messages, log-on to the appropriate system and send them.

This is not futuristic at all: this is now — at least all the technology is in place to do these things. We are simply waiting for the software which will pull all these aspects together in a seamless fashion, and prices to become more acceptable to schools.

But don't wait: the future has already started.

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Linking for learning: the evolution of communications technologies in Western Australian schools

Julie Bowden

Abstract

In contrast with educational developments in other countries, Australia has been slow to recognise the advantages of using communications technologies and in general has regarded the introduction of advanced technologies with some distrust. A system of open learning, however, has been introduced into the tertiary sector, largely through the medium of television and has provided additional education and training opportunities for thousands of rural students.

The growth of open learning systems in Australia has been characterised by educational institutions 'going it alone' in their endeavours to address the equity and social justice considerations associated with the education of isolated students. This has resulted in uneven patterns of development since the emergence of communications technologies in the 1980s. This development, accompanied by an incompatible mix of technologies, a deep concern for cost efficiency in an era of economic rationalism, and the relative shortage of research findings to illustrate the effectiveness of such systems, has militated against a national and comprehensive plan for all States.

The significant advantages afforded by the use of telecommunications have yet to be realised, despite the introduction of technologies such as telematics, which

allows a network of schools to be linked together audiographically with an expert teacher located at one school in the network. The future of telematics and other advanced technologies, such as interactive multimedia, electronic mail and video-conferencing, is only beginning to be mapped. However, collectively these technologies would appear to provide unique opportunities to address the far-reaching effects of dislocation experienced in many parts of rural Australia and help build an effective distance learning system. This chapter will examine the emergence and nature of such technologies as they are used to support teaching and learning.

Trends in educational uses of telecommunications

International trends Over the past decade, industry and government partnerships in many countries around the world have resulted in the promotion of communications technologies for education and curriculum delivery. For example, in the United Kingdom, government institutions such as the Manpower Services Commission have expended vast sums in developing and promoting materials for open learning education and training courses, and have been pro-active in sponsoring the transmission of satellite programs and courseware as part of their open learning initiative.

Driven by a similar economic imperative, the European Economic Community (EEC) has negotiated the sharing of institutional resources for open learning and training. This is in stark contrast to the level of support that has been provided in Australia, where a secure synergy between education and industry to sponsor partnerships designed to enhance the economic push for retraining is noticeably absent.

Corporate enterprises in North America have also become heavily involved in the development of flexible educational delivery systems through the sponsorship of pilot projects in universities, colleges and school districts. Private companies with competitive incentives have assisted in the development of telecommunications for distance learning.

The Canadian system of open learning, based around the extensive use of satellite delivery, has operated with a large degree of government control and support. The Open Learning Agency, and its subsidiary The Knowledge Network, coordinates a range of provincial open learning activities to a vast audience in excess of 21000 viewers.

Cost effectiveness appears to be the major determinant in decisions concerning the use of such technologies in developing countries where low-level interactive technologies such as teleconferencing and print-based materials are widely utilised. This also appears to be the guiding pattern in Australia.

The reconstruction movement in China has led to the development of a unique model using broadcast television and radio for mass education aimed mainly at the tertiary level. The Central Radio and TV University (CRTVU), together with twenty-eight Provincial and Autonomous Regional and Municipal Universities (PRTVUS), provides specific distance learning courses to hundreds of thousands of students, all taught by an experienced course instructor — usually a professor from the CRTVU. This model of distance education has been evaluated and, consistent with the findings from the British open learning systems, the per capita cost for distance education courses was found to be less than half that for students in regular higher educational institutions (Jianshu, 1990).

Australian trends During the 1980s, the growing level of interest in all Australian States in network technology (communications technology), which links classrooms, teachers and individual students to a range of external sources, has served to open up new avenues of learning. The use of technology for teaching and learning has provided a means of accessing information for those students who are disadvantaged by factors such as geographical isolation. It is only in recent years that the emergence of computer-mediated interactive learning has evolved even further in response to the need to provide greater access to the curriculum in a more interactive and collaborative manner.

Currently, all States in Australia are trialing a number of technological systems in an attempt to address the needs of rural and distance education students. The Open Learning Agency of Australia (OLAA), based on the Canadian model, is offering a wide range of tertiary courses using broadcast television as the primary mode of delivery. TAFE and school systems have become very creative in seeking solutions to match the needs of their learners. The introduction of facsimile machines, audioconferencing, audiographics, interactive multimedia, videoconferencing and television broadcasting has provided a mechanism for an interactive mode of teaching — one that can also address past inequities in the provision of access to education and training programs.

The physical size and vastness of Australia and the relatively small population concentrated around the east coast creates some problems of economies of scale for the delivery of education and training to remote areas. Access and equity for all potential clients has in recent years formed part of the Commonwealth and State training

agendas designed to meet the needs of a small number of Australians who, either by choice or necessity, live in extremely isolated conditions.

As early as 1973, the Karmel Report noted that there was significant evidence that students in rural schools were being disadvantaged. Again, the Australian Schools Commission in 1987, in a further report, suggested that such disparities were still being maintained despite the wide range of excellent rural projects that were being supported by the Country Areas Program. The Commission also commented that it was 'an urgent challenge for education authorities to provide full secondary education to students in rural and isolated areas, in a cooperative way with regard to the application of new technologies'. Current practices in Australia can be summarised as follows:

- the rapid growth of various technologies with most Australian institutions employing a mix of approaches;
- cost efficiency being the overriding concern in terms of accommodating highly interactive delivery systems, the need to provide special training for staff, and the development of interactive multimedia systems;
- the emerging nature of the distance education consumer and the drift towards urban living and open learning. The relative paucity of research on the efficiency of various distance delivery systems;
- the lack of valid and reliable resources to support the technological delivery of education.

Western Australian trends A recent report by the Department of Employment, Education and Training (Higher Education Series, Report No. 8, September, 1990), has highlighted Western Australia's special educational problems associated with distance learning. The participation rate for students in remote areas is the lowest in the Commonwealth with the retention rate to Year 12 being only 9.2% in comparison to the metropolitan retention rate of 63.7%.

This has been exacerbated by the perceived rural decline over the past few years and has resulted in a steady relocation of people from the country to city regions. The Kimberley Regional Plan (1986, p. 28), in seeking solutions to this problem, identified the following issues as being significant for education and training:

- the need for equitable access to preprimary, primary and secondary education;
- the lack of relevant, technical educational opportunities;
- the restricted choice of educational offerings.

Grant (1991, p. 4) has also pointed out that Western Australia appears to be lagging behind the other States in terms of addressing low participation rates in rural areas through the use of new communication technologies. This may be due in part to the decentralisation of the Western Australian education system since 1988, which has militated against wide-scale initiatives. This is also in spite of the State government's declaration in a submission to the Review of the Education and Training Needs of Rural Australians (1990, p. 3), that:

Telecommunications could be used to extend the availability of scarce teaching resources throughout the State and to increase the range of courses available to students in small rural communities.

The advantages of telecommunications

The economic and social imperatives associated with rural living are slowly being addressed by rapid developments in communications technologies. It is only in recent years that the emergence of computer-mediated interactive learning has evolved in response to the need to provide greater access to the curriculum, particularly for isolated students. The use of technology for the delivery of lessons and to facilitate access to a range of external information sources, has been enhanced by an empowering effect that generates the capacity in individual learners to take control of their own learning. Alternative delivery systems for education have been in use for many years (e.g. correspondence courses, television programs), but it is due to the more recent advances in information technology that the powerful computer-based systems can now transform learning.

The educational advantages of using communications technologies for learning can be summarised as follows:

- 'real-time' teaching and lesson delivery;
- support for students studying by correspondence;
- access to specialised curriculum;
- curriculum enrichment;
- development of collaborative teaching networks;
- access to professional development;
- provision of support services to students.

Universal access to computers, information technology and advanced multimedia systems is now such an important element that the Commonwealth government has

recently initiated a ten million dollar program to trial the use of technology to address post-compulsory retention rates in rural districts. The integration of technologies to assist teaching and learning is being seen as a significant step in addressing curriculum, resourcing and management issues not only for distance education purposes, but also in regard to the formalisation of district networks, school restructuring and school rationalisation.

With the introduction of telecommunications to schools in Western Australia, there have been some clearly identifiable problems. The lack of funding for both the establishment of the equipment and for the recurrent costs associated with a program that is embedded in a local school setting is a major impediment to its success. Likewise, the need for staff training, technological and curriculum support, and a commitment towards developing and improving instructional design skills for teachers, has had an impact on the growth of such systems.

Telecommunications in Western Australia

Esperance has been the first district to trial telematics, a technology that uses an extended classroom linking the teacher to between one and five school sites simultaneously. Telematics is an extension of audio conferencing and uses conventional telephone lines and computers to connect the teacher and the students with two-way voice and graphic communications. Telematics communications in an educational setting are analogous to face-to-face classroom interactions in which whiteboard presentations, visual aids and immediate feedback are salient features.

Groups of schools in the district have formed local networks to share their expert teachers and to enable students to access curriculum areas that would otherwise be unavailable (e.g. Languages Other Than English (LOTE) and a range of post-compulsory schooling programs). For the past two and a half years all schools in this district have cooperated in a trial using the Telematics equipment for curriculum delivery and professional development purposes.

Over the last two years, substantial additional input has also come from the Commonwealth-sponsored Priority Country Areas Program (National Element). This project aims to address national retention rates in rural areas by the use of interactive communications technologies. With this funding, Western Australia has established an outstanding record for developing the infrastructure to support groups of rural schools in delivering curriculum to meet the specific and identifiable needs of their students. Telematics has been introduced to sixty schools in regional Western

Australia, and the staff trained to deliver courses such as mathematics, computing, and LOTE to secondary students. This mode of delivery has been the outcome of collective planning between clusters of schools who have coordinated their timetables, bell times and even school development days in order to accommodate the telematics program.

The following outlines the major communications developments in Western Australia achieved by 1993–94.

Teleconferencing

Earlier teleconferencing trials consisted of ‘hands free phones’ to provide an interactive audio link. This has been enhanced by schools choosing to install facsimile machines primarily for administrative purposes. Other forms of audio technology to have been trialed over the last six years have included the use of low cost teleconferencing systems for students in district high schools wishing to access language classes offered by the Distance Education Centre in Perth.

Telematics

By the end of 1993, a large number of school districts will have implemented telematics programs. Approximately one hundred sites will have been established (12% of all schools in WA) in many rural areas. The Macintosh platform allows universal connectivity, not only with members of local school networks, but also with other State and interstate clusters. Below is an indication of the widespread use of telematics by school districts in Western Australia:

- Esperance
- Kalgoorlie
- Bunbury (North and South)
- Narrogin
- Merredin
- Moora
- Geraldton (North and South)
- Karratha
- Hedland
- Kimberley

Aspects of this program have subsequently been taken up by other districts and projects both internal and external to the Education Department. As the concepts and the principles are embedded in addressing the needs of the geographically disadvantaged, this program forms part of the strategic plan currently being developed by the Social Justice Branch of the Education Department in Western Australia.

Interactive multimedia

Interactive multimedia developments have likewise been emerging with initiatives associated with such programs as post-compulsory schooling, Aboriginal health, distance education provisions, languages (LOTE), and the movement towards open learning in Western Australian schools. Such a methodological shift requires the appropriate technologies to support learning. The development of the software is an ongoing, albeit slow process that often is subject to a content revision even before the program is completed.

Templot

An Education Department initiative, this has been developed to enable language teachers to utilise their own lesson content for the speaking and listening aspects of any given language. The notion of an empty framework that will accommodate up to twelve different languages, contain a number of video or semi-animated digitised models and record a student's progress through the program, is currently being trialed in Western Australian schools.

Electronic mail

Electronic mail has been used in several country schools and districts using dedicated digital data lines that connect schools to the Central Office mainframe system (Netmail). One innovative use of electronic mail has been introduced by the Carnarvon School of the Air. Daily air lessons are being supplemented by lesson notes, materials and homework that are posted electronically as hypercard stacks, using a software package known as Telefinder. Students receive and complete their work sets, which are sent via electronic mail to be assessed by the teacher. The process is completed with the return of the marked sets to the student within two days, thus minimising the six-week delays normally associated with postal returns.

Television broadcasting

The delivery of quality television broadcast programs throughout regional Western Australia has been ongoing for many years, through the Ed-TV Consortium, which has a negotiated agreement with the Golden West Network to schedule nine hours of educational programs per week. Such programs have a direct curriculum application, and reach a large, receptive audience of students and the general public. Of broadcast standard, programs such as the DEC Live Science Program have been instrumental in bringing curriculum material to regional Western Australia in an entertaining and professional format. Such programs are also characterised by an audio feedback loop that enables viewers to dial in and ask a question from the presenters who are teachers from the Distance Education Centre in Perth.

Videoconferencing

A number of videoconferencing initiatives has resulted in a range of short term teaching programs. The Live-Net Satellite trial was followed by a Telecom-sponsored program known as Westlink, and resulted in a lively market for the introduction of interactive programs to support learning in regional schools, TAFE centres and for a small number of tertiary courses. It has also been possible to provide a series of tertiary entrance examination revision seminars for students living in isolated areas. In 1992 and 1994, English, mathematics, physics, chemistry, accounting and human biology seminars were delivered by satellite to a large number of country centres.

Conclusion

The evolution of technologies for distance learning has yet to be institutionalised in the form of system-wide practices and through appropriate funding allocations. However, there is sufficient impetus from within schools and at most levels in education and across government to indicate that it is more than a passing fad. Given the need to address social and economic inequities in future years, the need to restructure education to ensure better outcomes and the need to provide a more responsive curriculum for the post-compulsory sector, there is sufficient evidence that communications technologies will feature in planning for schools for the next decade.

Clearly there is a place for alternative delivery systems in the future. Both State and Commonwealth governments are unwilling to fund substantial physical facilities in

smaller communities, and educational planners are now considering a more diverse approach. The paucity of research as to the effectiveness of telecommunications to address the needs of rural and remote students in fostering and encouraging access and participation in education and training is due perhaps to its relatively new entry on the educational scene.

Access to an enhanced curriculum and research materials for isolated students can only be possible through the addition of technologically planned instruction. Open learning will play a role in promoting individualised courses for isolated students, providing a greater degree of interactivity through electronic delivery mechanisms.

The notion of senior campuses and multi-campus arrangements that facilitate a broad range of alternative subjects and courses has yet to be established. Plans are underway, in both the government and non-government sectors, to build such institutions with advanced communications technologies to expand the capacity of schools to either develop specific subject networks or to provide courses within a local cluster arrangement.

Opportunities to develop and share a comprehensive curriculum will be possible through new developments in the videoconferencing and television industries. Low-cost, computer-based and computer-managed systems, together with the growth of the integrated serviced digital network, and an expanded use of the mobile net system for rural and remote communications, will revolutionise the teaching and learning process in the next few years. Western Australia more than any other State has much to gain from these developments. However, above all, the technology must not be seen as an end in itself — rather, more in terms of its subservient relationship to the systematic planning, thinking and delivery of services that are intended to produce outcomes of value.

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Telematics and language acquisition

David Elder

Abstract

Telematics is a term used to describe real-time electronic communications, provided for by a combination of standard technologies such as the telephone system, together with more recent computer technologies. Telematics is now one of the most fascinating new technologies for interactive language learning both in the classroom and at home. School children in France have access to thousands of services using telematics. At home, they can consult an electronic French dictionary and grammar database and conduct research into a variety of themes. At school, they can borrow books for class projects from the C.R.D.P. (the Regional Centre for Pedagogical Documentation), or exchange ideas on a given subject with students from another part of Europe using the Minitel, an electronic mail system. Students of Italian in France, for example, have already exchanged ideas on joint study projects with students of French in Italy, using Minitel. This chapter takes a look at the use of the Minitel and offers suggestions for its application in the context of the LOTE (languages other than English) classroom.

Minitel services for the classroom

The advantage of the Minitel is that the many services it offers can be adapted for activities at a variety of levels for language work. There are also obvious applications for other subject areas including geography, biology, law etc.

The AFP (*Agence France Presse*) news items provide students with highly topical material for work on comprehension, contemporary French society, grammar, politics, science etc., at a reasonably advanced level of language proficiency. Classes can also use this service to develop material for a weekly school news bulletin in French or in English on the latest scientific, political or social events in France or in the world. Pertinent translation work with students using the AFP service can also lead to an increased awareness of the world around them and reinforce basic linguistic skills.

The SV (*Santé Vacances*) service offers valuable information about vaccinations for travel abroad as well as some interesting facts about the geography, the population and the climate of the country the Minitel user may wish to study. The Orthotel database contains a complete dictionary and grammar search program which provides students with information about the meanings and uses of words in context. The Distal database is a medical encyclopedia with information about the symptoms and the treatment of various diseases and ailments. The Distal encyclopedia service has great research value for students of biology and languages. The SPA (*Société protectrice des animaux*) service gives students access to practical information about their pets and how best to look after them. This has obvious motivational value at quite a number of levels of learning.

The Minitel electronic mail service has made it possible for Australian students to dialogue with students in schools in France. The electronic mail box should be opened and the mail read at a prearranged time to limit costs and fruitless searches. Joint projects can be negotiated and developed with French schools on a variety of themes such as changing policies for the protection of the environment, human rights, leisure activities, adolescent life styles etc.

There are, in fact, many services that can be used at various levels for comprehension and grammar activities as well as general research. University students can use the Sunk service to complete a detailed thematic search on theses that have been registered or completed in their area of study. Thesis abstracts in English or in French can also be obtained. Far too many students in the English-speaking world are not aware of the research in France that has been completed in their area. Edith

Cowan University is, as far as we know, the first tertiary institution in Australia to make this service available on a regular basis to all its postgraduate students.

Using the Minitel

First and foremost, the use of the Minitel must serve the students. New technologies must meet predetermined educational objectives and reinforce the dynamics of the class. In most cases, short sequences and searches with appropriate worksheets lead to greater motivation and more successful, observable outcomes. The technical quality of the services consulted is important. Not all Minitel services provide texts in French of sufficiently high quality. There are also Minitel documents that contain grammatical and typing errors. The latter should only be used moderately in activities such as 'Spot the error(s)'. The role of error analysis here is simply to help students to become aware of the fact that they are capable of correcting certain 'authentic' texts with or without the use of a dictionary. But although errors are normal, natural and desirable during the learning process, a prolonged observation of grammar mistakes in any given text may lead students to focus heavily on the incorrect form. Language teachers, in particular, know very well that the 'process of unlearning' is much more time consuming than the acquisition of the correct form in the first place.

The authentic document

For some time now teachers have been fascinated — and swamped — by authentic audiovisual documents. However, the simple fact that an audiovisual document is 'authentic' does not automatically qualify it for use in class. In France, for example, authentic documents have tended to be used only for exhaustive and detailed study. This can be counterproductive. It is essential that the time allocated to the analysis of a Minitel document and the depth of the research involved depends on the motivational value, the pertinence and the relevance of the work for the course objectives.

'En direct'

Most teachers who have used texts 'en direct' have noticed that a feeling of equality develops between them and the students. In addition to this, their role as mediator increases as they can at times be replaced by particularly well-informed members of the group. However, in spite of these advantages, only a few texts should be studied 'en direct' by any given class. The most important reason is the

expense — a factor not to be considered lightly, especially when criteria for cost effectiveness are used more and more today to assess material and methods for learning. It is also difficult for most teachers to prepare high quality classroom comprehension activities when a text is viewed 'en direct'. Although news items, for example, are motivating when they are fresh, they can be down-loaded to reduce costs and even made available in print-out form to facilitate a more detailed type of analysis. The news from France can become an integral part of a weekly school bulletin and be used by teams of teachers within the framework of their interdisciplinary objectives. Teachers of English, science (including computer science, biology and physics), history and geography as well as French can easily find a series of interrelated, motivating and relevant objectives to study using the Minitel. It is important that the Minitel should not be thought of as purely an instrument for French classroom activities.

A balanced foreign language classroom

For some time now, audio and audiovisual techniques and technologies have tended to be used to the detriment of written work in the foreign language classroom. The Minitel allows teachers to use one of the latest technologies to ensure that the written text now plays a more balanced role in the communication, cultural and linguistic activities of the LOTE classroom. Certain rules, however, need to be followed to maintain the quality of the written text when using the Minitel. LOTE students should be able to polish their message in small groups before sending it via electronic mail to a French school. Other groups could work on the decoding of incoming messages. This approach has significant financial and pedagogical advantages.

Activities

LOTE activities to be used with the Minitel can probably be divided into three categories:

- Comprehension:
question-answer;
fill in the gaps;
multiple choice questions;
true or false statements.
- Expression:

reconstructing sentences;
expressing a personal point of view on a subject.

- Logic:
chronology;
causes;
technological procedures.

Minitel and technology Our aim should not be to encourage students of LOTE to memorise all the specific commands and procedures for logging into Paris! It is more important for them to clearly understand some of the basic principles that govern the use of telecommunications than to recite a checklist of operations that apply to a specific system or single piece of software. Indeed, instructions, disks and structured activities can all be prepared for students before coming to use the Minitel system. Also, teachers who work as a team find the Minitel much easier to integrate in their classes. For this reason, we have established at Edith Cowan University, a database for teachers who wish to exchange ideas in this area.

The Minitel connection – how to get hooked

All one needs to access the Minitel is:

- modem;
- computer;
- telephone line;
- compatible French communications software (e.g. *MacTell*; *LCE Com 3.04 VF*);
- an account with MinitelNet in France and an access number;
- an account with Austpac in Australia and an International User Identifier.

Access to Minitel provides, for example, the following information services:

- SNCF (the French Railways);
- AF (Air France);
- AFP (the French Press Agency).

Information technology and flexible learning in the primary school

Bob Hart

Abstract

Information technology (IT) can be a powerful medium for learning for children in primary schools. However, like other classroom resources and tools, IT has a potential that individual teachers and children need to realise. There are guidelines for using IT well — and they are the same guidelines for doing anything well in the primary classroom: learning experiences need to be meaningful, relevant and holistic. However, those teachers who are new to teaching as well as those who have considerable teaching experience, may find the prospect of using computer technology in their teaching foreboding. In this context, teachers need support, encouragement and training to be successful with IT. In the final instance, teachers themselves need to be clear about their children's needs, about curriculum aims and how IT can help extend learning for children in all spheres of classroom activity.

How can information technology be used to support good primary practice?

Information technology (IT) provides some powerful tools for learning which can stimulate children's creativity and productivity and lead to achievements never before possible in the known history of this planet. But like any resources they can also be used superficially or inappropriately. Successful use of IT is not just dependent on the selection of the right software and hardware or on the level of technical capability of teacher or pupil. More important is the context in which teachers and children use these resources.

IT is best exploited within a flexible learning environment. In fact IT can be an effective catalyst to stimulate, enhance and support such learning. Flexible learning, whether it is considered in relation to adults or to primary school children, can be described in a similar way. A flexible learning environment gives children (all children) access to learning. It encourages them to learn in their own chosen location (reading corner, art and craft corner, inside or outside the classroom, at home or in the community). It allows children to have reasonable control of their time, so they can do their work in the order they find most natural, at the most appropriate time and at their own pace. By careful observation and by direct questioning, the teacher can find out what the children want to learn and need to learn and negotiate a work program with them, giving appropriate support in terms of teaching style (coaching, tutorials, learning together) and by providing appropriate resources. IT includes some of those resources.

The most successful teaching and learning with IT happens in environments where teachers carry out the following process:

1. Make careful assessment of children's needs and interests.
2. Clearly define the curriculum aims.
3. Match the children's needs to curriculum aims.
4. Provide a fertile learning environment.
5. Produce educationally rich classroom activities.
6. Give support for active and flexible learning.

If these conditions have been met, carefully selected IT tools (computers, printers, scanners, modems, video cameras, still digital cameras) and other resources can greatly enhance children's learning. Mrs. Brightwell's class in Sunnyside School will illustrate these points:

The Sunnyside laundry project

Next door to Sunnyside Primary School is 'The Laundry' — a patch of wasteland which belongs to the City Council. It used to house a small laundry, hence the strange name, but this was demolished long ago. It is now used as a dump and is attracting vandalism. The council has invited the community to suggest how they would like to use the land.

Sunnyside is a busy urban area with very little play space, so Mrs. Brightwell's class of 8- to 10-year-olds have enthusiastically grabbed the opportunity and are busy designing a new adventure playground.

Sarah, Ramin and Dean are the survey team. They have just returned from the proposed play space with a few more detailed measurements for their site plan. They have drawn it carefully to scale and have scanned it into the computer. Today they are adding the positions of the surviving water pipes and foul drains.

The landscape design group has already used the plan to test out a variety of designs, showing positions of the club house, grassy bank, the wild nature conservation garden, the build-your-own-den area, the climbing area and practical things such as paths and fencing. These designs will later be displayed in the local library and visitors will be asked to vote on the most appropriate design.

The community group designed a questionnaire which it distributed by hand to every house in Sunnyside, asking what they would like to see in the playground. The group was particularly interested in what the elder neighbours would think. Now the replies have been collected and Wing Su, Derek and Kate are entering the final information into their database. They have been analysing the results and have advised the design group on what the community needed. When they have all the responses they plan to write a report to publish to the whole community.

Mrs. Brightwell had asked the children about the games they usually play in the playground. She was not surprised to find among the latest TV hero games quite a few that she played as a girl. Wayne and Susan were interested to know which games have survived and why. They have been out to the old peoples' home with their tape recorder and laptop computer and collected quite a few playground games and skipping rhymes. Now they are finding out how skipping games vary around the world. They wrote a letter on the word processor describing some of their games and asking their friends around the world what they played. They prepared an electronic mail package containing some drawings and photographs to illustrate their games and some sound files, so their friends could hear their rhymes

as well as read them. They posted the package on their global computer network to over 180 schools in 25 countries. Now the replies have started coming in and they have found some fascinating similarities and differences. They are just sending a response to thank Marit and Anders who live on a tiny island in North Norway.

Peter and Sue are in charge of costings. They have been putting all the work out to tender from local firms and have just received some estimates for fencing the play space. They have updated their spreadsheet (they call it the 'Laundry Bill') which shows detailed estimates for the whole operation, including supplying services, play equipment, landscaping and building the club house. They have passed the new estimates over to the sponsoring group.

John, Bethan and Tracey are writing letters to businesses in the city, explaining what the project is about and asking for sponsorship. They plan to hold a meeting of potential sponsors where the whole class will make a presentation using their multi-media software. They will be able to show video images of the play area as it is now followed by a sequence of possible designs. They have also videos and audio sequences of interviews with residents and some 3-D graphs showing the results of the community survey. The class is also writing a short musical drama for the presentation evening called *Nowhere to play*. Alan, Claire and Simon have written computer and synthesizer parts to accompany the class percussion band. After improvising for some time, the 'final' version of the script has now been word processed. There will not be a dry eye in the house...

Supporting the curriculum

The Sunnyside example illustrates how some of the best aspects of primary practice and flexible learning are being supported by the sensitive use of IT and provides a model against which any classroom activity, with or without computers, can be compared.

Firsthand experience The children were working on tasks that were not just relevant, but vitally important to their lives. These were real tasks, not just exercises. They are the kinds of tasks that adults do — surveying the site, drawing maps for the landscape team, researching suitable hardy plants or painting an 'artist's impression' of the finished site for a billboard.

Writing with purpose The children were writing in a variety of formats and styles and with real purpose — tenders to invite quotes for work, proposals to request

sponsorship, newsletters to publicise their project, questionnaires to collect information and letters to thank contributors.

They were communicating with a variety of real audiences. They were passing information to other children who really needed it in order to carry out their own tasks. Their questionnaires and newsletters went into the local community, their designs to the library, their requests for sponsorship to local businesses and their investigations of playground games involved children and teachers around the world.

Investigation They were carrying out investigations into the needs and opinions of the community, the safety of play surfaces, the costs of building, the optimum construction techniques for climbing frames...

Modelling They were making models, both conceptual and physical, testing them and refining them — the spreadsheet of development costs and the landscape designs which were being constantly updated. They also made physical models of the climbing frames using a variety of materials and structural shapes and tested their strength.

Holistic approach The teacher was interested in the whole child, not just as a learner, but as a person in a family, in an urban environment, in a community, in the world. The children were being given responsibility for tasks of adult proportions, and responsibility for themselves and their play needs and for the community at large.

Involving parents Their work involved their parents and grandparents — not just in the supervision of homework, but in a significant and meaningful way. Their opinions on the playground development were seriously canvassed and considered. They were asked to recall playground games from their own childhood. They were involved in designing the community questionnaire. Some were involved in the classroom, not on tasks like mixing the paints, but as partners in some of the children's investigations. The link between home and school had been further strengthened on a technical level by the parents helping the school buy the software and cables necessary so that children could easily transfer computer work between home and school computers.

Encouraging enquiry, local and global The children were encouraged to follow their own curiosity, supported carefully by a learning structure that ensured their success. A group was doing experiments on the safety of play surfaces by dropping fresh hens' eggs from various heights on to different surfaces. Members got talking

about children's head injuries and were encouraged by their teacher to contact local hospitals to find out the frequency and causes of head injuries. When they found that bicycle accidents were the most common cause, they contacted the Road Safety Department to find out about the cycle helmets scheme and invited the Road Safety Officer to talk to parents and children at their open evening. One thing led to another. During that evening the Officer mentioned that the United Kingdom has a very bad record for road accidents to children compared with other European countries. The next day the children sent a survey on child road accidents to their global computer network friends around the world. In this way they were able to appreciate and investigate an issue at a local level, a national level and a global level.

Autonomy and negotiation Children were encouraged to negotiate the content of their investigations, following their own enquiries and supported by the teacher, so long as they were productive. They were given the maximum level of autonomy that they were able to handle, making as many choices as they had the ability to make. This varied from child to child and from activity to activity and required the teacher to have an intimate understanding of each child's capability and just how much freedom to allow.

Responsibility for learning The children at Sunnyside could tell any visitor what they were learning from any task. Children are much more motivated if they are quite clear as to what they are learning and why they are learning it. While most primary children are quite happy to perform tasks just to please the teacher or their parents, they learn better when the teacher has explained exactly what can be learned and the benefits to the child. If the teacher cannot explain the benefits, perhaps the task is inappropriate.

While Mrs. Brightwell had clear curriculum aims and a comprehensive structure to which she could refer, she did not try to orchestrate all of the children's work by inching them a level at a time through attainment targets. She allowed the task to dictate the level of learning.

Allowing for surprise When children are motivated they will often perform at a conceptual and skill level far beyond that many teachers expect. The use of IT has clearly demonstrated this over the past few years. There was a time when teachers were concerned that young children would not be able to cope with a keyboard of upper case letters, but they did cope and it is not unusual to find that pupils are more competent with computers than their teachers. Children engaged in computer adventure games will often read at a higher level than they demonstrate with their class reading books. In playing adventures and some other computer-focused activities, children can also demonstrate a kind of 'street-wise' cleverness that is not

elicited by learning activities in which they have less control or commitment. Children using computers often surprise their teachers with their capabilities. Teachers must get used to being surprised by children.

Individual needs This teacher was also sensitive to the needs of all of her children. Most of the groups are of mixed gender and both girls and boys took active leadership roles with equal access to, and appreciation of, the technology. The tasks described allowed for mixed ability grouping and for vertical age grouping. There was also room for children with special needs, who could work at their own tasks at their own pace, able to produce professional looking results and make a significant contribution to the whole project. Children were allowed, on this occasion, to specialise if they wished and make a contribution from their own areas of competence.

For some of the children in Sunnyside, English is a second language, but they are able to use computers to communicate in their own mother tongue — Bengali, for example. This helps to celebrate their own language and to validate their culture and personal identity.

Collaboration The Laundry project encouraged collaboration and cooperation, not because the teacher exhorted the children to work together, but because, in the intrinsic nature of the working structures, the children actually relied on each other. This approach, which is encouraged by many IT-related tasks, is, in microcosm, the approach of adults, who rarely work alone. Most adults work in teams on shared tasks with contributions from people with the appropriate skills and experience.

Creativity This project allowed a great deal of space for children to be creative, not just in music, art, design and drama but in their approaches to problems and their solutions. The use of the computer as a design tool allowed the children to have many attempts, testing ideas and refining them until they reached a solution that worked. Sunnyside's site mapping group, for example, was able to scan its hand-drawn plan into the computer and then automatically trace this plan in an object-related graphics package. Subsequently, this allowed the children to alter and refine the plan as they wished.

Flexible time In primary schools there is the opportunity to allow a great deal of flexibility to children and sensitive use of IT can help. Using computers, children can continue with a task until they are ready for a break, save the work in progress and come back to it later, stopping when it is finished rather than when the bell goes.

Cross curriculum Primary schools are also in a position to allow children to pursue skills, knowledge and understanding without constraining them within the arbitrary boundaries of 'subjects'. Increasingly as IT evolves it encourages an integrated or cross-curricular approach. Multimedia, for example allows children to explore an enquiry by wandering among moving images, still images, text, music, sounds, databases and spreadsheets; in fact a wide variety of media which need have no subject boundaries. An enquiry might lead a child to follow strands that are one moment historical, the next geographical, mathematical, sociological, scientific and/or aesthetic.

Feedback Another aspect of good practice that most educators recognise is the use of feedback, which can be a great motivator if it is appropriate, speedy and mostly positive. Most of the IT-related tasks mentioned above provide instant feedback. Every action, on keyboard or mouse, gave an immediate response on screen, or in the movement of the robot. If its effect is unexpected, the child can usually see it straight away and either correct it, or follow the accident down a new path of enquiry. In projects like the Laundry project, where children's work is communicated to the community and has real consequences, the feedback is in the result of the work and is worth far more than a teacher's tick or grade.

There was a great deal more going on at Sunnyside. This was just a little peek into Mrs. Brightwell's classroom. But it serves to show how the use of information technology can be intimately woven into the learning activities of children in such a way that it becomes a tool to enhance the curriculum and children's powers to investigate and communicate and increases their creativity and productivity.

Extending the curriculum

The use of information technology (which does not just include computers but a whole range of technologies such as video cameras and audio tape recorders and synthesisers) not only enhances the curriculum, but has, over the last ten years, significantly changed the curriculum and introduced whole new areas of study. Teachers need to be aware of the changing nature of the curriculum, to accept and support those changes to open up the full benefits of IT to their children.

Communication

IT has changed the very nature of the writing process. Writing used to be a one-way sequential process. Correcting a story written by hand for an eight-year-old is a long, sometimes painful process involving lots of red ink, crossings out and the tedious copying out in 'best' writing. When correction is so time consuming, refinement is almost a punishment, but with word processors, children can correct mistakes easily. They can, for example, make the names of their characters more appropriate to the content and style of the story by a simple 'search and replace' operation. They can reorganise their work by cutting sections from one place and pasting them elsewhere. They can adapt their work for different audiences, adjusting the level and tone of language to suit the reader. There is no such thing as 'finished' anymore — every piece of writing can be saved for future refinement and re-use. This is a fundamental change in the process of writing.

IT has even introduced new reading and writing forms to primary children which could not have existed before computers. Poetry can be written in colour on a screen and then animated. Words can be spoken aloud by the computer as they are typed in. Conversely, the computer can write words on the screen as they are spoken by the child. This is a fundamental change in the nature of reading and writing, which are no longer separate activities. The education community has yet to exploit this significant development.

Collaborative writing was difficult to achieve when it meant inky crossing out and ugly insertions. John was likely to reject Ramin's new idea if it meant copying out their work again. Word processing makes true collaboration possible. Three children can compose together around one computer, or they can play 'consequences' with a story started by one author and refined and continued by another.

The computer adventure generator presents a totally new form of writing whose closest relation is improvised drama. In a computer adventure, the characters, scenes and events that children describe can take on their own life and interact with the child and each other to generate millions of possible story outcomes. The child could become a knight at the court of King Arthur and interact with Merlin or Lady Guinevere. These characters will respond according to the relationship they have with the character taken on by the child and they will all enjoy or suffer the consequence of their actions. We now take it for granted that children can create such a dynamic micro-world by the act of typing words on a keyboard. Most forms of writing, including drama, are thousands of years old. Teachers know them and understand them. This new form of writing has only come into existence in the past 20 years and has been available to children for perhaps eight years.

Information technology has changed our relationships with all communications media. The printed word used to belong to adults. They were the people with the typewriters and printing presses, children only received the printed word and read the books, newspapers, magazines and comics the adults wrote. While most of their years of education were spent learning how to read and interpret the mass printed word, children had no way of making a contribution or using the medium to express and broadcast their own thoughts. Children's ideas were delegated to chalk on slate or lines of ink or graphite which were shut away in exercise books in desks, or, if they were lucky, displayed on a classroom wall for other children to read.

Then children gained access to typewriters and photocopiers and later to word processors. They can now use desktop publishing packages to publish their own newspapers, comics and magazines, to give their own interpretation to events, to distribute their own ideas, stories and poetry. They can send them around the world on electronic mail networks and they can print them on laser printers to a quality almost indistinguishable from typeset text.

Children are no longer just passive receivers of broadcast television. They can use video cameras and audio tape to make their own television or radio presentations and multimedia systems to manipulate the images in a way undreamed of ten years ago.

Creativity

Musical composition, notation and performance have been closely linked and complex processes, which were available to some children but by no means all. Musical composition is now a different process. With synthesiser keyboards or with desktop computers, children can now enter sounds one at a time, arrange them into any order, edit them, add to them, refine them and play them back in sequence in any key. Those sounds can be chosen from an impressive preprogrammed collection of near-perfect orchestral instruments or effects, or they can be customised by the child. Perhaps the most liberating dimension of computer music composition is that the child can make corrections until the piece is perfect and then the technology will play back a perfect performance every time at any speed. This means that children do not have to have the extensive skills of the violinist or the manual dexterity of the guitarist to make excellent music. Music has been democratised and made available to all children, if they have access to the technology.

Investigation

Mathematics is not what it used to be since IT has given children access to tools that allow them to follow investigations which even adults in university laboratories would have found challenging twenty years ago. They can use spreadsheets and function machines to construct mathematical models and test out sophisticated hypotheses with instant results. In the example of the playground project above, the children had a spreadsheet of the costs of building the club house. They could investigate the effect of using different bricks by entering values for the various prices and seeing instantly the consequences for the total cost of the building.

Simple graphics software now allows children to investigate the properties of polygons; for example, the relationship between the number of sides and the internal angles. With Logo they can write a simple procedure so that when they enter the length of a line, the angle through which it turns and the number of repeats, they instantly generate complex stellar or polygonal patterns. Other software allows them to investigate the tessellation properties of shapes. All of this could be done with pencil and ruler, but would have taken weeks of painstaking work. Now it can be done at great speed, which means children can easily follow investigations at a much higher level than ever before possible.

The nature of the science curriculum has been changed by information technology which has enabled children to see the unseeable (through slow motion and time lapse photography for example); to measure the immeasurable (using data capturing probes to measure changes in temperature, light, humidity over very long or very short periods); and control the uncontrollable (robots, Lego models, cardboard, wire and wooden models).

Topic work will never be the same since IT has introduced new forms of manipulating information which enable children to investigate enormous collections of up-to-date data in a variety of formats — text, sounds, diagrams, photographic images and moving pictures and get quick, accurate responses.

Much of children's research work in the past has been limited by the quality of their available source material. A tatty copy of *Reika, a Japanese Schoolgirl*, first published in 1967, will not tell children much about modern Japan or about real Japanese people. Books take a year or two to publish and like this one will be out of date on the day they are released. Information technology increasingly gives children access to up-to-date information of high quality through on-line electronic databases and news networks, regularly updated CD-ROMs or through person-to-person contact around the world by electronic mail.

As computers become more powerful, they can handle higher quality images with full colour and high resolution, and they can present accurate digitally recorded sounds and music. Significant works of art, music, literature and science are becoming available on CD-ROM — Beethoven's symphonies, for example, or the entire works of Shakespeare.

Multimedia systems provide a very high level of intellectual, sensory and emotional involvement. The children can also have a great deal of control. They choose the direction of their enquiry. They select the information they want, in the medium they want, in the order they want. They can reorganise it and present it in their own way.

The potential for learning with multimedia is quite stunning. With currently available hardware and software, children can hear the *Carnival of the Animals* in full digital stereo and at the same time follow the written score on screen — one part or the whole score; they can divert into an enquiry into the composer's life; investigate the melodic theme for each animal; glue the composer's themes together into a symphony of their own; write their own themes; or draw the animals represented, write about them or investigate, on moving video sequences, the movements of each animal that inspired the themes.

Images from earth-orbiting satellites have changed our concept of geography, indeed our concept of planet earth. We can now receive views from space showing weather movement, ocean currents, crop coverage, the extent of human habitation and pollution. This has given children a concept of the whole earth as a finite and vulnerable traveller in space. Just one such satellite image of the earth at night, showing the lights from human habitation leads to a new understanding of the distribution of modern settlements around the planet and raises some fascinating questions.

The world in the classroom

These developments are having a profound and irreversible effect on many aspects of the primary curriculum, but arguably the most exciting progress is being made by new generation electronic communications networks which are bringing down the walls of the classroom by allowing cheap and efficient communication with children and adults around the world.

Older electronic mail systems allowed only text to be transmitted and suffered from being rather complex and unwieldy to use. The new systems are simple to use and

allow children to send, not just text, but sounds, images, databases — in fact anything they can have on their computers, to other children all over the world.

This new technology and the enthusiasm of teachers for bringing the world into the classroom has lead very recently to many valuable classroom projects carried out on a global scale which exemplify the way that sensitive use of information technology can revolutionise the work of primary teachers and children.

One international group of schools (The Shadows Project) is carrying out a simple but powerful global experiment which will help them develop their understanding of seasonal changes. Children around the world are asked to measure the length of the shadow of a meter stick at solar noon. The data is sent by electronic mail to a school in New York where children enter it into a database for all participants to interrogate.

Another group (Looking After the Planet Project) is raising questions about the delicate ecological balance of people and nature and encouraging teachers and pupils to explore issues such as recycling, energy use, land use, the ozone layer, pollution, wildlife conservation, the ocean, the wilderness etc. Pupils and teachers from the remote island of Røvær in Norway, from Kangaroo Flats in Australia, from London and New York City, and from many other varied locations, exchange ideas, collect and share environmental data and invent ways of saving their planet, starting in their own backyards.

Through the One World–One People project, pupils and teachers around the world are taking responsibility for people in distress and hardship and becoming actively involved in helping them — the Kurds and child victims of Chernobyl, and a children's hospital in Estonia, for example. This work is not just giving children a warm glow of satisfaction from helping others but also leading them to a realistic appreciation of the ways that aid can help or hinder.

Much of popular history and culture derives not from textbooks but from person-to-person oral communication. This hand-me-down history and culture can easily be swamped by international media and the relentless progress of Coca Cola and Macdonalds. Through the Oral Witness project, children around the world are taking the opportunity to preserve that culture by recording (using all appropriate media — video, audio, text, photography etc.) the fast-fading memories of their elders. They are asking how does the march of history really affect 'ordinary' people, their lives, their families, their homes? How does their perception of events compare with the history books? What culture — stories, songs, rhymes — is being passed from generation to generation? What can we learn by listening to our grand-

parents? They are sharing what they find with other children and adults around the world.

Global electronic mail networks give children the opportunity to understand each other's cultures, to empathise with each other and to examine global community and environmental issues together. What might seem mundane and commonplace in one culture is fascinating to another. Conversely, there are some issues that are important everywhere in the world. How do global issues affect us at a local level? Tourists seldom see a community, since by their presence, they change it. Through the 'My Community project' children give each other a private view of their communities looking at the community's major concerns — from issues that affect the individual and the family to local and global concerns.

Global collaboration can lend new dimensions even to cooking. Children taking part in the 'Global Cookbook' project are looking at the food they eat and asking: Where did the ingredients come from? How were they grown? Who worked on the farms? Under what conditions? For what wages? What was the effect on the ecology and people of the growing country? Children around the world are taking a holistic look at the culture and ecology of food and creating together an electronic book showing how the whole world is focused on their kitchen tables.

Electronic mail has something special to offer children with special needs. It removes many preconceptions. When Jenny in Berwick on Tweed sends a message to her friend Julio in Chile, Julio cannot see her wheelchair, or hear the distortions in her voice or the see the contortions of her face when she tries to speak. Julio does not know it took Jenny an hour to write that little message with a blow switch. Julio will just judge the information he receives. Jenny's special needs can be invisible for a moment and she can carry on a relationship just like anyone else, without being stared at, pitied or patronised.

Making IT projects work

All the projects and the activities mentioned above capitalise on the best of primary practice. They are built on firsthand experience, they are based on real and important tasks, they allow for flexible learning, they give children maximum autonomy, they require collaboration, they allow for children's curiosity within a structure that ensures success, they are cross-curricular, they encourage investigation, they work on up-to-date firsthand information, they can be matched to a wide variety of chil-

dren's abilities, they encourage investigation and understanding on a personal, local and global level, they are open-ended enquiries and will produce many surprises for children and teachers.

Having said this, teachers starting to introduce IT to themselves and their children cannot expect to run classes like Mrs. Brightwell. She has had years of experience in the use of IT. Teachers should expect to introduce just one computer application (perhaps word processing) and explore its potential as a resource for meeting the children's needs and the teachers' defined curriculum aims. It might take up to a year for teachers to be satisfied that they are making sensitive use of their first application, before further applications could be added. These will not take so long to become established, but teachers should still expect to spend considerable time investigating whether the database or adventure generator is really the very best tool for the job in hand. Teachers need to give themselves and their children time to explore.

It might also be useful, at the beginning, to restrict the use of the computer to a single project and not expect to use it across the curriculum until teachers and pupils are confident.

Teachers need considerable support to make a project work. Information technology can present a great challenge to them. It represents one of the most powerful forces for change this century. Change is not easy. Teachers need support in dealing with change. They need the support of school managers who will allow them to use their initiative, value the contribution they are making, give them non-contact time to learn new skills, and encourage them and reassure them when it doesn't work. Often the technology will not work and teachers will need some technical support — perhaps from more experienced colleagues. They also need allies — supportive colleagues within the school, who are willing and able to learn alongside them, and contact with colleagues in other local schools who are exploring similar avenues. They would also benefit a great deal from contact, via one of the global telecommunication networks which offer contact with teachers and researchers around the world.

Teachers introducing IT into their work need appropriate hardware and software available in their classroom either permanently or for extended periods. If the computer is to be used as a tool for learning, teachers and children will need to be able to reach out for it whenever they need to. For that they need the appreciation and support of the community — parents and school-governors, who might well be the source of funds for the equipment.

Information technology can be used as a tool to enhance and extend children's learning, communication, creativity and productivity when it is not seen as an end in itself or something to be learned about. The skills of handling hardware and software, while necessary, are not the starting point for planning the successful use of IT. Successful use of IT in primary classrooms depends more on the teacher having a clear understanding of children's needs, clear curriculum aims and a flexible, open and imaginative approach to learning and teaching.

Computers and young children

Sue Trinidad

Abstract

Computers have gained wide acceptance into mainstream education as an educational tool for children of all ages. There has, however, been much debate on the appropriateness of computer use in the preschool setting and whether, at this age, young children are cognitively ready to benefit from computers. This paper reviews literature presenting arguments for and against the use of computers with young children and, further, discusses recent research carried out in Western Australian preprimaries which has investigated the effects of computer-based learning on young children in the natural classroom setting. These research findings have implications for teachers and school computer policy which are discussed, along with suggestions and recommendations of what software should be used with young children when using the computer in the preprimary or preschool.

Introduction

A statement made by Lepper and Milojkovic (1986) expresses the possible impact of computers on young children. They stated 'that by the time today's preschoolers have finished their schooling (USA), they will have had more direct experience

with computers than 95% of today's adults' (p. 13). Parents are aware of the need to be computer literate, and consider it highly desirable for their children to have this experience early. This was supported by local research carried out by Burgess and Trinidad (1990a, 1991) and Trinidad (1992) in Western Australia which confirmed the trend towards many young children having computers at home. The research showed that from 31% to 67% of preschool children at six different preschool centres had access to a computer out of school hours. It appears that young children are as familiar with computer technology as they are with television and video players. The importance parents place on children's knowledge or experiences with technology is perhaps reflected by the increasing prominence of technology in the home, and is epitomised by the comments made at a recent seminar by Stringer (1993):

Before the microprocessor came along, Hi-Technology was largely the reserve of adults. Children were often not permitted to touch the telephone, the wireless, the gramophone or the TV set unattended. Today they (children) are the ones in charge. The video recorder, the Nintendo console, the Teletext decoder and the programmable CD player are all devices which they 'play' like virtuosi and which we adults generally use cautiously, even seeking advice from our children.

Computers are now an integral part of the Western Australian school environment. Most primary schools have a least one computer between two classrooms, with many schools having one computer per class. Microcomputers are becoming increasingly popular in Western Australian preschools and preprimaries. The Western Australian Education Department's position on computer usage with younger children is clearly stated in the Western Australian Computer Education Program *Resource Document No.13: The Early Childhood Classroom* (1990) as:

Technology in the information age will create a demand for readers and writers who can select from the available tools, the one most suited to the task. So that children can make the relevant informed decisions, it is highly important that an early understanding of and familiarity with the capabilities of computers is gained. It is also important that this knowledge and understanding be acquired in the context of everyday classroom activities, so that it is accepted as part of the child's everyday educational world. In addition the positive benefits which the computer has for learning in the classroom, are as suitable in the early years of education as they are in the latter. (p.1)

Although computers have been widely accepted into society and education as a necessary tool, there has been much debate on the appropriateness of their use with young children. While initial literature was sceptical about the use of computers with young children (Barnes and Hill, 1983; Brady and Hill, 1984; Hill, 1984), recent literature has expressed the view that preschoolers are more competent with computers than has been previously thought (Anderson, 1988; Blemings, 1985a,

1985b, 1986, 1987, 1988a, 1988b; Brinkley and Watson, 1988; Clements, 1987; Shade, 1987; Shade and Watson, 1988; Woodill, 1987). These authors assert there are many positive benefits to be gained from using a computer in the early childhood program. According to their perspectives, a computer, if used with appropriate software, can create an environment which encourages social interactions, language, early literacy, cognitive development, fine motor and coordination skills. These authors acknowledge the computer is another tool to be used along with crayons, pencils, paint and building blocks and can be used to enhance the early childhood learning environment.

Children's development and computers

Although initial fears were that children would become antisocial as a result of being absorbed in solitary interaction with the computer, a number of authors stress that working with computers in preschools encourages social interactions and cooperation. It seems that computer-based learning activities facilitate cooperation, communication and helpfulness among preschool children. Teachers have also reported heightened interest levels and increased attention spans with children when given instructions pertaining to the computer (Blemings, 1986; Campbell and Schwartz, 1986; Clements, 1987; Shade and Watson, 1988). Anselmo and Zink's (1987) study showed that the computer provides a vehicle for two types of interaction: child-computer and child-child. They found that the child-computer interaction depends to a great extent on the software. This was reinforced by Borgh and Dickson (1986) who compared two software packages and recorded verbal utterances as social and non-social comments while investigating the impact of micro-computers on social interaction. Genishi's (1988) study analysed the talk of six children and found the children to be highly task orientated and cooperative when using Logo. Muhlstein and Croft (cited in Clements, 1987, p. 38) found that preschoolers' language activity, measured as words spoken per minute, was almost twice as high at the computer as at other activities of play dough, blocks, art or games. Podmore and Craig's (1989) study found that when comparing children's behaviour pre- and post-computer, kindergarten and junior school children talked to their peers about tasks more frequently and asked the teacher for help more frequently post-computer. Hoover and Berghout Austin (1986) compared computer free play with more traditional preschool free play from a social/cognitive perspective. No gender differences were found when using the Parten-Smilansky social/cognitive play hierarchies but sociometric status did influence computer play with those children, who engaged in more positive social interactions when using the computer constructively. While most studies emphasise the benefits of using com-

puters with young children in encouraging social interactions, Burgess and Trinidad's (1990b) study looked at the complexity of social interactions in three different preprimary centres. This study reinforced the fact that young children were engaged in discussion and shared decision making when using the computer during free play, although joint decision making or cooperative learning was not always necessarily a consequence of children working in groups with a computer-based activity. Different children working with others at the same activity demonstrated behaviour which ranged from deliberate aggression to reflective, planned cooperation. The stimulus of the computer activity was not always, in itself, a catalyst for bringing together individual and group resources for the achievement of a common goal. Training in computer use, a well organised situation with developmentally appropriate software, careful grouping of children and the number of children who use the computer at one time appeared to be important considerations when using the computer in the early childhood classroom.

While Barnes and Hill (1983) and Bobrow (1985) argued that preschoolers needed to actively explore their environment and not be limited to the eye-hand coordination of the computer, others (Beaty and Tucker, 1987; Hinitz, 1989) have argued computers can help children in terms of physical development, namely fine motor skills. While using the computer, children are actively involved in pushing keys on the keyboard or handling the joystick, light pen, an alternative key pad or touching the screen. Children are actively manipulating what appears on the monitor screen, as opposed to passively watching television programs. The use of the computer by children requires eye-hand coordination and fine motor skills, which are part of psycho-motor development, and appear to be increased by interaction with the computer (Goodwin, Goodwin and Garel, 1986; Swick, 1989).

Computers may enable young children to demonstrate knowledge and understandings which are not revealed by traditional means. Activities which provide a print-rich environment may stimulate the development of language and literacy skills in a meaningful context. The computer, with appropriate software, can produce such a print-enhanced environment. Word processing programs may provide the necessary 'scaffolding' or support for young developing writers (Clements, 1987). Chang (1989) and Hofmann (1986) have reported success with young children using a 'talking word processor' which enables four- and five-year-old children to work with printed language without being cognitively aware of the written word. A study conducted by Porter and Sherwood (1987) showed that young children can use word processing to develop their creative writing abilities. This finding is reinforced in a study by Dewsbury and Dean (1987) where the computer and specifically designed software were used as a catalyst in early literacy for young children

and formed the basis of software specifically designed for young children by Dewsbury and Dean.

Both Anselmo and Zinck (1987) and Lawler (1982, 1985), observed that non-readers may be encouraged to read when using specially designed 'microworlds' on the computer. Brinkley and Watson (1988), and Shade and Watson (1988) showed that children as young as two- and three-years-old can learn successfully from discovery-based software. Both research teams recommended age three as an appropriate time to introduce a child to a computer and discovery-based software. In particular, software which creates 'microworlds' in which children can use their own ideas may encourage novel approaches to stories or problems (Hinitz, 1989).

Computers may give children an increased sense of power over their environment, which helps generate greater self-esteem (Blemings, 1987; Lawler, 1986). In an evaluative study conducted by the Queensland Education Department and reported by Blemings (1988a), it was noted that children who were interested and able to handle the computer system were highly motivated to concentrate, and to persevere in the face of challenges and problem solving. Furthermore, Shade (1987) observed children expressing high levels of elation and personal pride in their accomplishments using discovery-based computer microworlds when the child was in control of the learning situation.

Working with computers can not replace concrete exploration with real paints and crayons but it may give children an added dimension which allows them to engage in Piaget's symbolic representation (Shade, 1987). Computer programs can be used to reinforce the symbolic aspects of lessons children have experienced in other forms (Lawler, 1982, 1985; Shade and Watson, 1988) and as a symbolic machine the computer is not unlike activities such as communicating with gestures, speaking, pretend play, counting, tapping a rhythm, singing, making a picture or a clay object (Sheingold, 1986). Blemings (1986, p. 5) states that 'computer programs can give young children a unique opportunity to 'play' in an abstract environment with concepts acquired and understood through concrete experiences'. Furthermore, as a part of our everyday world 'the computer is worthy of inclusion in the early childhood classroom as an object to explore, manipulate and understand' (Sheingold, 1986, p. 35), creating an environment in which young children's development may be encouraged.

What types of computer-based learning experiences should young children be exposed to?

With a large variety of educational software programs available for school computers, an increasing amount of this software is stated as being suitable for the young, or the physically/intellectually handicapped learner. The development of alternative devices to the QWERTY keyboard, such as the joystick, the mouse, switches and touch sensitive pads and screens have increased the range and quality of software for these applications. With increased availability of computers and software throughout the school system, the computer has become more than a tool for the drilling of specific academic facts. The predominant role of the computer in schools in the early eighties was outlined by Woodill (1987) as 'drill and practice software'. This type of software reflected the dominant educational philosophy at that time, when educators believed that children learn best through practice, repetition, memorisation and extrinsic reinforcement. For young children this type of software included letter, number and colour identification, whereby the child pressed the key corresponding to the presented cue. Part of the reason for the proliferation of this software at this time was due to it being easy to program. The Western Australian Education Department presents the view of how the computer should be used in the learning environment in the 90s. The then-Ministry (1990) states in its resource document No. 13, that 'through careful choice of software packages and the use of flexible approaches, exciting learning can take place which also caters for the learner's individual needs. An additional value to early learners is the computer's capacity to pass the control of some learning to the child' (p. 1). A list of recommended software for the Acorn computer accompanies resource document No. 13.

Given that the computer may play a positive role in the development of young children, what are developmentally appropriate experiences when using computers? This decision requires the selection of software which will reinforce the concepts being developed in the learning environment. As Fein (1986) insists, 'a teacher must find a match between their philosophy of education, their teaching style, and the use they make of the microcomputer' (p. 133). Although McMillan (1988) argues that evidence from both theoretical and empirical sources suggests that computers by themselves are not advantageous or disadvantageous for young children, he states that 'as with any new item of preschool equipment, their value depends on the context within which the item is used, and on the manner in which the environment for learning and development is established by teachers and parents of young children' (p. 12). The Western Australian Education Department reinforce this position by stating:

Care must be taken however to ensure that the type of learning which is fostered by the use of the computer in the early childhood environment both complements and enhances the types of learning styles and information offered across the curriculum. The use of the computer should be correctly sequenced into the accepted hierarchy of concept acquisition along with other teaching/learning tools. That is, the interactive nature of a learning task should have the highest priority (Western Australian Computer Education Program Resource Document No. 13, 1990, p. 1).

Developmentally appropriate software for young children

Haugland and Shade (1988) stated that 'developmentally appropriate software' for young children should be viewed as a continuum showing the 'characteristics of age appropriateness, child control, clear instructions, independent exploration, process orientation or learning through discovery, real world representation, have sound technical features, allow for trial and error and finally, allow the child to create visible transformations with the software' (p. 38). Hofmann (1986) reviewed approximately 250 commercial software programs on the basis that recommended software should facilitate the growth of productive thinking processes in children. From this review he developed guidelines for developmentally appropriate software. He found that software could be classified on two dimensions, that of the type of experience and user control. Hofmann describes two sorts of experiences possible to facilitate learning through software. The most powerful experience for a child is to learn through environmental interaction. The less desirable experience is to learn through drill or sheer memorisation. There are three types of control in software. The first, 'Strong-control software' (arcade type games), is entertaining, requiring quick motor reaction and anticipation from the user. The second is 'No-control software' (drill and practice or tutorial), which is non-interactive and the user simply responds in rote fashion. Hofmann found this type of control provides little avenue for decision making and the best that a user can hope to gain from this type of software is some rote learning or memorisation. The third type is 'Subtle-control software' (word-processing, open-ended discovery-based software), which has the important consideration of the user's perceived control, which rests on the degree to which the user can manipulate the microcomputer environment in a purposeful, exploratory fashion. Ideally, 'developmentally appropriate software' for young children should encourage purposeful experiences within the microcomputer environment, allow for substantial learning experiences and exhibit 'subtle-control'.

Another study in the area of hardware and software field testing was conducted by Blemings (1985a, 1988a, 1988b, 1989) on behalf of the Queensland Education Department as a project of national significance. This is the only study in Australia of this kind to date. This study investigated the types of computer-based learning experiences which were developmentally appropriate for preschool children, and which hardware and peripheral devices were necessary for young children. Issues which would facilitate the decision-making process in respect of computer applications in Queensland preschools were investigated as they arose. These trials were qualitative in nature with an action research model being used to evaluate the materials and with no attempt being made to control variables, or to measure with tests any changes in aspects of learning and development. However, in observing the impact of the computer in a normal, unmanipulated preschool environment, Blemings (1985a, 1985b, 1985c, 1986, 1987, 1988a, 1988b, 1989) has provided detailed information about the 'realities' of using computers with Australian preschool children. These materials include a video and a software selection guide which is used by the Western Australian Education Department when in-servicing early childhood teachers.

The teacher must therefore be a software connoisseur, wisely choosing software programs which are intellectually sound and appropriately motivating (Silvern, 1986). The software should be open-ended programs which encourage children to ask thought provoking questions (Hofmann, 1986; Shade, 1987). Computers are neither panacea nor pernicious (Clements, 1987), but computer usage must be related to the curriculum goals of early childhood programs with appropriate software being chosen on the basis of 'developmentally appropriate' guidelines. The effectiveness of computer-based learning experiences depends on the quality of the software, the amount of time the software is used, and the way the software is used.

A local research study

As yet there has been little research into the effects of long-term computer-based learning with young children. Although the volume of literature relating to the use of the computer with young children continues to increase, attempts to verify the effects of computer-based learning on young children's development are sparse. Although assertions are made by many authors on the possible benefits of using computers with young children, it has not been proven that computers cause children to learn better (McMillan, 1988; Woodill, 1987). There has been much written on the effects of the use of the Logo computer programming language, developed by Papert (1980), particularly with young children. Clement's (1985); Genishi's

(1988); Lawler, du Boulay, Hughes and Macleod's (1986), Shade's (1987) and Try's (1989) studies emphasise the potential benefits of young children using open-ended or discovery-based software such as the programming language Logo although attempts to verify Papert's (1980) claims for learning with and through Logo, are clouded by a variety of debates about the research designs and methodologies used in these studies.

A recent research project in Western Australia may help to put these arguments in context. In assessing the arguments for and against the use of computers in the early years of schooling it is essential not to lose sight of the key question: *What educational benefit do computer-based activities offer young children?* A survey of recent literature (Clements and Gullo, 1984; Clements, 1985; Clements and Nastasi, 1988; Miller and Emihovich, 1986; Try, 1989) does not give a clear picture as to whether it was the computer-based activity (Logo) which enhances learning, or the amount of extra teacher intervention received as one group experiences Logo and the other group does not. However, the issue was addressed in a local research study (Trinidad, 1992) where the emphasis was placed on investigating the realities of computer usage and software types in the natural setting of the early childhood learning environment. In doing so, the study examined how children's learning and development can be understood within the social contexts in which the learning takes place. The study took place at three Perth metropolitan preprimary centres using Acorn computers, concept keyboards and Western Australian Education Department-suggested software.

By gathering both qualitative and quantitative data from 121 Western Australian children in the three centres, the study investigated the effects of computer-based learning on young children's development over two years. The research design involved several methodologies. Systematic quantitative pre-test and post-test data were collected using the Battelle Development Inventory (BDI) and analysed from the first year (the experimental phase) and the second year (the follow-up phase) of the study. The research design involved six groups of children at the three preprimary centres where two groups did not have any computer exposure for 25 weeks, and four groups had 50 weeks' exposure with the computer using either Software Type 1 or Software Type 2. Within this framework the social interactions of the children working at the computer were video recorded, then analysed on the basis of Friedrich and Stein's observational scale which was adapted for a study conducted by Nida, Lipinski, Shade and Watson (1984) and used by Podmore and Craig (1989). To assist in the analysis of the children's reactions to computer-based activities, software used by the children was classified into two groups using Haughland and Shade's (1988) continuum for 'Developmentally Appropriate Software' with Hofmann's (1986) guidelines of environmental experience and user

control. Software Type 1 included predominantly drill and practice software or 'no-control software'. Software Type 2 included open-ended discovery based or 'subtle control' software; that is, word processing, adventure-thinking software and Logo through the Valiant Roamer. Additional data on the children's computer usage at school and at home were analysed, as were their social preferences when using the computer. In addition to the experimental data, case study data were analysed from the field observations of 24 target children, selected by their scores on the Matched Familiar Figures Test (MFFT) which measured the children's ability to think reflectively. These observations, taken over the two years, provided data on the different learning styles in relation to the use of the computer.

The major findings of this study were that children will not be disadvantaged if they are not exposed to computer-based learning experiences in the preprimary setting. Given similar conditions, children's cognitive and social development was already occurring at or near the maximum rate in the enriched environment found in both preprimary centres and primary schools such that additional input from computers had no significant effect on the children's overall development. This study showed that the computer-based learning activities did not contribute to an increase in the measured cognitive and social development of children at preprimary and Year 1, nor did Software Type 2 (i.e. open-ended, discovery-based software) produce greater cognitive or social development than Software Type 1 (i.e. drill and practice software). The ethnographic data helped to develop an insight into the way the children interacted with the computer, software type and each other, encouraging individual learning styles. Children were observed to be task orientated and cooperative when using the computer for both Software Type 1 and Software Type 2 and on several occasions individual children were given the opportunity to acquire and practise learning strategies with peers and adults. These results pose some interesting challenges for teachers. Is it the computer-based activities or extra teacher-peer scaffolding and/or intervention that results in a positive environment encouraging children's learning, as supported by other studies (Clements and Gullo, 1984; Clements, 1985; Clements and Nastasi, 1988; Miller and Emihovich, 1986; Try, 1989)?

In studying the natural classroom environment it was found that exposure to the computer-based learning environment gave children an opportunity to interact with the computer, peers and adults in a context which facilitated social interaction. Due to the importance of the effects of socialisation on the learning styles of young children, one important outcome the case study data analysis has highlighted is the amount of social and interpersonal cooperation that occurs. The fact that the computer and appropriate software provide an interactive environment means that the children are encouraged to socialise while they are using the computer. The Software Type (Software Type 1 or Software Type 2) did not have a great effect on the

learning styles of the children but the combinations of different children did. Individual differences were found among the case study children but all children were found to be task orientated and cooperative when using the computer. The children were involved in two sorts of cooperation; that of directed cooperation, whereby their partner or the adult directed them and provided the necessary scaffolding to complete the task, and mutual cooperation, where children worked together towards a common goal. Whether the computer-based learning environment provides an advantage over other activities found in the early childhood environment with regard to peer scaffolding and other positive forms of social interaction, is an area for future research.

Implications for early childhood teachers and school computer policy

This study provides information for teachers about the practical application of computer-based learning activities in early childhood settings. Although the results gained in this study are restricted to the sample population, it appears that given a similar situation, using a computer earlier does not necessarily cause any added advantages to a child's overall development; therefore, those children who are not exposed to computer-based learning experiences in early childhood classrooms are not necessarily disadvantaged.

If the teacher does choose to have computer-based learning experiences in his or her preprimary/preschool centre, it appears that the software used on the computer is dependent on the active contributions of the users and the adults who assist the children. In the process of planning for the use of the computer in the classroom, the total integration into the existing curriculum should be considered, with the concepts currently being developed with children determining the decision as to what software is to be used. As Blemings (1986) states, 'the power of the computer as a learning tool is dependent on the software' (p. 4). Ultimately, the software used must be related to the curriculum goals of early childhood programs. When the impact of computers on early childhood programs is placed in a 'developmentally appropriate' framework, the following observations have been argued by Swick (1989): that 'computers provide an exciting, dynamic learning tool. They can enrich existing curriculum practices by providing a medium for extending learning to new visual and manipulative modes' (p. 8). But computers need to be implemented into the classroom through careful planning and preparation on the part of the teacher.

The author was based in an early childhood environment for two years observing and participating in the computer-based learning of young children. During that time the computer was seen as a valuable resource being used effectively and inef-

fectively to encourage and discourage children's independent approaches to learning. As educators, we need to be aware of the adult and peer influence in an environment through scaffolding and modelling. The case study data in this study demonstrated that the computer can be used as a tool to encourage young children to use a strategic style (Cullen, 1992) of learning in an early childhood environment.

From the observations made throughout the two years of the study, support can be given for using both types of software. The literature supports the use of Software Type 2 (i.e. open-ended, discovery-based or 'subtle control' software), as Software Type 1 (i.e. drill and practice or 'no control' software) is seen to offer the less desirable experience because the child is learning through drill or sheer memorisation. The author suggests that both software types have merit in an early childhood classroom. As Hofmann (1986) described, two of the most powerful learning experiences that can be gained from software are for a child to learn through environmental interaction and user control. These behaviours were observed in varying degrees, dependent on the environmental influences, with both software types. What was shown to be important was the amount of environmental influence through the type of scaffolding provided by the adult or peers in helping the child achieve his or her goals while using the computer. Children who talked about their learning, 'thinking aloud', used strategic learning skills which were often passed onto other children in the group (Fein, 1986), showing an increase in the children's awareness of learning (Pramling, 1988). The importance of sensitive teacher intervention is supported by Cullen (1992) and Jones, Palincsar, Ogle and Carr, (1987). Sensitive teacher intervention or strategic teaching can provide opportunities for learners to make choices and decisions, and prompt children's acquisition and use of strategic learning skills (Cullen, 1992).

It is suggested that Software Type 1 (i.e. drill and practice) might be the first software used by the children in the preprimary, before moving onto Software Type 2. From the observations it was shown that Software Type 1 was most suitable for the preprimary environment. If the computer is set up as another free-choice activity centre, coupled with Software Type 1, it becomes an activity area which encourages children to work independently and cooperatively, fitting in with the free-play philosophy of preprimary or preschool. This software allowed children to gain confidence in using the computer and be in control of their own learning. Such software was easy to use by the teacher (who may be hesitant in using a computer in the preprimary). Table 1 (appendix) provides a list of suitable software classified as Software Type 1 available for all hardware platforms. These programs are letter- and number-recognition software.

Software Type 2 needs more teacher intervention, careful scaffolding and planning. This software is more suitable for young children beginning to read and write if it is going to be used independently by these children. The preprimary or preschool teacher might use the computer to model concepts of print by using a word processor like *Prompt Writer* (Acorn computer and concept keyboard) to type and print out group stories and class diaries. Once the children move into Year 1, the structure of the class enables many of the software classified as Software Type 2 to be used more effectively in small groups. Many Year 1 children are cognitively ready to use open-ended or discovery-based software independently as they are reading and writing. This software is best introduced in a group situation and can then be used in group activities where pairs of children use the computer. It is important that the adult be aware of scaffolding; that is, facilitating the problem-solving environment by asking questions which assist the children to solve the problems independently, not just by giving the instructions or answers. Table 2 (appendix) describes a list of software that is classified as Software Type 2. This software allows for 'subtle control' by the child and includes easy-to-use word processors or tools which allow the child to design, create and paint things on the computer, then print them out to take home. Other software, such as adventure-thinking type games, allow children to experience control over events within the program and stimulate thought and discussion. These types of software programs are ideal at this level if carefully implemented by the adult to encourage a cooperative problem-solving environment. Many of these software programs provide ideas for 'off-the-computer-work' as well as 'on-the-computer-work' and enhance opportunities for children to solve problems independently while using the computer, providing the adult facilitates questions which enable children to investigate the cause and effect of their own actions, elaborate and refine their knowledge and, most importantly, express their own ideas and solutions. Questions should challenge children to reflect on the thinking process they use to encourage the reorganisation of their ideas into more adequate frameworks (Burns, et al., 1990) to gain the full benefit of this software.

Teachers using a computer in an early childhood classroom need to give consideration to the positioning of hardware, software, linked visual aids, the establishing of rules and procedures, and the grouping of children. The manner of access which the children have to the equipment influences the way it is used. For example, setting the computer up in the shop corner can model real-life situations. Siting of related charts (i.e. keyboard, alphabet and number charts) next to the computer encourages children to seek information independently. Often by carefully selecting partners for children, the teacher can encourage them to work cooperatively and independently, hence the quality and quantity of the learning improves. Establishing rules such as only two children use the computer at one time and that children work

together to help each other use the computer, encourages young children to be aware of other children's needs and also to act as peer tutors, offering the necessary scaffolding to those children who might need it (Forman and Cazden, 1985). Young children are capable, if shown, of loading and running the software and turning the computer and monitor on and off. If the computer is set up as a free-choice activity, the teacher can use a 'sticky dot record chart' to monitor children who monopolise the computer and redirect them if necessary. Children who use the computer place a sticky dot next to their name and those children who have not used the computer can be noted easily. These children can be encouraged to use computer by pairing them with a suitable partner.

Finally, the computer can present an environment which provides a level of interaction and feedback that static materials cannot. This environment can encourage young children to share and play cooperatively so they are developing social skills. Through this environment, children can be encouraged to solve problems, respond to software instructions and feedback where they are learning to follow directions, apply old learning to new situations and understand cause and effect so they are developing thinking skills while working cooperatively with peer and adult scaffolding. Such an environment can encourage young children to operate a computer mouse and keyboard, put a disk into the computer and turn on a computer, so they are developing coordination skills. But as educators we must be aware of the careful integration of computers into our teaching programs. As one writer stated when commenting on the appropriate use of computers with young children: 'Our goal as educators is to develop problem solvers, not programmers; communicators, not word processors; fulfilled children not early achievers' (Clements, 1987, p. 42). With the prominence of technology in our homes and in our schools, computer-based learning activities should be worthwhile experiences used to achieve educational goals, otherwise young children may not benefit from the use of computers in early childhood classrooms.

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Appendix

TABLE 1. Software type 1: drill and practice

Software Type	Macintosh	IBM-compatible	Acorn Archimedes	Acorn Compact/ Acorn 128	Amiga
Numbers		Sticky Bear Numbers	Animated Numbers	Animated Numbers	Kinderama
		First Numbers			
	New Math Rabbit*	New Math Rabbit*	Little Red Riding Hood	Numbercopter	
	Kidsmath	Math and Me	Ten out of Ten Maths		
	Millies Maths House*	Millies Maths House*			
Letters	Daisy Quest*	Talking Phonics Plus*			Grade A letters*
	Reading Maze	Kids Stuff			Robot Readers
	Reader Rabbit 1	Animated Alphabet	Animated Alphabet	Animated Alphabet	
		Ready for Letters*		Nog and Nippet	
	Bailey's Book House*	Bailey's Book House*			
		Reading and Me			
		First Letters and Words*			
	Easy as ABC	Easy as ABC			

*Software with speech capabilities

All software is available from ECS (09) 240 1633; Wooldridge CS (09) 242 5177;
Dataflow (02) 310 2020; Edsoft 008 338 873; New Horizons 008 808 656

TABLE 2. Software type 2: open-ended

Software Type	Macintosh	IBM-compatible	Acorn Archimedes	Acorn Compact/ Acorn 128	Amiga
Painting pictures	Kid Pix*	Kid Pix*	Kid Pix*	Timpaint	Deluxe Paint
	Kid Works 2*	Kid Works 2*	Imagine		
Designing cards, and stories, etc.		Printshop	Poster	Printbox	Pelican Press
	Superprint	Superprint II	Folio		PrintMaster+
	Puzzle Story book*	Puzzle Story Book*			
	Kid Picture**	Kid Picture**			
Word processing	Once Upon a Time – Puppet Playhouse	Once Upon a Time – Puppet Playhouse			
			Pendown	Pendown	
			Talking Pendown*	Folio	
	Once Upon a Time	Once Upon a Time	Touch Explorer 3 (+ concept keyboard)	Prompt Writer (+ concept keyboard)	Picture Book
	Kid Works 2*	Kid Works 2*			
Adventures; discovery games	Kid Desk^	Kid Desk^	Optima*		
			Stylis*		
	Playroom	Playroom	Jiglet	Concept Kids	Katies Farm
	Ruff's Bone*#	The Tree house	Dreamtime	The Circus	McGee
	Bailey's Book House	Bailey's Book House	My World	The Farm	McGee at the Fun Fair
	Arthur's Birthday*#	Snap Dragon	Teddy Bear's Picnic	Teddy Bear's Picnic	Jigsaw
	Just Grandma & Me*#	Dinosaur Discovery Kit*	Pip Discovers Dino- saurs	Albert's House; All About Me	
	Tortoise and the Hare*#	Facemaker – Golden	Sherston Naughty Stories*	All About Us	
	The Three Little Pigs	The Three Little Pigs		Pip's Island Adven- ture	
	Little Monster at School*#				
Logo			First Logo		
	Valiant Roamer***	Valiant Roamer***	Valiant Roamer***	Valiant Roamer***	Valiant Roamer***

*Software with speech capabilities; **This requires Kid Pix or Kid Works 2; #CD-ROM;

***This is a small robot and does not need a computer to work; ^Alternative easy-to-use interface provided.

All software is available from ECS (09) 240 1633; Wooldridge CS (09) 242 5177;

Dataflow (02) 310 2020; Edsoft 008 338 873; New Horizons 008 808 656

Computer technology and the maths classroom: a mismatch between opportunity and reality

Nerida Ellerton

Abstract

This chapter will focus on the role of the computer in the teaching and learning of mathematics. In the last ten years there has been a dramatic increase in the number of computers acquired by schools. In particular, many children in primary classrooms now have access to one or more computers on a regular basis. The mathematics curriculum, however, has remained relatively untouched by this technology. The computer was originally welcomed as an opportunity to introduce new approaches to the teaching and learning of mathematics at all levels; the reality however, is that computer use is still, for the most part, superficial. This chapter explores possible reasons for the apparent mismatch between opportunity and reality.

Introduction

Purchasing a computer for use in the mathematics classroom is a bit like buying a chair for your home. Comfort and utility are likely to be high priorities, and the purchaser is likely to go to some trouble to ensure that the new acquisition 'fits in' with

the current arrangements. Regardless of the final choice, the new chair (or computer) is likely to attract attention — it will stand out, for a while, as an addition to the room.

The questions I would like to pose, though, are these. Will the room take on a new dimension because of the new acquisition? And will its presence transform the room into something fundamentally different — or will the new acquisition soon become absorbed into the powerful culture that already exists?

The strength of a metaphor often lies in its ability to force us to face the underlying assumptions we make about a particular situation. A chair cannot, by itself, change what happens in a room — and neither can a computer. This will depend on what we do with the chair (or the computer), where it is placed, why it was purchased, and when and how it will be used.

I believe that one of the reasons why computers have had little impact on mathematics classrooms is because superficial responses have been given to these issues of what, where, why, when and how, rather than deeply considered, reflective responses. The purchase of a chair will only change what happens in a house if you, the purchaser, want it to, and take steps to help the changes occur.

The opportunity

Although descriptions of computers in the 1960s were linked with mathematics and mathematical calculations (see, for example, the entry under 'computer' in Grolier Universal Encyclopedia (1966, p. 235), which described a computer as an 'automatic device that performs mathematical calculations and logical operations', there appeared to be a reluctance or an inertia which inhibited the recognition of the opportunity that computers presented for education in general, and for mathematics education in particular.

At a National Council of Teachers of Mathematics Conference on 'Computer Assisted Instruction and the Teaching of Mathematics' held at Pennsylvania State University in 1968, reference was made to the fact that, although the computer had made a major impact on the worlds of science and business, it was not as well known that it was 'already affecting the educational enterprise in significant ways — especially in terms of its possibilities for mediating instruction' (Heimer, 1969, p. iv). There can be little doubt that the opportunity for applying the computer in mathematics education was recognised, but its recognition was apparently totally

bound in the context of the teaching and learning theories which were dominant at the time.

In Australia, mathematics curriculum documents recognised the place of the computer in the application of mathematical ideas, extolling that 'these complex devices require highly qualified persons to supervise their construction and they require mathematically competent persons to operate them and to prepare the information for them' (Education Department of Victoria and the Australian Council for Educational Research, 1966, p. 19). Presumably, such a comment was included to help motivate teachers in their day-to-day roles in mathematics teaching. There was no reference, however, in this document to the use of computers in the mathematics classroom.

In 1982, the Minister of Education in Victoria commissioned a study of computers in education. The report, produced by Shears and Dale (1983), described policy and practice both overseas and in all Australian States and Territories. It is perhaps surprising that Shears and Dale found that the use of computers in education was 'not a practice which is accepted or even considered desirable by the authorities in all the countries which were visited' (p. 1). The report acknowledged that Australia was, in fact, 'committed to the utilisation of computers in schools and educational institutions' (p. 29) but had not yet established policy and procedures for the use of computers in education.

Shears and Dale (1983) summarised data from surveys which reflected the use of computers in education around Australia. For example, in primary schools in Western Australia, 'the computer is used as an integrated learning resource in the normal teaching-learning programme.... It is accepted that the computer can serve as an additional resource to motivate students and to stimulate and enhance problem-solving abilities through the use of computer-assisted learning techniques provided these are carefully integrated into the total education programme' (p. 44). In primary schools in Victoria, 'teaching games and simulation for the purposes of familiarisation were the common uses, with a few schools using computers also for mathematics at upper primary levels' (p. 30). South Australia's approach gave the highest priority to using the computer for the support and extension of existing curriculum activities and to 'the integration of educational computing into school curricula as a motivational device' (p. 48).

Thus the computer was being interpreted as a resource to be integrated into the existing program — the chair in the metaphor was to be absorbed into the old context and culture of the room. Was this the 'new vitality' spoken of by Galanter (1983), when he wrote about standing at the threshold of a new age of literacy —

computer literacy — whose demands on our schools, both now and in the immediate future, may well overshadow the demands of the past? Children's needs for this new literacy are growing and will continue to grow. Our schools will be a central agent for this growth, and indeed the schools may find a new vitality in this new initiative. (p. 17)

The opportunity gathers momentum

During the 1980s in Australia it became increasingly recognised that 'computers have a great potential for improving the teaching of mathematics' (Ministry of Education (Schools Division) Victoria, 1988, p. 38). Direct dollar for dollar subsidies to schools for the purchase of approved computing equipment were implemented in several States, including Western Australia. School communities embarked on enthusiastic fund-raising drives to make sure that their school was not left behind in the ratio of computers per classroom, in comparison with other schools. Often, little attention was given to the uses to which the newly acquired resources might be put in the school (Bigum, Henry and Kemmis, 1986).

Three dilemmas The consequences, though, of equipping schools with computing resources before the educational implications had been investigated, were three-fold:

- The computers tended to be gathered together into one room or central area:
 - for security reasons;
 - so that groups of children from all Year levels could have access to the computers;
 - so that teachers with computing skills could work with children from any Year level.
- There was insufficient time for adequate in-servicing of teachers, so one or two teachers (in primary schools) with computing skills were given time release from their own classes to teach in the computer room.
- Teachers were faced with the dilemma of working with children who had a wide range of computer skills — from those who had never used a computer to those who were already skilled at programming.

Although these three points have implications across all curriculum areas, they have particular relevance in the area of mathematics teaching and learning. First of all, with the model of a specialist teacher dedicated to teaching in the computer area, came the message that computing was 'special', and for an elite minority who were good at it. Often, the teacher who was most involved with teaching in the

computer area was also a teacher whose expertise lay in the area of mathematics. Other teachers, by implying (consciously or otherwise) that 'Ms. X (or Mr. Y) will explain it to you', were also passing on to students that skills in mathematics were a prerequisite for computing skills.

Specialist 'computing' teachers Such assumptions placed huge burdens on the specialist 'computing teachers' themselves, as they needed to become conversant with computing resources across a wide spectrum of curriculum areas. Few computing teachers, therefore, had the time or the opportunity to undertake the professional development work needed, and in addition, were forced to focus on the computer rather than on how mathematics teaching might be improved in a computer environment.

Many software manufacturers were quick to assume that mathematics lent itself to the production of instructional packages. 'Skill and drill' software flooded the market, and served only to reinforce the notion that mathematics could be taught as isolated skills with little reference to linking these to the children's real worlds, or to the development of language skills in the mathematics area.

Integration? A further danger of having the computers set aside physically in a central area was the difficulty of integrating the use of the computer into the everyday teaching of the curriculum. Again, mathematics is particularly vulnerable as it is difficult to isolate activities that can be saved for the class to undertake when it is their turn to use the computer room. Clearly, this can lead to isolation rather than integration of the computer into the mathematics classroom.

The point should be made here, too, that having computers on trolleys which have to be booked in advance is only marginally more satisfactory than having a central computer room.

Underlying assumptions It is the assumptions which underlie the three dilemmas above, however, which are of the greatest concern. There can be little doubt that one of the prime assumptions made was that it was more important to have the computer than it was to know how best to use it. What was overlooked was that, whatever the physical arrangement chosen for the computer, and whatever approach was adopted regarding the teachers who would work with students and the computer, each school had already locked itself into a particular philosophy of computers in education which would, in turn, lock it into particular teaching and learning approaches.

Yet the use of the computer in education was heralded as having 'great potential'. In reality, the computer was being used, often unconsciously, to reinforce old stereotypes. For example, computers were seen as more a male domain (see, for example, Hoyles, 1988), and mathematics continued to be taught as a collection of fragmented skills.

Other visions At a time when the personal computer was becoming a financially viable proposition, Seymour Papert (1980) published his book, *Mindstorms*, in which he challenged readers to reflect about how computers might change the way in which people think and learn. His book challenged the ideas of 'computer-aided instruction' which had grown from notions of mastery learning, and in which the computer could be used to teach the child. Mathematics was particularly vulnerable to this approach because it was often taught in a step-wise fashion, devoid of context. Instead, in Papert's (1980) vision:

the child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building. (p. 5)

Papert went on to describe how computer environments can be designed so that 'learning to communicate with them is a natural process, more like learning French by living in France than like trying to learn it through the unnatural process of... instruction in classrooms' (p. 6).

Computers, according to Papert, can be 'mathematics-speaking' and 'alphabetic-speaking' entities. By focusing on the computer as tutee rather than tutor, Papert saw how students could learn mathematics in 'Mathland' — and he created the computer language Logo to enable students to communicate, mathematically, with the computer.

Reality in Mathematics Education project In 1979, the Reality in Mathematics Education (RIME) project, coordinated by the Education Department of Victoria, began by surveying teachers, tertiary mathematics educators, and employers about possible changes in the direction of mathematics education. Lessons were developed in conjunction with schools between 1980 and 1981, with extensive trialing taking place in schools in 1983. In 1984, a set of 91 lessons was published for Year 7 and beyond, and by 1988 the range of the lessons had been extended from Years 4 to 10. The lesson plans were to be viewed as guides only, and included many opportunities for adaptation to a particular class's needs.

The introduction to the RIME Lesson Pack in 1984 was emphatic that 'RIME lesson plans comprise neither a complete nor definite course of study', and continued by explaining that the orientation of these lesson plans was towards the professional development of teachers, and that the plans concentrated 'primarily upon those aspects of a balanced curriculum for which good resources are scarce' (p. 2). By 1988, twenty of the RIME lessons had a computer component which was intended to enhance and extend the lesson.

Problem-solving strategies A number of computer 'games' invoke strong problem-solving strategies, and can be integrated as part of a mathematics program. As with any activities introduced in the mathematics classroom, however, such activities should not be seen as an end in themselves, as something for 'early finishers' to undertake. Rather, computer 'games' can be used to encourage discussion and collaboration among students, and as an opportunity to link the students' real worlds with the formal language of mathematics.

Computer simulations The solution of most real-world problems invokes the application of mathematical modelling. This process can be described as one of taking the problem, formulating a mathematical model which reflects at least some aspects of the problem, solving the mathematics of the model, and returning to the context of the real world to interpret the answer. It may then be necessary to review the mathematical model, improving and extending it if necessary.

The computer can be a valuable tool in mathematical modelling, particularly when simulations are involved. Simple programs can be constructed which allow students to generate simulated results in a few seconds which would either take unproductive lesson time or may prohibit the students from attempting a particular problem.

Spreadsheets Spreadsheets give students the opportunity to invent and explore their own data. Spreadsheets help students to organise and display their data, and let them perform simple, repetitive calculations quickly and efficiently. Thus students can see the relationship between the operations they used and the results produced while the reasons for performing the operations are still fresh in their minds. The logic behind displaying data in tabular form starts to make sense when students have the opportunity to use spreadsheets in the context of solving problems.

Algebraic investigations Although graphic calculators now offer powerful ways of carrying out algebraic investigations, so, too, do computers. Successive approximations, for example, can be used as a strategy for solving quadratic equations. One of the advantages of using a numerical approach to the solution of quadratics by using

a simple computer program is that a similar program can be used to solve cubics and higher order polynomials.

A holistic view of mathematics In all of the examples described in this section, the view of mathematics presented by integrating the computer into the mathematics program is holistic rather than fragmented. For example, the graphing of functions is a simple extension of their computation, rather than a laborious task which involves mastering a set of new skills, and the simulation on the computer of a large number of throws of a die provides a sound model for the application of the computer in the world outside the classroom.

The reality

So much for some of the opportunities presented by using the computer in the mathematics classroom. Certainly, many of these opportunities have been and continue to be taken up by primary and secondary teachers alike. The reality, however, in classrooms across Australia is that the computer is rarely integrated into day-to-day mathematics programs.

The National Statement on Mathematics for Australian Schools (Australian Education Council and Curriculum Corporation, 1991), for example, whose aim is 'to provide a framework around which systems and schools may build their mathematics curriculum' (p. i), makes relatively brief comments about the ways in which computers may be used in the mathematics classroom. Under the heading 'Use of Technology' in Chapter 3 (which is titled 'Enhancing Mathematics Learning'), one of the few references to technology made by the National Statement mentions that:

There is a range of ways in which computers may be used in mathematics classrooms including 'number crunching,' data analysis, as a simulation device, graphics, symbol manipulation and spreadsheets. Each of these uses has implications for what is most usefully taught in mathematics and how it is taught. If the use of computers is to be regarded as a normal part of doing mathematics then students will need access to computers in the rooms where mathematics is normally learned. (p. 23)

What the National Statement fails to make explicit is the way in which the computer impinges on what is taught, and on how it might be taught. With a 220-page book which sets out quite detailed objectives for each of the content strands, the comment on the importance of incorporating the use of the computer into the mathematics curriculum would appear to have been given little more than lip service.

The mismatch

At first sight, the extent of the mismatch between the opportunity presented by computers in the mathematics classroom, and the reality of current practice seems difficult to reconcile. Writing in 1988, di Sessa pointed out that 'How one intends to use computers to aid learning depends in a dramatic way on what one thinks is important in learning' (p. 49). In other words, if a teacher believes that students learn mathematics best when the content is broken down into isolated fragments, then any use of the computer in this mathematics classroom is likely to perpetuate the teaching of mathematics as a series of fragmented pieces of knowledge.

Similarly, a teacher who believes that students learn mathematics best when holistic approaches are used, is likely to use the computer in the mathematics classroom in ways which will present a holistic view of mathematics to the students. Indeed, some teachers have been observed using skill and drill software (which assumes that mathematical understanding can be built up as an individual achieves successive mastery of the various processes and operations) by gathering the children around a computer and using the program as a stimulus to generate class discussion (Del Campo and Clements, 1987). Conversely, I have observed pre-service teachers giving precise programming instructions to children who were beginning to explore the Logo microworld. In other words, the teacher's view of learning can be a more powerful force than the paradigm implied by the particular computer application.

The mismatch, then, is of a fundamental nature, and relates to the conscious and unconscious beliefs held by teachers about the nature of mathematics and of mathematics teaching and learning.

In the past, most in-service programs on the use of computers in the mathematics classroom have been directed towards helping mathematics teachers acquire basic computing skills, and to help them make informed choices of software. The above examples suggest that in-service and pre-service programs should be linked directly with the development of holistic approaches to the teaching of mathematics. In other words, the computer becomes a way of looking at the world of mathematics rather than a means of carrying out isolated pieces of mathematics.

A mediating role

One of the challenges facing educators is how best to capture the opportunities provided by the computer medium when faced with the constraints and realities of the school mathematics classroom. Computers, in fact, occupy a unique niche at the interface between formal mathematical language and symbolism on the one hand, and everyday real-world situations on the other.

The mediating role of technology has been represented diagrammatically in Figure 1. The computer, as mediator, provides a stimulus for discussion about the mathematical formulation of a solution to a particular real-world problem. In turn, the computer provides a way of helping to structure a mathematical model which would be appropriate to solve the problem, as well as an efficient tool for performing the mathematical operations. Subsequently, discussion would take place to interpret the solution in terms of the original real world problem.

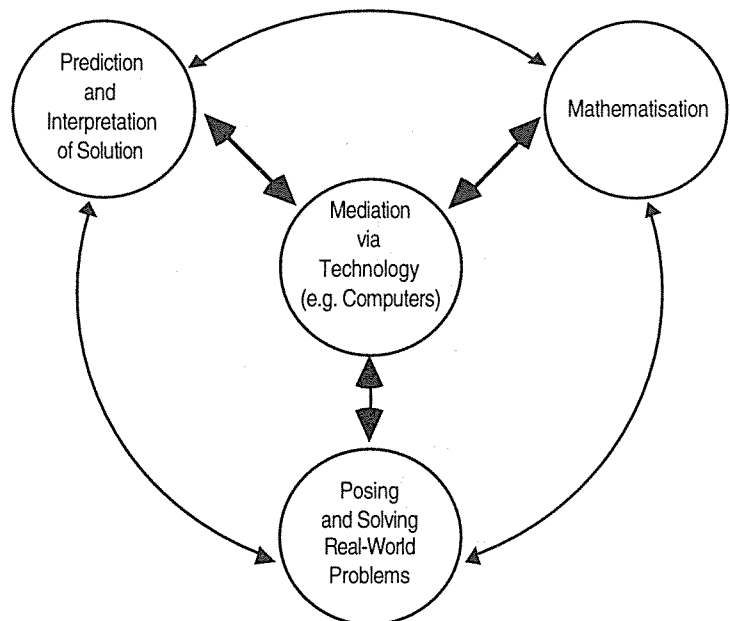


FIGURE 1. The mediating role of technology in the solution of real-world problems

Viewed in this way, the computer mediates across the gulf between children's day-to-day experiences, their interpretations of mathematical problems, and the formal mathematics they come to associate with school. The computer has been assigned a number of roles — from tutor, tutee and tool, for example — but, in fact, the role of the computer in which the student has perhaps the highest degree of control over the situation is that of mediator. Not only can the student decide on the extent of the mediating role given to the computer, but the student can determine the quality of that role. Thus the computer may sometimes be tutee, sometimes tool, and sometimes a vehicle for discussion — the choice and nature of the role is in the hands of the student. As di Sessa (1988) explained:

A major problem with formalisms in past pedagogy is that they have stood quite apart from intuitive knowledge. Indeed, they are often made to be the antithesis to intuitive ideas, rather than to be productively engaging of them. The computer can play a multitude of important roles squarely between these poles, making for productive transitions in both directions. (p. 63)

The teacher's role is one of facilitator — to provide an environment in which the students do, indeed, have the freedom and the capacity to adopt the computer as mediator.

Some examples

The final section of this chapter will outline some examples of using the computer in a mediating role in the mathematics classroom. Only brief details will be given, the emphasis being on the role of the computer rather on the details of the particular examples provided.

Logo and the turtle Papert (1980) viewed school mathematics as a social construction, and concluded that, for most people in our culture, it would be inconceivable for the content of school mathematics to vary much from what it was when they went to school. Topics in school mathematics curricula had largely been chosen by 'a set of historical accidents' (p. 51). Papert felt that one of the major factors which determined what was included in school mathematics 'was what could be done in the setting of school classrooms with the primitive technology of pencil and paper' (p. 52).

Clearly, at least some of these accidents of history arose because of pragmatic considerations. Thus, for example, before calculators were readily available it was important for most people to be able to perform calculations with the four opera-

tions quickly and accurately. Although Papert referred to 'the intellectual value of some knowledge, indeed, of a lot of knowledge, about numbers' (p. 51), he felt that, because of the ready availability of technology, we should be able to free ourselves 'from the tyranny of the superficial, pragmatic considerations that dictated past choices about what knowledge should be learned and at what age' (p. 52).

According to Papert (1980), mathematics is a 'living' language which should be learned by speaking, and should not need to have each sentence or section graded as would be the case with a 'dead' language. Mathematics, however, has traditionally been carefully graded at each step — each student's performance on 'sums' being monitored — much as would be the case with a 'dead' language like Latin. Through such passive teaching approaches, mathematics remains fragmented and uninspiring to all but a few students.

With the advent of technology in the mathematics classroom, educators are faced with a choice — either accept traditional approaches to the content and teaching of school mathematics and continue to grapple with finding appropriate ways to teach it — or allow the computer to be used as a 'mathematically expressive medium' (Papert, 1980, p. 53). Figure 1, in which the computer is viewed in the role of a mediator, is consistent with Papert's vision. However, it is clear that, in the 1980s in Australia, not all educators were able to articulate this vision as clearly as Papert.

Integration of Logo There has been a tendency to describe Logo simply as 'a computer language which was created to give children more control and power over mathematical ideas' (Hooley, 1987, p. 17). Although this statement is accurate, it stops short of carrying forward the main thrust of Papert's ideas — namely, that Logo as well as other microworlds have the potential to rewrite the school mathematics curriculum. In his discussion paper prepared for the Ministry of Education (Schools Division), Victoria, Hooley (1987) saw the computer as a multi-purpose tool, and likened it to a pencil:

being used quite informally when we have a task to complete such as a letter, message or note to write, a poem or song to compose, the jotting down of thoughts to ponder at a future date, a calculation or measurement to perform, or simply to doodle and draw with for enjoyment. (p. 11)

Integration of the new technology was interpreted, in the case of the Logo turtle robot, as giving children the opportunity to construct 'extremely complex, beautiful and thought provoking designs... with the child becoming immersed in geometrical concepts, courtesy of computer graphics' (p. 17). Thus, although the discussion paper had talked of the excitement and the apprehension generated by the computer field, and had referred to 'new insights into what the computer offers for curriculum

change' (p. 8), it had effectively calmed the perceived apprehension of mathematics teachers and curriculum developers by indicating how the Logo and the turtle robot could fit in to the existing curriculum. In the words of the metaphor which began the chapter, the room would soon look and feel no different from what it was before the chair had been purchased!

Using the turtle to generate mathematical discussion and visualisation But there are other ways of using the turtle robot with young children. Children are quickly captivated with the power they exercise over the turtle by means of the computer keyboard. Clearly, children can be allowed to explore the relationship between the commands they give the turtle, the tracing on the screen and the movement of the turtle across the floor, but such an activity is likely to involve only a few children, with only one or two of them having any real ownership of the task.

An alternative approach, suggested by Del Campo and Clements (1987), is to ask a larger group of children to suggest a list of simple movements for the turtle — forward, backwards, right turn, and left turn. The children also need to specify the number of 'steps' and the size of the 'angle.' Two other children write down the list of about eight movements, and other children enter the commands into the computer (as a list of commands) but do not press <Return>. All children then place a small marker where they think the turtle will stop after 'walking' through all of the commands. To stimulate discussion, the teacher may suggest that children work in pairs. Once all markers have been placed, the return key is pressed and the turtle begins to trace out the path chosen. All those present have a degree of ownership in the activity, and 'see' directly whether or not the strategies they employed to predict the turtle's destination were appropriate.

Del Campo and Clements (1987) reported instances where, given the freedom to explore, young children went well beyond what they would have experienced in a standard mathematics curriculum. For example, seven-year-old children were keen to reflect on what a command such as '600 degrees right' might produce, and many were accurate in their predictions.

Without such activities, children are likely to find that it is difficult to link the commands they type into the computer with what these mean on a flat two-dimensional surface such as the page of their notebook (if they are trying to think through a Logo program) or the floor (if they are trying to act out for themselves what particular instructions might make the screen turtle do). Furthermore, the mathematical language which emerges as children discuss such situations is an integral part of the process by which links are formed in the children's minds. Such links cannot be formed via instructions from the teacher or from a text, but can only be generated

by the children themselves in an active context of which they are a part. In such ways, Logo presents an ideal microworld to facilitate constructivist approaches to teaching and learning.

The microworld of Cabri-géomètre Cabri-géomètre is a microworld in which students can manipulate geometrical shapes. Balacheff (1990) contrasted a pencil-and-paper mathematics education environment with a Cabri-géomètre environment in the following way:

‘to construct’ in a paper-and-pencil environment means to construct one drawing, whereas in Cabri-géomètre it means to construct a class of drawings. (p. 4)

Thus, in the Cabri-géomètre microworld, students’ reflections on changes which need to be applied to one figure in order to produce a given family of geometrical figures help the students to recognise invariant geometrical relationships. The application of software packages such as Cabri-géomètre in the mathematics classroom therefore challenges traditional pedagogical approaches to the teaching of geometry — with the computer again in a mediating role.

Mathematics projects and investigations The first of the Investigative Project Common Assessment Tasks set for students trialing Units 3 and 4 (Year 12 equivalent) of the Victorian Certificate of Education Space and Number Course in 1990 was to produce a written report on a mathematical investigation of the theme ‘fractals’ (see, for example, Mousley, 1990; Aikenhead and Williams, 1990). At the time, few teachers had any background knowledge in the area, and few secondary school textbooks made any reference to the theme. As Mousley (1990) wrote, ‘most teachers were shocked, horrified and frightened by the thought of having to teach a theme they knew little about, with so little time for preparation’ (p. 52).

Four weeks was the time allowed by the Victorian Curriculum and Assessment Board for the completion and submission of the students’ reports. Although there was certainly no requirement for students to use technology to investigate the fractal theme, some students chose to use the computer as a powerful mediator for performing repetitious calculations and presenting the results in graphical form. As Mousley (1990) commented, ‘many students have the impression that mathematics has not changed for at least 200 years and that they are in classrooms to absorb a set amount of knowledge, rather than to play a part in its production’ (p. 51). The theme and open-ended nature of the investigation implicitly contradicted these long-standing traditions.

Two teachers in two of the 1990 trial schools worked together to describe how Logo had been used to explore the recursive nature of fractals. As an understanding

of recursion is essential if students are to develop an understanding of fractals, and as Logo supports recursive programming, Aikenhead and Williams (1990) described how they built on students' understanding of the Logo environment to develop appropriate procedures for investigating the Koch snowflake and other classic fractal figures. Thus the opportunity afforded by both the theme of the investigation and the mediating environment of the computer meant that relatively simple mathematics could be shown to generate 'a range of startling images' (p. 37). The traditional view of school mathematics had indeed been soundly challenged.

The impact of symbolic calculators in the mathematics classroom The question of whether symbolic calculators such as Mathematica, Derive, and Theorist will encourage students to perform mathematical tasks mechanically, without necessarily understanding the underlying concepts, has been discussed by Lee (1993). He suggested that the controversy over the use of numerical calculators in the mathematics classroom has helped researchers identify the issues which need to be considered in the use of symbolic calculators.

In particular, the opportunities presented by the application of symbolic calculators in the traditional context of school mathematics force educators to face questions such as 'Will the use of symbolic calculators degenerate the learning of mathematics to the manipulation of mathematical symbols only or deteriorate the mathematical thought processes of students?' (Lee, 1993, p. 251).

Answers to questions such as this must await research data — but if research on numerical calculators can suggest any directions for the field of symbolic calculators, then the use of symbolic calculators in the mathematics classroom has the potential to bring about radical changes in the school mathematics curriculum.

Changing the culture of the mathematics classroom The above examples were chosen to illustrate possible settings in which the computer may have a mediating role in the mathematics classroom. However, it is not the particular activity which determines the role of the computer in the mathematics classroom, but rather the nature and quality of student–student, student–teacher and student–computer interactions which take place. For example, Healy, Hoyles and Sutherland (1990) found that, for effective collaboration between two students to take place in a computer environment in the mathematics classroom, the two processes of identification and formalisation of mathematical relationships must be shared between the collaborators. Thus successful collaborations appeared to take place when one student made the majority of the suggestions concerning mathematical relationships or pattern recognition, while the other formalised them on the computer.

Teachers and educators concerned with developing appropriate school mathematics curricula are faced with the challenge of how best to allow the computer to be a catalyst for change. As Bishop (1993) wrote:

Personal technology has negated many of the traditional logical sequences thought to be so essential to mathematical development e.g. calculators are challenging the ideas of sequencing of arithmetic learning, and symbolic manipulation computer software is doing the same for algebra and calculus... Educationally, these personal technologies are putting so much potential mathematical power in the hands of individual learners that developing and examining individual, and particularly creative talents becomes much more of a general possibility. (p. 13)

This chapter began with a metaphor concerning the purchase of a new chair. The purchaser of the chair determines whether the chair is absorbed into the existing culture of the house, or whether the culture of the home is changed because of the new possibilities created by the presence of the chair. It is not the introduction of the computer into the mathematics classroom which is likely to change the culture of the teaching and learning of mathematics — it is the role given to that computer by those who use it which will prove to be of fundamental importance.

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Creating computer– supported learning environments for maths

Paul Newhouse

Abstract

While the number of available educational software packages is increasing at an exponential rate, the quality of instructional design is improving and the number of computers available in schools is increasing, there is still little evidence of the impact of computer–based applications on learning in secondary classrooms. It is likely that the key reason for this discrepancy concerns the implementation strategies or models employed by teachers for embedding computer applications into the learning environments they create. What we need to create are computer–supported learning environments in which computers support both the realisation of a preferred learning environment and the development of learners within that environment.

The value of using mathematical modelling, particularly when applied to real–world problems, for the development of mathematical skills and concepts is well supported by many leading mathematics educators. However, the learning environments required to fully develop this approach to learning have traditionally posed many difficulties for individual students. Typically, they require students to work in groups, to complete computations beyond their skill level, to work independently of the instructor and to complete tasks a tedious number of times. There are many ways in which computer technology can support learning environments appropriate

to mathematical modelling and support learners in gaining the benefits of such an environment.

Introduction

There has been tremendous debate over the past 20 years concerning the role computers should play in classrooms. Arguments such as computers will replace teachers and computers, like television and radio, will come and go in schools, have been expressed. I firmly believe that computers have an important role to play in classrooms and that the 1990s will see that prophecy fulfilled. However, I am also a strong advocate for the necessary role of the teacher and student peer interaction in classroom learning; that is, the total classroom environment. Therefore I am interested in the ways in which computers can support such learning environments, not control or dominate them in the way that Computer Based Learning (CBL) is sometimes envisaged.

If we assume that the environment in which the intended learning takes place is important and that learners need support, then the way in which computers can be used in relation to these contexts becomes significant. Using computers in learning should not be restricted by unproductive debates about the comparative effectiveness of CBL and traditional approaches. Rather, the technology should be used to enhance learning environments that are already known to be effective. I contend that in many cases, as educators, we know what we want to achieve. What we need are the tools to allow us to get on with this. Computers are but one tool to which we might turn.

A new direction in mathematics education is the use of mathematical modelling to develop mathematical skills and concepts (Herrington, 1988). While this approach has a solid educational rationale, it has been slow to evolve in our schooling system. I contend that a major reason for this situation is that it requires a fundamental change for both teachers and students and, in this respect, both teachers and students can benefit from technological support.

A mathematical model may involve representing an environment, problem, situation or concept, whether real or otherwise, with a set of mathematical constructs such as formulae, graphs, vectors, matrices, tables etc. Such a model facilitates the solving of a problem using mathematical representations of the problem and associated solutions. In this way, a mathematical model can be used to help solve a real-life problem. Although the solution to the problem is important to the students, it is

the processes involved in arriving at the solution that are, in many ways, more important. This is a process approach rather than a content approach.

To realistically develop a modelling approach to mathematics learning, the computer is an essential support to both the student and teacher. The computer is needed to allow the development of an appropriate functional environment (Riel, 1989). It is not practical to investigate or implement a large number of mathematical models without computer support and it is also not practical to tackle a wide range of real-life problems without that support. The real question is not whether to use computers for mathematical modelling but how best to use them to support that modelling.

What is 'real-world' mathematical modelling?

Mathematical modelling involves representing an environment, problem, situation or concept, whether real or otherwise, with a set of mathematical constructs such as formulae, graphs, vectors, matrices, tables etc. It involves solving a problem associated with physical life on earth using mathematical representations of the problem and associated solutions.

Although the solution is important for the students, the processes involved in arriving at the solution are in many ways more important. I see the most fundamental processes involved in problem solving using mathematical models as the steps listed in Figure 1. The last two steps are further expanded by Herrington in his presentation of the sequence of processes involved.

In tackling a real-world problem, the student performs a sequence of processes that begins with:

1. Formulating a mathematical model of the situation.
2. Solving the mathematical model which results in mathematical solutions.
3. Interpreting these mathematical solutions against the reality of the problem.
4. Revising and improving the model.

(Herrington, 1988, p. 4)

With average to lower ability students it is often the case that the fifth fundamental step of implementing the model takes most of the students' and teachers' attention. In many cases the teacher chooses the model for the class or discusses the choice with the class. This step involves a number of sub-processes, as shown in Figure 1.

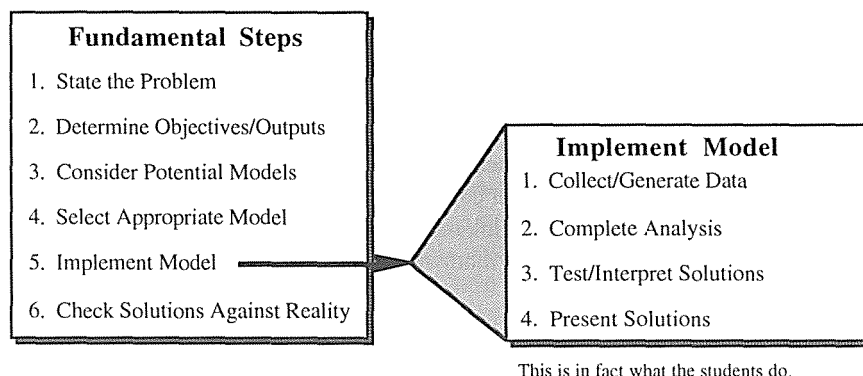


FIGURE 1. Mathematical modelling processes

Each process requires students to develop and use a set of skills, strategies and conceptual understandings. For example, in selecting a model students would firstly need to practise using a series of potential models, determining how they operate and what their strengths and limitations are. Students need to develop skills involved in generating and handling data, completing computations and communicating solutions. They also need strategies for selecting models, gathering data and making conjectures and analysis. Students need to develop working understandings about the real world and methods of modelling it and beliefs about mathematics and its usefulness.

To develop these skills, strategies and understandings, students need to be given appropriate activities, exercises and investigations which are centred on aspects of the problem area. There is some debate as to the difference between an investigation and a 'real-life' modelling exercise. Herrington identifies the difference between the two to be:

An investigation differs from a problem in the sense that students are required to pose their own questions. Questions of the form 'What would happen if?'... lead students to employ mathematical processes such as gathering data, identifying patterns, making and testing conjectures, making and formalising generalisations, proof and explanation and communicating findings. (Herrington, 1988, p6)

I consider investigations to be part of the modelling process in that they develop the skills, strategies and understandings which are required to select, formulate, imple-

ment and test a mathematical model. Since I am interested in lower ability mathematics students the distinction appears unnecessary. I am fundamentally interested in the ability of these students to cope with real and concrete environments or problems. Therefore they need investigative activities in order to become familiar with the 'real-life' problem and the associated model.

Where does the computer fit in?

The question to be addressed here is how best to use computers to support the modelling approach. Should the whole modelling process be presented using computers or are there other roles that computers can play?

At the present stage of software development programs that integrate all the processes of mathematical modelling are few if any. However, programs do exist that aid in the process of solving and refining the model for mathematical solutions. (Herrington, 1988, p. 5).

There is no need for software to incorporate all processes and, in fact, I think this desire to find such software has been a stumbling block for the use of computers in mathematics classrooms. It may be appropriate to use a computer to do only one part of a problem or one process of the modelling approach. If the computer does the task well and is easy to implement and integrate, it is appropriate to use it for that purpose. The ideal is to have the hardware and software available to be used by students when it is clear (obvious) to them that it is needed to assist efficiently and effectively in one or more of the processes (or steps) described earlier.

Computer support should only be used if it improves productivity (i.e. improves quality or quantity of output) or allows a process to be done which could not realistically be done in any other way. As I have said, the computer does not have to be the centre of the modelling process; it may facilitate part of a modelling experience such as being an investigative or computational tool or used to check and present solutions, as indicated below:

- Model a real environment (e.g. Logo environment).
- Investigative tool:
 - generate data for model;
 - assist in analysis.
- Computational tool.
- Check solutions.

- Presentation/communication tool.

The modelling approach to mathematics usually involves individual or group-based projects. With each such project students typically have difficulty with at least one task which may then inhibit their overall progress or reduce their motivation. They often became frustrated with tasks which require a low skill level but consume a large amount of time; for example, continually erasing and redrawing diagrams. These types of tasks then become an ideal application for computer support. In addition, a fundamental problem at all times is lack of student familiarity with the realities of real-world problems. This may also be an area where computer information packages can be used to provide supplementary information. The computer offers a range of useful tools which assist the modelling approach and make the approach substantially more viable.

Creating computer-supported learning environments

Fraser and Walberg (1991) describe a classroom environment as the social-psychological contexts or determinants of learning within the classroom. It is clear that the concept of classroom environment is central to the implementation of computer-supported learning environments (De Corte, 1990, p. 70). The important questions concern the effect of the introduction of computers into the classroom environment and whether any changes are perceived to be positive and assisting in the creation of desired attributes of the classroom environment by students and teachers. The steps to developing a computer-supported learning environment are, broadly considered:

- Identify potential for computer support:
 - Where are the obstacles to learning or low productivity?
 - What type of tools do students want or need to use?
- Select appropriate software.
- Organise access.
- Select appropriate implementation model.
- Manage the implementation.
- Evaluate success.

I have argued previously that there is tremendous potential for computer support in activities associated with mathematical modelling, particularly for lower ability students. Providing that appropriate software can be located and access to computer hardware can be organised, the next most crucial factor to consider is the selection of an implementation model and managing that implementation.

Implementation models

It has become clear over the past decade that the successful use of computers in learning is dependent more on the implementation strategy incorporated by the teacher than the actual hardware and software used, or even the association of the software to the task (Van Den Akker, Keursten, and Plomp, 1992). It is convenient to classify implementation strategies by model types and associated parameter values.

I will consider 'implementation model' to mean the characteristics of the method by which computer use is integrated with the implemented curriculum. It is, therefore, concerned with the expected roles of the computer system, support materials, teacher and students within the classroom and the manner in which it is intended that these entities should interact with each other to create the planned learning environment and outcomes. I define three main types of models: Whole-Class, One-to-One, and Group-Work Support, represented in Figure 2 (Newhouse and Oliver, 1989). The choice of implementation model depends on the hardware and software available, the task and the type of interaction desired.

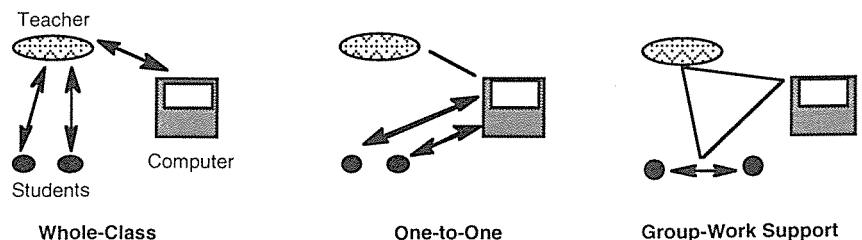


FIGURE 2. General models of implementation

The particular model adopted as the implementation strategy will fit one of the outlined model types but will have specific parameters associated with the strategy. Typically, the model parameters I consider are: Location, Task Direction, Required Student/Computer Ratio, Access and Operating Instructions. These parameters and their possible values are given in Table 1.

TABLE 1. Implementation model parameters

Location	laboratory or classroom
Task Direction	teacher, computer or student
Required Student/Computer Ratio	for example, 3:1
Access	unlimited, roster or self-selecting queue
Operating Instructions	demonstration, on-line, text, peer tutoring or presentation

Variously the teacher's role is that of planner, facilitator, monitor and evaluator. Van Den Akker, et al. (1992) found that the interaction between teacher and courseware and the design of support material were crucial to the successful implementation of computer-supported learning. The teacher aims to:

- provide learning tasks and directions (e.g. worksheets); that is, set the scene, indicate when computer support is needed and enhance student motivation;
- provide access to computers when and where needed;
- provide operational instructions for software;
- provide support for both computer operation and task completion. It is hoped that for most of the time this will involve discussion of the task rather than the tools;
- monitor student progress (e.g. set checkpoints).

Conclusion

Clearly, teacher characteristics are the most significant determinants in whether classrooms will involve computer use and what types of classroom learning environments are developed. Teachers often have difficulty making use of computers in their classrooms and require significant levels of support. Van Den Akker, et. al. (1992) assert that the interaction between teacher, courseware and the design of support materials is crucial to the successful implementation of computer-supported learning. It is likely that successful learning environments incorporating

computers will be those in which computer use is: optional; associated with significant rather than peripheral, activities in the course; available when and where it is needed; and focused on tool applications. The appendix contains an example of the implementation of a teaching/learning strategy, making use of a computer-based tool designed to assist in the development of a successful computer-supported learning environment.

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Appendix

An example modelling project: orienteering

The problem Prepare the map and instructions for an orienteering course around the school grounds. The course must start and finish at the same place, have at least six straight legs, be at least 500 metres long and involve a question to ask at the end of each leg.

Objectives of student project:

- To interpret the information supplied on a map with contours in order to design an appropriate orienteering course.
- To present a two-dimensional plan, on the map, of the orienteering course.
- To develop a set of instructions and questions for participants completing the orienteering course.
- To check the accuracy of the course and readability of the instructions and questions.

Overall strategy This project takes the equivalent of about 7 x 40-minute sessions of class time. It requires a photocopy of the map of the area (e.g. school) available for the orienteering course, compasses (one per group), measuring devices such as trundle wheels and a computer program called *Orienteer*. This program operates on the Apple Macintosh or within Microsoft Windows 3.0 on an IBM-compatible computer; it will also run on an Acorn Archimedes or Acorn RISC-PC, appropriately configured. There are a number of stages to the project; an example of the likely tasks and processes that might be included in each stage is shown overleaf.

Computer implementation strategy The computer is used as a tool to check each group's course and provide feedback. It also has an assessment role in providing a numerical value representing how accurate the instructions provided by the students are. A group-work support implementation model seems appropriate with a self-selecting queue providing computer access. In this way only two or three computer workstations with a printer are required to serve a class of 20 to 25 students. An initial whole-class demonstration allows students to see what the software can do for them and motivates them to want to use the software. Specific operational instructions are best provided by giving individual help to the first few groups and then allowing peer tutoring. The internal documentation with the software can also be relied upon.

Tasks and processes

Introductory Exercise (2 sessions)

- Explain to class what is involved in the project. Provide a copy of the project instructions.
- Two possible introductory exercises to practise bearings and distances are:
 - completing a four-leg practice course on the school oval, using compasses for direction and paces for distance); or
 - drawing a scale diagram of the classroom (10 paces = 1 cm).
- Give students a revision worksheet on calculation of bearings.

Drawing Activity and Initial Measurement (1 session)

- Students sketch a map (in pencil) of their proposed course and prepare a record sheet to contain their bearing and distance measurements.
- Students go outside with compass and any distance measuring devices required (many students may decide to use paces) and accurately determine the bearing and distance for each leg of the course.

Checking Accuracy [Use of Computer] (1 or 2 sessions)

- Students enter bearings and distances into computer program, ORIENTEER, to check accuracy. If necessary they can get a printout.
- Students re-measure any legs which appear to be inaccurate and perhaps check on computer. (This process can occur a number of times.)
- Students walk over course and determine a question to ask at the end of each leg (this is to check that participants reached the correct end point).

Trying Out the Courses (1 or 2 sessions)

- Students include questions with instructions (bearings and distances).
- A copy of each group's questions and instructions is given to all other students. The students try each course, complete the questions and write a comment about the course and its instructions.

Preparation of Report (1 session)

- Students may paste computer printout to back of map.
- Students hand in: map; instructions; questions; results of other students trying their course.

Teaching and learning writing with computers

Ilana Snyder

Abstract

This chapter discusses the potentially powerful role computers can play in language and literacy classrooms, particularly in the teaching and learning of writing. With computers, students can develop their writing skills in exciting, engaging and liberating ways. Any enthusiasm for electronic writing is counterbalanced, however, by the recognition that computers may be used to support different, even competing, pedagogies. Thus it is the responsibility of classroom teachers, curriculum planners, school administrators and policy makers to decide if, how and for what purposes computers are used in literacy education.

The chapter is divided into two sections. The first examines a number of computer writing applications which have the greatest possibilities in language classrooms: word processing, CD-ROM, hypertext, e-mail and networking. Included are research findings which illuminate our understanding of the effects of these computer applications on students' composing processes, the texts they produce and the sociocultural contexts of the classrooms in which they're used. Also considered in the discussion of these applications are suggestions for useful ways in which computers may be integrated into the culture of literacy classrooms. The understanding common to the consideration of all the computer writing applications is that they are as effective as the teaching and learning environment in which they are located.

The second section explores the use of computers as part of the processes of change associated with innovative practices in education. It suggests that a new classroom environment is created when computers are introduced: interactions among the participants are affected and reorganised, and a new system of possibilities and social demands is formed to which all have to adapt. The use of computers for writing often challenges teachers' prior learning and classroom practices, and requires the acquisition of new skills as well as new definitions of teacher and student roles. The computer-mediated writing classroom can be one in which not only the students are active learners, but also one in which teachers function as curriculum creators or innovators in their own classrooms.

Introduction

When computers are integrated into the culture of the English classroom, the teaching and learning of writing have the potential to alter significantly. For both teachers and students, the computer-mediated experience can be qualitatively different, often better, than with pen and paper. Indeed, with computers, students can develop their writing skills in exciting, engaging and liberating ways.

In this chapter, I discuss the important role computers can play in English classrooms. Any enthusiasm for the advantages of computers, however, is tempered by the recognition that the technology's capacity to enhance students' writing abilities is not automatically guaranteed. Computers may be used to support different pedagogies and social practices; they can be used for change or to retain the ways things have always been. For to a large extent, computers represent a neutral technology: the political and educational ideologies of individuals, systems and institutions determine the practices surrounding their use. It is the responsibility, therefore, of classroom teachers, curriculum planners, school administrators and education policy makers to think carefully as to whether, how and for what purposes computers are used in literacy education.

The chapter is organised into two main sections. The first focuses on computer writing applications which have the greatest possibilities in English classrooms: word processing, CD-ROM, hypertext and electronic communications, including e-mail and networked classrooms. Word processing is given the most attention as its use is connected with significant changes to writing practices. Moreover, the basic features of word processing are intrinsic to all the electronic applications considered. Incorporated in the discussion are research findings which illuminate the effects of the applications on students' composing and reading processes, the texts they pro-

duce and the sociocultural context of the classrooms in which the writing is generated.

The second section explores the use of computers as part of the processes of change associated with innovative practices in education. It argues that the use of computers for writing often challenges teachers' prior learning and classroom practices, and requires the acquisition of new skills as well as new definitions of teacher and student roles. The computer-mediated writing environment is considered as a context in which not only the students are active learners, but also one in which teachers function as curriculum creators or innovators in their own classrooms.

Before beginning the discussion, however, I need to position myself as author in this chapter. I'm an ardent user of word processing. I'm committed to composing directly to a computer. In fact, I can no longer write anything more substantial than a shopping list without one. I'm also a dedicated user of electronic mail. I look forward to my daily exchanges with the same anticipation I once reserved for the postal delivery. My most recent electronic passion is hypertext, which enables playing with reading and writing practices in ways entirely suited to a post-modern world. But I am not a 'technophile', nor am I a computer expert. My research interest in the area of computers and writing reflects my conviction that language teachers need to recognise the enormous changes to literacy education heralded by the information revolution. They cannot afford a Luddite evasion of a technology which is integral to students' literacy development and futures. They need to think carefully about effective ways in which to harness the computer's capacity to enrich the teaching and learning of writing.

My inaugural encounter with the electronic technology was in the computer lab of the Harvard Graduate School of Education in 1986. It was the Spring semester and I was taking *Computers and Writing* offered by Colette Daiute. I chose this course believing that as a woman and as an English teacher I should learn about the computer technology which was greatly affecting reading and writing culture both in and out of schools. The program included a weekly lecture and a two-hour lab session in which class members were expected to explore a range of software applications suitable for literacy education. Access to the technology-rich lab was unlimited so I spent many hours there each day learning about computers.

Those first weeks were a struggle. Although I had taught myself to type ten years earlier on a Corona electric typewriter and could manage 25 words a minute, I had no understanding of what computers could do, nor how they did it. The first task for the course was to write a critical comparison of two word processing programs. It

was through this assignment that I began to grasp the generic functions of word processing and to reflect on how the packages realised them differently.

I completed all of the required writing for the course on the computer. Initially, composing directly onto the machine was difficult: I had to juggle the competing cognitive processes of learning how to use the technology and striving to make meaning in a written text. Accustomed to the notions of the page, note-cards, books and filing systems, I had to adjust to text displayed on a screen, recorded in the computer's memory, stored on a disk. However, once I felt confident that I could save text effectively and consistently, manage basic editing procedures, and move and copy text, I began to experience the advantages the technology offered me as a writer. I could experiment with the sequence of a piece by 'cutting and pasting' electronically. I no longer dreaded making a significant mistake which, with pen and paper, would have required me to begin typing a page again. Above all, I welcomed the phenomenon of having to enter text only once: I was freed from the arduous process of recopying the entire text, which I had always resented.

By the end of the course, I was a convert to word processing. I had begun to find the experience of writing with a computer intensely absorbing — if interrupted while concentrating on the computer screen, I felt as though I'd been brought back from another world. I had imagined myself to be a classic humanist who scorned, or perhaps, more accurately, feared, all things technical. In my rarefied world of language and literary studies, there was no place, no need, for computers. However, I had now entered the temple of technology and was seduced by what it offered me, not only as a writer, but also as an educator. In this chapter, I examine just what computer writing technologies offer teachers and students as writers.

Electronic writing applications and practices

The very first decision which must be made by English teachers is whether or not to introduce computers into the writing classroom. There are a number of persuasive arguments which may serve to convince them to avoid computers, particularly if they are predisposed to reject the technology. One is the high cost of computers as an initial investment (Moran, 1993). Moreover, these costs may persist if accompanied by a desire to keep up with the latest developments. Another is the frustration often associated with their use, especially when there is no technical support. A further argument is that the use of computers tends to isolate students, removing them from the group to stare at video screens and to perform automated drill and practice, depriving them of the rich interactions which constitute an integral component

of successful language classrooms. And finally, there is the seemingly contradictory research information about the computer's effectiveness as a writing tool (Hawisher, 1989; Snyder, 1993a). Some teachers feel that if the expenditure is so high, there should be, at the very least, a guarantee of improved writing quality. Of course, there can be no such guarantee.

Why then should teachers and schools consider providing students with access to computers for writing purposes? The response to this question is complex. It is to do with making teaching and learning writing more potent and enjoyable, but it is also to do with energising the processes of change in the social and textual practices of the English classroom. In the discussion which follows, a number of intriguing computer writing applications are considered within the broader frame of educational innovation. As teachers become more confident and experienced with these technologies, they will begin to redefine teaching and learning practices in a computer-mediated writing environment.

Word processing

Word processing remains the most commonly used computer writing application in English classrooms. It is the one with which teachers feel most comfortable even though the majority would exploit only a fraction of the software's capabilities. To many teachers, word processors are still instruments through which writing may be stored, slightly amended and printed; to others, word processing provides the means by which thoughts, ideas and concepts can be formed, shaped and developed in ways never possible with pen and paper.

Computers equipped with word processing software control the creation, storage, retrieval, modification and presentation of text. The computer provides the student writer with a flexible, fluid composing environment. Ideas can be creatively combined, rearranged and revised. Word processing can release student writers from the impulse to produce words in a more or less linear progression. When writing with computers, student writers can learn how to exploit the computer's capacity to move backwards and forwards in the text, to attend to different parts more spontaneously.

Word processors support school writing in a number of important ways. They can encourage students to generate ideas and text (Snyder, 1992, 1993b). Without the fear of making an indelible mark, students can explore their ideas and manipulate their words easily. The fact that the text on the screen lacks permanence encourages students to experiment, a process which is central to revision and learning (Snyder, 1992). In a word processing environment, a number of good writing strategies get

substantially easier. For example, the ability to move into a working draft from any kind of pre-writing activity such as free-writing, notes and outlines makes turning early thoughts into writing a useful and purposeful exercise (Balestri, 1988).

In the fluid writing environment offered by word processing, students do not necessarily perceive planning, composing and revising as discrete stages to be worked through in a linear direction. Rather, the three recognised phases of writing blend in a peculiar fashion (Balestri, 1988). Indeed, well before computers arrived on the scene, writing theory and research informed us that the stages of the writing process are not discrete and that writers move in and out of them in complex, recursive patterns. However, with word processing, the writer's capacity to respond to writing problems and decisions in a truly recursive fashion is made even simpler (Catano, 1985).

Word processing also manifests another phase of writing, presentation. In thinking about presentation or representation, student writers' awareness of audience is heightened by visualising the product to which readers will respond. Student writers have the choice of a variety of fonts and formats; they can see what the words will look like in print at any stage of the writing process. With word processing, they have to think about the visual aspects of composing. They have to consider page layout and design: columns, margins, tabs, fonts, pitch and point size. The graphic dimensions of writing become important, no longer just a distraction from the more serious task of using written language alone to express and develop complex ideas.

Notions of the draft and drafting change when texts are computer-generated. The shift in meaning of these concepts in the context of computer writing raises a number of important questions: Is a draft the last saved version of an evolving text on a particular day? Or is a draft what the writer prints out at the end of a writing session? Does the injunction to student writers to produce a number of drafts of a text have the same significance when the computer is used? The draft, and the practice of drafting, which have become part of a process writing orthodoxy, need to be re-scrutinised and re-evaluated for their usefulness in the context of fluid, continuously altering, computer-mediated writing.

With computers, students have to key in text only once. Although it has been argued that the process of recopying can be instrumental in generating important changes to an evolving piece (Daiute, 1986), probably the most significant benefit the computer offers student writers is release from a tedious, unpopular task. Theoretically, they have more time for revising and improving the text, not only editing

it. A distinction is made here between 'revising' which consists of meaning-level alterations and 'editing' which involves surface-level changes to text.

Whether or not students actually use the time saved from recopying for revising, however, seems to depend on the teacher. Without teacher intervention and encouragement to revise, and direct instruction in effective strategies for revision, student writers tend to write longer but not necessarily better texts (Daiute, 1986; Snyder, 1993b). Students may submit what is essentially a good-looking edited, but perhaps unrevised, first draft (Sudol, 1991).

This apparent reluctance by student writers to take advantage of the flexibility the technology offers and to make substantive changes to text is perhaps because the neatness of computer-generated print, both on the screen and in hardcopy, creates an illusion of 'publishable' prose. Paradoxically, they may spend even less time than with pen ensuring that the text is thoughtful and well argued. Alternatively, they may fall into the editing trap in which they concentrate on minor editorial changes at the expense of major revisions of thought and organisation.

When teachers engage in direct teaching of writing strategies, they can be assisted by the use of word processing. The technology that allows the projection of the monitor display onto a large, overhead screen enables teachers to highlight the unique facilities word processing offers writers. So that students make good use of the technology, teachers can give direct instructions in how to access the word processor's capabilities. With the overhead projection of the computer screen, they can show that text may be manipulated easily as changes are decided upon. Further, in the context of a genuine writing situation, teachers can reveal what writers think about while composing. By articulating their thinking processes out loud as they generate text, teachers can expose the choices writers make when solving the problems of forming sentences, clarifying ideas, and finding words. This particular use of the computer represents a dynamic electronic realisation of how writers make meaning in a text. It may serve to demystify writing processes in an illuminating and compelling way.

Thus word processing can be used to extend students' understanding and practice of composing. It can also be used merely as a fancy typewriter: students write their pieces with pen then have access to the machine to transcribe the text for printing the good copy. However, even minimal computer resources do not mean that the technology must be used in this limited way. When there's only one computer in the classroom, students may not have as much access as they'd like. But when available, it can be used to compose directly, either individually or collaboratively.

- Despite the fear that the use of computers will isolate students, research has shown that there is increased participation and collaboration among students and teachers when they are used (Groundwater-Smith, 1992; Snyder, 1994). Electronic classroom environments encourage cooperative encounters in which teaching and learning are shared by teachers and students. Shifts in the responsibilities of students and teachers are a direct outcome of this change in the power relations of the classroom (Snyder, 1994). In response to these shifts, teachers may become more receptive to student ideas and expertise.

However, it is not the computer itself which decentralises authority in the classroom and alters the power relations within it. Research suggests that the tool does not function as an independent variable impacting on students and teachers. Rather, it becomes part of the pattern of social interactions and culture of the particular classroom. The effects of computers are always mediated and altered by the particular sociocultural context within which they operate. So if the teacher sees value in collaborative work, the computers have the capacity to facilitate such learning patterns.

Using word processors for writing shapes the ways teachers think about teaching and learning writing and also shapes the ways student writers understand and practise writing. As Cochrane-Smith, Paris and Kahn (1991) concluded from their investigation of beginning writers learning to compose with computers, initially teachers use the technology to support their usual goals for achieving students' writing development. They adapt the use of the computers to fit their ongoing programs. Over time, however, the computers also shape the practices of the teachers. Eventually they restructure some of the social processes of their classrooms and develop new ways of seeing and thinking about students as writers. What emerges is an interactive relationship between the writing contexts teachers and students construct, on the one hand, and the capacities and requirements of word processing, on the other.

Overall, the word processing research findings highlight the progress which has been made in thinking about computers in English classrooms. It is no longer assumed that the word processor is in some way intelligent or capable of teaching writing skills independent of human input. Rather, it is now seen as a far more adaptable and flexible technology for writing than those used for hundreds of years. It's recognised that when the technology's capabilities are carefully integrated into the social practices of the writing classroom and decisions are made as to how to exploit its potential, positive changes can occur.

CD-ROM

Most schools have at least one CD-ROM (Compact Disc – Read Only Memory) drive attached to a computer. A CD can carry far more text, pictures, sound and video than a floppy disc. For example, a floppy disc could carry the contents of one telephone directory whereas a CD could contain the contents of all the directories in Australia.

Dictionaries and literary texts are already available on CD-ROM. The CD version of the *Oxford English Dictionary* is not only cheaper, much to the chagrin of book publishers, it is also capable of far more. For example, it is feasible to search by definition for a word or to identify all the new words added since 1991. There is potential for learning about language not accessible to students before. The works of Shakespeare, newspapers and comprehensive poetry resources are also available. And this is just the beginning. Teachers will want access to the resources offered by CD-ROM in their classrooms and this is practicable if the school is networked, as discussed below.

CD-ROM has significant implications for reading and writing practices in the English classroom. Some teachers, however, have been critical of the computer screen as a place from which to read text. It is evident that appropriate amounts of text, size, font and the use of colour need further investigation (Haas, 1989). However the same criticisms were probably made of the first books when they replaced rolls of parchment. Bolter (1991) has pointed out that these rolls were read from top to bottom very much as a computer screen. It seems that it is largely a matter of what we expect when we read and write and what we are accustomed to which shape at least our initial response to new technologies.

Hypertext

Hypertext refers to non-sequential electronic writing — text that branches and allows choices to the reader. Hypertext, by definition, must be read at an interactive screen. Hypertext is a series of text chunks connected by links which offers the reader different pathways. It is both an author's and a reader's medium. A hypertext system allows authors to link information, create paths through a corpus of materials, annotate existing texts and cross-reference with other texts. Readers can browse through linked, cross-referenced, annotated texts in an orderly but non-sequential way (Tuman, 1992).

The term 'hypertext' refers to both the process of reading large amounts of digital information and the organisational structure of that information. These two dimen-

sions of hypertext are inextricably connected (Sefton–Green, 1993). A hypertext program can be used to create pieces of text, pictures, and in more advanced versions known as hypermedia systems, moving pictures and sound sequences. All of these elements can then be linked together in a network of connections, so that at any one point in the network users can choose which pieces of information to access next. The hypertext that users encounter can be created by someone else so that it is fixed, it can be written from scratch, or it may be a modifiable hypertext which can be extended or rewritten.

A hypertext can be designed to be as open or closed as the writer wishes: users may be tightly constrained within networks with few links at each point, or very open with plenty of alternative routes through the network. It is impossible to write hypertexts without considering how readers will encounter the material and it is impossible to read them without to some extent realising the limitations of their format. Ultimately, a hypertext is limited by the number of texts it contains and by the choices the writer has made as to which to include and which to omit.

To explore how this practice is different from reading a book, consider the following example of a modifiable hypertext: You sit in front of your screen and call up a novel by Henry Handel Richardson. The title, *The Fortunes of Richard Mahony*, appears on your screen in a menu surrounded by all the other works by Richardson, along with other texts such as biographies, histories of Australian literature, studies of other illustrious female writers who assumed male pseudonyms, maps of Victoria and the Goldfields, clips from documentary films on the Goldrush period, contemporary poetry and art. You can browse through any of these ‘texts’ or alternatively open *The Fortunes of Richard Mahony* and read. When you are reading the novel, you can go off at a tangent by clicking on a *hot* word or button (perhaps highlighted by bold print) that interests you so that you could proceed in directions of your own choice. You could even add a text of your own which becomes part of the web. Of course, you may not want to read a book the length of *Richard Mahony* on–line, not least because it is neither practical nor comfortable. For the present, it seems to depend on whether the reading is a formal and deliberate activity as opposed to an informal reading for pleasure. However, there are those who predict a future in which there are no printed books, a future in which all reading will be on–line.

A hypertext, then, is the interconnected world of the possible texts on a particular subject. In moving around the hypertext, the reader is not confined to the structure of the linear narrative text. A traditional text provides readers with only one path, the author’s, through a given body of information. A hypertext is what each reader makes it. Every reader of a hypertext is in a sense an author, tracing an individual

pathway through the material (Landow, 1992). Current critical theory emphasises reading as an active process and identifies the ways in which meaning relies upon inter-textual links and references. Hypertext seems to embody on the screen what it is readers do as they read.

As yet there is little empirical research on hypertext. In the main, articles and books on hypertext represent accounts of enthusiastic personal use, and of courses which have integrated the software effectively. Joyce (1988), for example, argues that the basis of creative thought lies in our ability to make connections and that the inestimable value of hypertext rests on its ability to represent information in the same fluid way we use it in the course of ordinary thinking. Hypertext breaks down the linearity of traditional text and replaces it with a non-sequential and multidimensional text, a process which radically alters the connection between reader, author and text. Bolter (1991) describes students using hypertext to read and write the kinds of playful, associative stories that can be created only with such a program. For Landow (1992), a fully developed hypertext system provides readers with access to a comprehensive range of historical, literary, textual and biographical materials that may serve to enrich students' reading of literature. Readers move from screen to screen establishing a web of relations (Landow, 1992): they can come to understand the interconnectedness of literature, history and art.

Communicating with computers

Using computers to communicate is a relatively recent phenomenon. At the school level, computer-mediated communication (CMC) is still a new and little used facility, though interest and experiment are growing. Teachers are increasingly thinking in terms of local and wide area networks. File servers, modems and telecommunication networks represent the hardware; electronic mail, information services and computer conferencing represent the software. As with all the electronic writing applications considered, on its own CMC offers very little. It is up to the teacher to envision uses for the classroom.

Electronic mail Linking computers into a telecommunications system provides a means for people to exchange written messages across distance, to get information from remote databases or to join in the shared construction of one. Educational networks or groups can be created over local, national or international networks. Local Area Networks (LANS) can link individual terminals by cable within a campus or building; Wide Area Networks (WANS) can connect together individuals or schools over large distances, nationally and internationally. The technology needed for electronic communication is a telephone line linked to a central computer, a compu-

ter with a modem to link it to the telephone and the appropriate software for word processing and communications.

The ability to communicate between computers via a telephone line and a modem has created some very interesting classroom ideas. It offers the opportunity to provide real audiences for students' writing. This can take the form of simple pen-pal activities. It can also be exploited, as Moore and Tweddle point out:

... to collect examples of dialect from around the world, to create and sustain a 'real time' adventure game which can be tailored to suit the curricular needs of specific groups of children and to create a context where cultural differences can be explored in meaningful ways. (Moore and Tweddle, 1992, p. 17)

This technology is still far from being widely used in schools. However, in Victoria, Victorian Certificate of Education (VCE) information and results already travel between schools and the Victorian Board of Studies (VBOS) electronically. With the technology available, there is the potential there for students' texts to be transmitted to other schools and to other countries. Further, the possibilities are not limited to school-age students. Pre-service students in the Faculty of Education at Monash University have linked electronically with a similar cohort at the University of Saskatchewan, Canada. The intention is that they use the medium to discuss theoretical and pedagogical issues surrounding the use of computers for writing.

Networked classrooms When computers are networked students can 'talk' to each other. Two sorts of programs enable this: a simple word processor and a conversation program of some sort. The networked classroom connects student writers directly with each other. It is important in providing opportunities for students to communicate through reading and writing immediately with other people in different locations, both synchronously and asynchronously. It is also important in providing students with the opportunity to communicate in real-time with each other rather than with their teachers.

Networking provides 'the equivalent of the face-to-face meeting, in which what is said by each is heard by all' (Scrimshaw, 1993, 94). It thus provides a new forum for collaborative learning, giving members access to the views of others in a form different from the face-to-face encounter. Computer conferencing is perhaps best seen not simply as a new form of written communication or a new form of 'spoken' communication, but as a 'novel hybrid containing features of both and still visibly evolving its own conventions' (Scrimshaw, 1993, 94).

As with hypertext, to date there has been little empirical research on networked classrooms and CMC. Enthusiasts seem convinced that the networked classroom is

intrinsically more democratic than the traditional classroom. I would argue, however, that as with all computer writing applications in the classroom, networking can provide a more efficient extension of existing instructional practice or it can be used as a radical alternative. The networked classroom can facilitate what is currently seen as central to an effective writing classroom: texts can be presented for discussion and peer review; they can be exchanged in and out of class; texts can be written and edited in and out of class; texts can be annotated by teachers and students. However, the networked classroom can also serve to transform the traditional roles of teachers, students and texts; it can remove the teacher from the centre and allow students to pursue their own interests in their writing. In such an environment there are no isolated authors, no privileged texts, only equal, actively engaged readers and writers. The teacher's voice is just another voice easily disguised by the use of a pseudonym. The students write to and for one another, not for the person up the front.

While the teacher may have set up the class and be maintaining the structure, the actual discussion that forms the basis of the class proceeds independent of teacher control. In this regard, the networked classroom represents a new form of interaction as well as a new means of organising instruction. Indeed, advocates believe that the networked computer classroom can create a strong sense of community among both students and teachers (Handa, 1990). They claim that this sense of community develops a true network that allows for freer communication between writers (Handa, 1990).

Meeting the electronic challenge

The use of computers for school writing 'portends new possibilities' (Olson, 1988, p. 121). Integrating the technology into the English classroom challenges teachers to appraise the ways they deal with the experience of literacy education for their students. As they devise and revise ways to utilise the capabilities of computers for writing, they also have to think about how they exert influence in their classrooms. They have to think about their instructional and organisational strategies and experiment with alternative approaches. It is asking teachers to be reflective about their practices, to reappraise them.

Developing a coherent set of well-articulated teaching practices which incorporate the use of electronic writing applications, and reflecting on the teaching and learning experiences of the participants in the electronic environment, can be a significant educational process. It facilitates ongoing professional development and can

lead to change and improved practices. Another way of explaining this process of change is to represent it as a dialogue which is established between existing routines and innovative practices (Olson, 1988). What may emerge from this continuing dialogue are new pedagogies and better learning based on the effective combinations of software, hardware and social support.

Clearly, there is not one way in which to use computers effectively in the writing classroom. The computer may be used in ways that differ significantly from classroom to classroom, from school to school. The ways in which they are used interact with the goals and curriculum of particular teachers with the result that students will not have uniform experiences across classrooms or even within them. Such uniformity is not even desirable. Indeed, if we believe that classrooms are interactive and communicative cultural environments in which teachers and students together construct and reconstruct understandings, then difference is inevitable and appropriate. Teachers' ways of using computers for writing in the classroom are closely related to their responses to the particular computer application, their assumptions about effective teaching, students as learners and the nature of language and literacy development. Teachers have to consider what they expect students to learn in the writing classroom and what to accomplish. They need to consider how computers might help them meet their goals for students' writing development.

The introduction of computers into the English classroom as part of curriculum innovation can be particularly effective when teachers play key roles in the implementation. However, curriculum change in which teachers adopt a central role takes time. Teachers have to think through their beliefs about computer writing applications as appropriate technologies which fit in with their goals in a writing program. Reflective teachers can try out ideas in their classrooms, observe the effects carefully, and then revise their strategies to explore the possibilities for improved writing practices that computers offer for themselves and the students.

For pre-service teachers, the point is a similar one. The excitement and enthusiasm often associated with innovative teaching and learning practices are important; indeed, they are often productive and generative. However, these forces are most effective when accompanied by reflectiveness, and a willingness to discuss experiences with colleagues. These processes form the foundation of a strong pedagogy for the English classroom, for teachers to learn together, to constantly reconsider what they do and to reflect on what it is that they value in their classrooms. It is the teachers who determine the teaching practices not the technology. It is through these considered experiences that teachers can begin to develop new traditions for

teaching literacy, traditions which exploit the potential of the new technologies to enhance writing practices.

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Using a concept keyboard to improve young children's writing

Martyn Wild and Jenny Ing

Abstract

Many children do not find it easy to write. They may have difficulty with finding ideas, with sentence structure and maybe even with the mechanics of writing. The demands of using correct structure in functional writing, considered to be the most important form of writing for children to learn, make such texts even more difficult to create. The use of a concept keyboard as an alternative input device for word processor use has the potential to help children structure their writing better. This chapter describes an ongoing research study investigating the value of using the concept keyboard as a device to assist children in creating functional texts. The methods used in the investigation are described towards the end of the chapter.

Introduction

Not all children find writing easy. The range of perceived difficulties is broad (Cambourne, 1988; Goodman, 1986; Graves, 1983; O'Brien, 1992; Perera, 1984; Snowling, 1985; Walshe, 1981). For example, children may have trouble with the creation or development phase of writing; they may be able to dictate texts but show reluctance to put their thoughts on paper because of inept handwriting (Butler

and Turbill, 1984; Graves, 1983), poor spelling, or structural difficulties with sentences and paragraphs (Snowling, 1985). In particular, children often have difficulties with writing the common forms of functional texts¹ such as letters, invitations etc. (Christie, 1986; Collerson, 1988; O'Brien, 1992). Indeed, with the writing of functional texts most children appear to need assistance with structure (Christie, 1986; Collerson, 1988; Rothery, 1992; Sloan and Latham, 1992). As functional texts are those most likely to be used in everyday written communication in childhood as well as in adult life (Collerson, 1988; Wing Jan, 1991), it will be useful to identify means by which a teacher can assist children to learn the necessary skills for writing these texts. The remainder of this chapter explores the notion that the concept keyboard might be of particular value as a device to assist children in learning such skills.

Children's writing

Over the last 20 years or so, there have been dramatic developments in approaches to researching and teaching writing. A large number of these changes can be related to a shift in emphasis from the product to the process of writing (Graves, 1975). In this, the work of Graves has been seminal: he suggested that writing was not a single event but rather a process, during which a text might be drafted, discussed, edited and re-drafted a number of times before it was considered to be complete (Graves, 1981). In addition, there has been parallel interest shown in the importance of social context in learning writing (Heath, 1983; Vygotsky, 1978). Both these changes continue to exercise a significant influence on writing pedagogy.

It has been traditional to describe text in various ways and for many years it has been held that of the four broad types of written text (i.e. narration, description, exposition and argumentation), exposition is the type most commonly used in the world at large (Kress, 1982). However, Kress infers that this is not reflected in the teaching of writing and that creative writing is taught to the detriment of more useful writing types; he asks:

1. Texts of an expository nature are frequently referred to as being of the *functional* or *informational* genre and such texts are as described by Perera (1984, p. 216), as those 'used to get things done in the real world, to inform, advise, persuade or instruct'. These texts include recounts, reports, procedures, instructions and explanations.

How many school leavers will be called on to become 'creative' users of language... users of the genres most highly valued in the school, the 'poetic' or literary genres? (Kress, 1982, p. 125)

Indeed, it has been said that the writing most often undertaken in primary schools in particular, is of the narrative type (Collerson, 1988). Collerson has explained that in primary schools, writing has become synonymous with 'story writing', largely since stories play an important role in the lives of primary school children and because the word 'story' is so often used as a name for the writing session. When writing is treated as a curriculum 'subject', the idea of writing taking place in all areas of the curriculum can easily be lost and writing becomes mostly narrative (Collerson, 1988, p. 6).

In addressing this situation, there has emerged a school of thought that suggests children should have the opportunity to write many different kinds of texts in all years of their schooling, particularly texts of an expository nature (Collerson, 1988; Derewianka, 1990). It is stressed that teachers need to exercise a positive role to ensure that various text types are taught and that an undue emphasis on 'creative writing' is avoided (Collerson, 1988, p. 8; Christie, 1986). Expository writing has been variously described as: 'the type of writing needed for life' (Collerson, 1988, p. 11); the 'type most commonly used' (Kress, 1982, p. 125); and, 'a necessary and integral part of the achievement of writing' (Kress, 1982, p. 99).

There is little doubt that to be able to convey meaning through writing and more especially to be able to write functional texts effectively is important. If attention is to be given to functional writing, it is of value to consider the place of structure in the teaching and learning of functional texts.

Structure

Latham and Sloan (1989, p. 6) consider structure in text as a distinct framework unique to a text type and related to that text's particular purpose. Rothery (1985) reinforces this when she discusses the text types, reports and expositions: '...each has different goals and is structured differently to achieve these goals' (cited in Martin, 1985, p. 71). Indeed, any particular genre can be defined, in part, by its schematic structure (Derewianka, 1990, p. 7).

Children need to learn to write in a particular genre by identifying and practising its accepted structure. In terms of teaching, this might be encouraged by recourse to a

number of standard strategies: for example, by the teacher modelling the process and by students practising writing in the correct format (Johnson, 1989; Derewianka, 1990). Knowledge of text structure could also benefit other aspects of children's learning. For example, Jones and Idol cite evidence supporting the notion that when students are familiar with the structure used in expository texts they are likely to be more successful in comprehension and recall information related to that text type (1990, p. 225).

Writing and word processing

Much has been written about the use of word processors as an aid to the writing process; in particular, the literature indicates that word processing can provide special benefits to reluctant and less able writers. Particular benefits reported have included:

- improvements in overall quality² (Snyder, 1990; Eaton, 1986; Kaplan, 1986; Rosengrant, 1985; Womble, 1984);
- increased output of writing (Dudley-Marling and Oppenheimer, 1990; Dalton and Hannafin, 1987; Crozier, 1986; Fisher, 1983);
- greater learner motivation and increased writing satisfaction (Derewianka, 1990; Snyder, 1990; Crozier, 1986);
- increased learner acceptance of teacher intervention (Snyder, 1991; MacArthur, 1988; Morocco and Neuman, 1986);
- increased peer collaboration (Snyder, 1991; MacArthur, 1988);
- increased levels of revision³ (Dalton and Hannafin, 1987; Collier, 1981; Daiute, 1986).

However, such findings are not consistently reported within the literature. As Snyder suggests, the findings of revision studies (i.e. those studies concerned with the effects of word processor use on the revising of texts) display the most convergence (Snyder, 1991) while those dealing with the effects of word processor use on the

2. Such improvements have been found to correlate with children's willingness to revise texts (O'Brien, 1984; Case, 1985).

3. However, Daiute (1986) and Dudley-Marling and Oppenheimer (1990) among others, have shown that in many cases only low-level revision occurs, especially with inexperienced writers.

quality of writing provide contradictory messages (Millar, 1984; Duling, 1985; Eaton 1986; Kaplan, 1986).

Computers and keyboards

Traditionally, access to a word processor is via a standard *qwerty* keyboard. Effective use of this keyboard requires a knowledge of its unusual and forbidding layout. For inexperienced keyboard users this takes practice. Indeed, children's lack of ability in using the standard keyboard, often referred to as poor keyboarding skills, may well reduce the advantage of using the word processor for writing (Daiute, 1986; Dybdahl and Shaw, 1989; MacArthur and Schneiderman, 1986; Snyder, 1987).

The concept keyboard is an alternative input device now found in many primary schools, which can be used in addition to or instead of the conventional keyboard. It is a flat, electronic board, with its surface marked into 128 pressure sensitive areas. Each of these areas can be programmed individually or in blocks to produce text on screen. The programming is represented on a paper overlay which is placed over the concept keyboard and, when touched, provides the programmed message on the computer screen. When areas of the concept keyboard are grouped, a larger target area is provided on the overlay in which words, pictures, symbols or three-dimensional shapes can be used to indicate the matching text programmed for each area. Consequently, it might be expected that use of the concept keyboard for writing could reduce: (i) the need for children to concentrate on the mechanics of their writing; and, (ii) the need for children to have well-developed conventional keyboard skills.

The system is flexible in that overlays can be produced quickly to meet the changing needs of an individual child. For example, it is possible to create an overlay which provides scaffolding to encourage use of correct text structure in writing. This might be achieved by careful placement of text options together with possible colour-coding of text, on the concept keyboard overlay. Also, it is possible to include on an overlay, those words which a child recognises but finds difficult to say or spell, facilitating writing of an acceptable form. An alphabet can also be included on the overlay encouraging a child to write freely without having to laboriously search the standard computer keyboard for the letters needed.

The concept keyboard appears to offer a means of overcoming children's lack of standard keyboarding skills and thereby alleviating some of the difficulties children

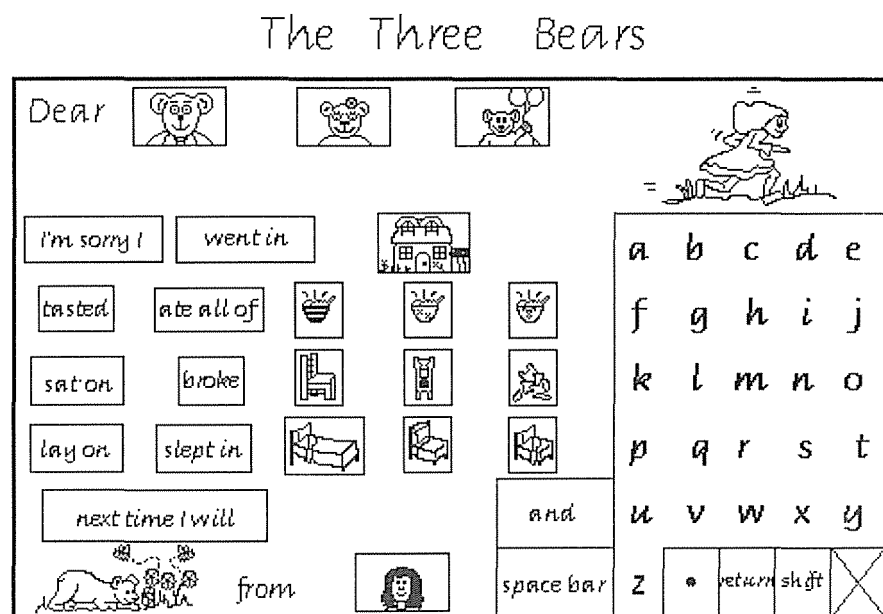


FIGURE 1. A concept keyboard overlay for supporting children's writing

face in creating texts. With appropriately designed overlays, it may also be possible to provide specific assistance with the creation of correctly structured functional texts.

Writing and the concept keyboard

There are few research findings regarding the benefits of the concept keyboard as an alternative input device for word processor use. Much that is available in this area is characterised by anecdotal record. For example, Ward (1986), Read (1986) and Dyson, et al. (1988), report the benefits to particular learning disabled children of using a concept keyboard. Johnson (1989) describes examples of concept keyboard use for language development with young children and suggests that such use can lead to greater writer independence; she also describes use of the concept keyboard specifically as a scaffolding device for writing.

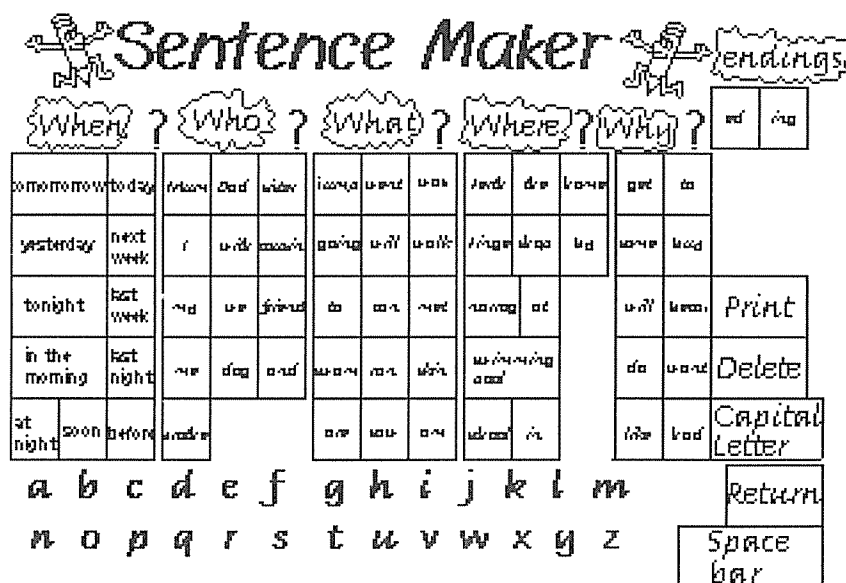


FIGURE 2. A concept keyboard overlay for supporting creation of correctly structured texts

A research study

The remainder of this chapter maps out both the method and some of the initial findings of an investigation into whether children using a concept keyboard produce better structured writing of recounts (i.e. a text form of the functional genre) than when they use conventional classroom methods such as pen and paper or word processor with a qwerty keyboard.

A class of 28 Year-five children at a Perth metropolitan primary school were chosen as subjects for a case study: children of this age are still developing skills in writing functional texts and are not likely show undue concern about using a concept keyboard for writing (as might older children). All children provided a sample of writing in two formats of the recount text type, at each of four phases in the data collection (i.e. a letter and a science report, these being representative of personal (subjective) and distant (objective) texts, respectively, mentioned by Perera, 1984).

For each format and at each phase, these samples were analysed to determine the degree to which they met the criteria for the text type recount based on Sloan and Latham (1992), Derewianka (1990) and Wing Jan (1991). Analysis was completed for individuals, and profiles established for each child to chart the nature and amount of writing development over the four phases.

At the first phase in the data collection, children created the texts without previous instruction to determine their existing skills. At phase two they wrote similar texts after being taught to write a recount by the method and strategies typically used by the classroom teacher. For both these phases, children were free to produce their texts by hand or by use of a word processor in accordance with normal classroom practices (i.e. during 'writing lessons'). It was standard classroom practice for approximately 24 (out of 28) children to prefer to write by use of a word processor rather than by hand. A small number sometimes chose to write by hand if a computer was not available when they were ready to write; the remaining children consistently chose to write by hand in preference to the word processor. There were three computers in the classroom available at all times, each providing use of a word processor.

In the third phase all children completed a text in each of the two forms using the concept keyboard with appropriate overlays designed by a member of the investigation team. Revision of schematic structure for recount was provided by the teacher, as part of normal classroom instruction. In addition, deliberate guidance in structure was provided on the concept keyboard overlay via, (i) colour coding to indicate the three main elements of a recount: orientation, chronological statements and closure; (ii) provision of 'time' words for chronological statements; and, (iii) helpful layout of words and phrases to assist with sequencing. In the final phase, children provided their two respective samples of writing using the concept keyboard but with overlays not specially designed to provide guidance for structure. It was decided to use the concept keyboard for completion of this final phase of writing, to avoid issues that would arise if children returned to text creation by hand or word processor. It is probable that children will continue to write better structured texts using the same medium — the concept keyboard — than if they reverted to other means of writing.

The analysis of the data collected has still to be completed. However, it is already becoming clear that given the on-task support provided by the use of the concept keyboard (i.e. direct support to the writing of correctly structured texts), most learners create significantly better texts of the functional genre, such as recounts. However, when this direct support is removed, some learners revert to writing poorly structured texts, even although they continue to use the same medium (i.e. a con-

cept keyboard). In this case, it would appear that some children used the support of an overlay without reference to meaning. For example, some children would identify the correct sequence of text by its colour code and when this code was removed at the final phase of data collection, similar text was not sequenced appropriately.

Conclusion

It is likely that children benefit by using the concept keyboard to write recounts; that is, they create texts which are better structured. It is also likely that, given the use of appropriately designed concept keyboard overlays, this skill will be applied to the construction of other texts of the same genre. It may be further hypothesised that the concept keyboard lends similar benefits to writers of other genres, given that all text types are characterised by a particular structure (Latham and Sloan, 1989). However, what is yet to be established is whether writing skills of the type described here are transferred beyond the writer's use of the concept keyboard; for example, once the support of the concept keyboard is removed, does the writer continue to produce texts that reflect a correct structure? The early results of the study described here suggest otherwise.

However, it may be that the design of this study is at fault: in reality, the teaching and learning of writing skills requires the use of a wide range of strategies and isolating but one of those strategies and seeking to test its usefulness alone is unrealistic. Indeed, it may be that when the use of the concept keyboard is applied as one of a number of teaching strategies, its value and, in particular, its long-term benefits for individual learners become much more apparent.

The purpose of this chapter has been to identify some of the benefits of concept keyboard use by young children as well as to consider how it may be possible to investigate such benefits in the context of writing pedagogy. Benefits to learners of using new technology cannot simply be assumed; they have to be rigorously researched.

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Material-centred primary science and computers: contradictory or complementary?

Judith Cousins

Abstract

Science in the primary school should be material-centred with children developing inquiry skills through first-hand experiences. Teachers are sometimes loath to incorporate computer work into their science lessons as they see this as contradictory to the philosophy of encouraging children to carry out hands-on experiments and investigations. This chapter considers how computers can be integrated into a class science program so that the underlying rationale of activity-based, 'real' science is maintained.

Introduction

Material-centred science is an approach to teaching which began in the 1960s and is still supported by educationalists today. The focus of such teaching is on providing the learner with real objects and materials for investigation. The materials themselves become the primary source of information with the children often choosing their exploratory methods and lines of inquiry. This focus on using concrete materials to foster children's learning is based on the work of psychologists

such as Piaget, Ausubel and others who believe that intellectual growth proceeds from manipulating real objects then pictures and finally symbols. The concrete experiences help children form the mental pictures and later the symbols.

In conjunction with the material-centred approach to science teaching, emphasis is placed on the development of the processes or skills of science. The rapid growth of scientific information is such that no one could learn, understand and remember all new knowledge, but by developing the skills of science with young children, they can then use such skills (observing, measuring, predicting, controlling variables etc.) to find out information for themselves. Thus equipped, children can plan and carry out their own investigations.

The introduction of computers into primary schools has provided somewhat of a dilemma in the area of primary science. On the face of it, when working with computers, children are not involved with 'real objects' and many teachers fail to see how computer work would enhance science skill development.

This chapter will consider ways in which the computer can be used to initiate interest in science topics, develop science skills and foster positive attitudes towards this subject. It is not suggested that all science work should now take place in front of the computer screen but rather that the computer can be used as another tool children can use to further develop their investigations. This is supported by McLeod and Hunter (1987, p. 30) who say, 'The computer should remain, appropriately, a tool that provides data as needed in useable form'. Indeed Stager (1990, p. 814) says, when describing microcomputers, that they are 'a transparent tool always available to the student for solving problems that are intrinsically interesting and important'.

Science and computers

There are many ways computers can be used to complement and extend a primary science program but the central aim should be that they are used to support the basic premise that primary science should develop inquiring minds and a scientific approach to problem solving. First-hand practical experiences are essential for children and the computer can not and should not replace these; but neither should teachers disregard this technological tool. As Squires (1985, p. 20) says, 'computing and science in the primary curriculum are relevant to each other and, within the context of a technological tradition, their spheres of influence will probably overlap to an increasing extent'.

The computer does, of course have many characteristics which enable it to be a motivating and useful learning aid. It can have a worthwhile place in the teaching and learning of primary science and may well prove to be a valuable resource that teachers to date have largely overlooked. Nevertheless, as Nicholls (1985, p. 12) suggests, it needs to be used to support a science program, not as an end in itself:

It (the computer) is a more versatile tool than those before, and children must become experienced in using it, but, in school, the micro has its limitations and, wrongly used, can present real dangers to the progress of primary education today. This is particularly evident in primary science and worries me greatly.

The concerns that Nicholls has centre on using computers to teach facts through repetition and testing (i.e. always requiring a 'correct' response), the possibility that time spent working on the computer could be more valuably spent doing hands-on activities with real objects, the learning of concepts in isolation (i.e. that software often focuses upon understanding out of meaningful context) and the lack of relevance of software to the child's environment. Such concerns require careful consideration if the computer is to be used to enhance children's learning and not inhibit it. In the following section the ways in which a computer can be used to support primary science programs in a classroom will be developed.

One of the problems teachers note when discussing the difficulties of teaching primary science is that an enormous amount of material is needed to make their programs interesting and relevant to the children. Providing the necessary materials for hands-on science for a class of thirty children can be quite daunting. Unfortunately there is no way around this except, at times, to organise the class into groups working on different tasks, thus the same materials are not required by everyone at the same time. This is an occasion to use the computer. One pair, or group of three, could be usefully employed at the computer(s) while others work with materials. The teacher, of course, has to ensure that what is being done on the computer supplements the science tasks or activities.

Drill and practice

Although primary science focuses on skill development there is still a place for facts to be learned. The computer can provide another means by which to reinforce understanding and carry out simple testing on an individual basis that would be time consuming and possibly difficult for a teacher to undertake with the whole class. When the computer is used in this way, children can work at their own pace and at their own level without coming under the scrutiny of their peers or the teacher. There is evidence that such learning can be beneficial for some children:

Used in self-paced study or as a way to supplement a lesson, this type of computer program offers positive reinforcement, a wide variety of well-formulated questions with correct answers, and the chance to let students learn at their own speed. (Elron, 1983, p. 13)

The strength of this type of program may lie in the immediate feedback given and the opportunities provided for children at both ends of the learning continuum (i.e. the child requiring many experiences and reinforcements to develop understandings and the child who is always a step ahead of everyone else) to work individually. The ability of computer programs to provide colourful, animated and unusual learning contexts can also provide motivation for learners.

Problem solving

Material-centred science encourages problem solving and indeed it can be said that good science is good problem solving. Quite often teachers simply provide children with a variety of materials and allow them to experiment to find out the properties of such materials and how they can be used in investigations. It is more usual, however, for teachers to set investigative questions which require children to manipulate materials in order to obtain a finding. The computer can readily be used in this way:

Microcomputers offer science teachers an attractive technology for developing students' problem solving skills. Using these electronic tools, students can discover solutions to difficult problems far beyond drill and practice routines. (Cox and Berger, 1981, p. 29)

The process of problem solving can be modelled and developed with children to improve their abilities with this skill. The process steps have been described as:

- brainstorming;
- exploration;
- problem definition;
- generation of solutions;
- evaluation;
- identification of best solution;
- implementation of action plan;
- assessment of results.

(Bovill, 1990, p. 20)

Computers can be used as a resource by teachers to foster and support children as they move through these steps. The computer's 'versatile nature means that it can play different roles in different circumstances' (Straker, 1993, p. 59). These roles can be seen as suggesting problems and supporting problem solving (i.e. through the use of databases, graphs, and drawing packages).

One of the most important features of problem solving is the opportunity it provides for cooperative group work. Research by Jones (1985), Johnson, Johnson and Holubec (1986), Goffin (1987) and Bybee, et al. (1990), shows that students work more effectively when they work cooperatively rather than competitively. Cooperative learning can be a means for children to foster positive social behaviours and communication skills, develop decision-making skills, improve self-confidence and capitalise on the diversity of views presented. When working at the computer in pairs or possibly groups of three, cooperation is necessary. For example, students will often reason, negotiate, role-play, rationalise and question in order to arrive at a consensus decision.

Databases

Children need to understand that databases are part of our everyday lives. They will all be familiar with the telephone directory — a database which has structured information organised for ready access, as does the school library, dictionaries and encyclopaedias. Computers can be used to access and manipulate enormous amounts of information.

The management of collected data from scientific investigations can present children with considerable difficulties as the recording and organisation of such gathered information can appear quite daunting to young children. The use of a database on a computer can help children learn how to manage large amounts of information in a structured manner, how information can be readily presented and how retrieval of the information can be achieved.

Databases can be categorised as either 'fixed' or 'flexible'. Fixed databases are those which already contain a fixed set of data and although the information can be accessed, it cannot be edited or added to. Such data might be used by children to retrieve information on a given topic. Flexible databases allow children to provide their own data. Using a flexible database may involve children not only in providing the data but also in deciding which data to include, which to leave out, how to format the data and then testing hypotheses against the data to find solutions to given problems.

Both forms of database are useful in science activities. In particular, fixed databases can provide information which would otherwise be difficult for children to collect themselves; for example, data about extinct animals or exotic plants.

The development and use of flexible databases is an extremely valuable undertaking for children. The data gathered during a problem-solving science activity can be collated, sorted and displayed. It can be corrected and edited simply and quickly. Comparisons can be readily undertaken and questions devised which can be responded to by considering the presented data. For children with some literacy difficulties, using a flexible database in this way may alleviate problems associated with manual recording. It also allows the teacher the opportunity to provide for children of differing abilities, as some children can input data using the keyboard, even if they have difficulties with written composition. As Wayth (1983, p. 78) says, 'The computer can accept results and display them in any desirable form: pie chart, histogram or simple table of results. If the computer is not used for anything else in science then it can at least be used in processing results'.

The use of databases in the recording and retrieval of information can be a very useful accessory to primary science. As McLeod and Hunter (1987, p. 155) say, 'students using databases practice inquiry as they determine what questions they want to ask, what data they need to answer them and how they should best organise that data'. Just as scientists study relationships and patterns to reach conclusions so children can develop their investigation and problem-solving skills through analysing their own data with the aid of the computer:

As they pull up and scrutinise individual files, the students are acting the way scientists and their assistants do when they gather data. And when they ask the computer to produce the data in various configurations, they are like a research scientist organising the results of experiments to test a hypothesis. (McLeod and Hunter, 1987, p. 155)

A further strength of databases is that the children can add further information at any time. This may be information from their own experiments or from library research, thus reinforcing the concept that science is a growing body of knowledge.

Simulations

Science lessons often require children to imagine a situation and then to problem solve one particular aspect of the situation. Initial motivation, or an extension to the situation, can be provided through the use of a simulation program which presents a scenario requiring children to make choices in a problem-solving context. The advantages of using simulations are that they can provide situations in a realistic

fashion which the teacher would be unable to reproduce in the classroom; they can show idealised conditions and present situations with clarity. The danger aspect is, of course, removed, so more advanced models, which the teacher may be reluctant to carry out in a room of thirty children, can be shown on the screen. As Maddison (1982, p. 111) says, 'the use of models and simulations is similar to the use of experiments in science teaching, though the range of experiments is increased, and their use extended to a wider range of subjects'.

Although the value of simulation programs is readily apparent they should not be used as a replacement for 'hands-on' science activities in primary classrooms. Instead they must be used, as with databases, as supplementary material or in situations where the real experience cannot be obtained. A major focus of primary science is the development of the principles of scientific investigation, which require logical reasoning and analytical thought. At times simulations can be a successful way of reinforcing such principles:

There is a number of scientific investigations which excellently display these principles in a manner which is conceptually straightforward, although the experiments involved may be practically difficult to carry out. In such circumstances computer simulations can provide an environment in which practical impedimenta can be removed, allowing the all-important thinking process to be explored. (Govier, 1985, p. 32)

The value of discussion of results, ideas and suggestions has been previously mentioned but must be also highlighted in relation to simulation programs. The reflection time, sometimes at the beginning of the lesson, more often at the end of the experiment, is often overlooked by teachers; however, this can be the most significant part of the activity. It is here the children consider their results and where learning is fitted with previous knowledge. A simulation program can stimulate discussion, provoke thought and focus attention. It can encourage cooperative decision making and reasoned debate.

Opportunities for safe experimentation, exploring new environments and stimulating an inquiry approach are provided by the well considered use of simulation programs to supplement material-centred science lessons.

Conclusion

This chapter has discussed some ways in which computers can be integrated into material-centred primary science. The advantages and disadvantages of using drill and practice, databases, and simulation programs have been emphasised because they form the majority of much software available to teachers in primary schools. There are, of course, other types of programs and uses which have not been presented. For example, the use of interface material to enable electronics and robotics to be undertaken is another excellent way to supplement science programs, but may be beyond the ability of many schools to provide either the necessary hardware or software or the teaching expertise.

Science at primary school needs to involve children in practical, hands-on activities and time working on the computer should not replace the time spent in carrying out material-centred investigations. Straker makes the point that:

Most important of all, the use of the computer needs to spring from and relate to children's own direct experiences. There are times in any primary classroom when 'hands-on' experience at the computer keyboard is valuable; but the time spent in related 'hands-off' activities is just as important. (Straker, 1993, p. 7)

Computer use can, and should, focus on being supplementary and complementary to the first-hand science activities children are experiencing. The successful integration of computers into the primary science course in a classroom relies on the teacher seeing the potential in specific programs, demonstrating the potential of programs to the children and developing their skills in effectively using them (such as databases and simulations), and in organising and managing the class so learning potential is enhanced. The computer, when properly implemented within a primary science class, can be a productive and valuable tool.

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Interactive multimedia applications in education

Ron Oliver

Abstract

Although the term 'multimedia' has been around for some decades, in previous years its meaning implied the concurrent use of several media. In today's usage, multimedia still refers to the concurrent use of media, but in an integrated form on a single device, the computer. The term interactive multimedia (IMM) refers to a relatively new form of computer software. In common with most software packages, this form of software is interactive in that it operates under the control and guidance of the user. However, it also incorporates a variety of forms of information (media), and it is this aspect of the software that has made it very appealing to teachers, trainers, instructors and students alike.

IMM involves 'the integration of audio, graphics, animation and text utilising the computer as a control and presentation platform' (Edgar, 1992). The development of the personal computer with a multimedia capability has had a significant impact on the form and quality of computer-based instructional materials. Developments now include electronic books that talk to the reader, electronic encyclopedia and stimulating instructional materials.

Multimedia systems

A multimedia computer system incorporates hardware and software components that facilitate the production and display of various media forms. These include:

- an operating system using a graphical user interface;
- high memory capacity;
- CD-ROM;
- expanded output capability to include full stereo sound;
- a display monitor capable of producing at least 256 colours in a high resolution format.

Large numbers of pictures, sounds and other forms of information contained in multimedia software necessitate high levels of information storage capacity, more than can be provided on a single floppy disk. For this reason, multimedia programs are usually delivered on CD-ROM disks. These disks have the capacity to store up to 600 Megabytes, the equivalent of about 500 floppy disks, and are an ideal platform for computer software of this nature.

Many hardware vendors now sell computers with multimedia capacity as a standard configuration. New application software versions frequently contain a multimedia capability in recognition of the capabilities of personal computer systems. For example, when using Microsoft's word processing package *Ms Word*, the user with a multimedia hardware capability is now able to include text, images, sound and real-time video into a document. For users of both the Apple and Windows operating systems, the inclusion of real-time video into most documents is simply a matter of cutting and pasting a video file.

Multimedia interactions

IMM applications are in many cases extensions of existing forms of computer-based instructional materials. Their functions and controlling capacities have been extended and there are now some significant differences that set conventional computer-based materials apart from their multimedia counterparts. The main differences are in the manner in which the user interacts with the software. IMM applications usually involve a graphical user interface and mouse-driven control system incorporating pull-down menus, click-able buttons and icons. As software

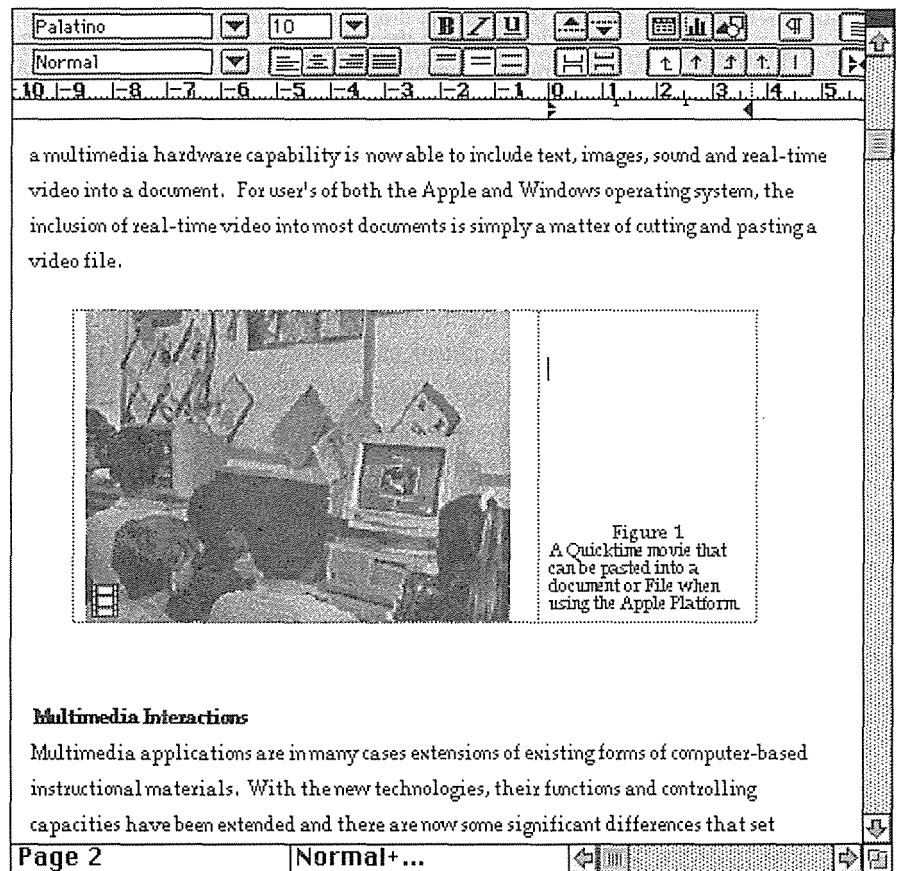


FIGURE 1. A movie that forms part of a word processed document. The reader clicks to view the movie or can proceed to read the document. It is possible to place a number of media forms within word processed documents

designers move to simplify the manner in which the user controls the program, interfaces are becoming intuitive and self-evident. Few users of IMM packages expect to have to read instructions for use. The expectation is now that the instructions will be obvious or else can be learned and gained from experience with the package.

Many multimedia interfaces now use metaphors or links to the users' known worlds to create the controlling environment for the package. Figure 2 shows the operating environment for the software package *MacSchoolroom*. The interface for this program uses a classroom metaphor to provide the operating environment. Within the classroom are a number of identifiable objects which users can select by clicking the mouse. Clicking on the objects is the means by which the program is controlled. For example:

- clicking the fire-alarm in the top left corner causes a window to appear in which the user can select the volume level for the sounds created by the program;
- clicking the painting on the easel jumps to a painting activity where the user is given a blank canvas and a number of cans of paint to work with;
- clicking on the money chart jumps to a mathematical activity involving money.

Can you guess what is chosen when the user wishes to leave the program?

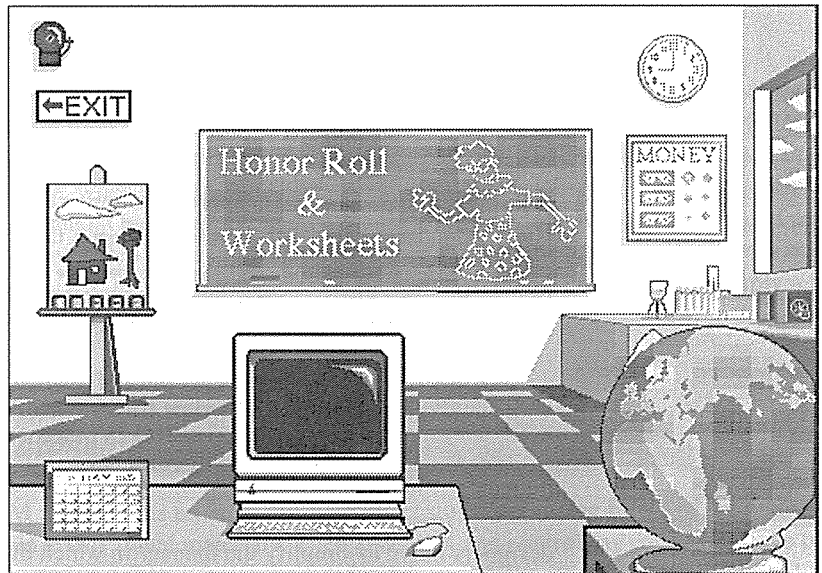


FIGURE 2. An interface for a multimedia package that uses the design metaphor of a classroom to provide options to the user

Navigating through some multimedia systems can become quite involved. The various parts of a multimedia program often form an intricate web of levels and associated pathways through banks of information — visual, audio and text. Moving from one level to the next as the user makes selections often makes it difficult to identify the current position in relation to the starting point. Designing effective interfaces is a science as well as an art and there are many projects underway looking to create the best ways for navigation in such complex systems.

Multimedia applications

There are a number of different forms of multimedia applications for schools and education. Some of the more common applications include:

- interactive information sources; for example, electronic encyclopaedia and books;
- multimedia tools: software for producing multimedia products;
- instructional materials: tutorials and computer-based learning packages.

Interactive information sources Many reference books and encyclopedia are now published in a multimedia format. The multimedia format enables the electronic versions to include all the features of the conventional book including text, graphics and pictures. The IMM versions also include animations, sound and video. A number of well-known encyclopedia are now published in a multimedia format. Apart from the obvious advantages of the extended media, there are other advantages of this format over the print format:

- *Cost* There is a big saving in the production costs of the format. A large number of printed and bound volumes are replaced by a small disk costing less than \$0.50 to replicate. The information can be updated more easily.
- *Information access* Information can be accessed in many more ways. While printed materials use an index to organise information, electronic versions employ a computer control. It is possible to look up information in a range of ways. For example, the computer can be instructed to show every article in which a word or combination of words appear.
- *Information retrieval* Once the relevant article or articles have been located by the computer, important sections can be copied from the text to an electronic workpad. After all the required information has been scanned and collected in this way, a printer can be used to obtain a hard copy.

While the advantages are many, we need to consider some of the less appealing consequences of usage. Some of these include:

- *Equipment* The use of the electronic books demands access to computing equipment. In instances when equipment fails or is unavailable, so too is the information.
- *Single users* Whereas an encyclopedia consisting of 25 volumes could at some stages be used by up to 25 or more concurrent users, electronic books with their technology base require increased amounts of equipment if they are to serve more than one user. Schools are able to buy specialist hardware to support multiple use of CD-ROM applications.
- *New skills* The skills required to access and retrieve information from electronic sources are quite different from those used with print-based materials. Schools moving to employ the new technologies must also develop students' skills in use of the new technologies.

Multimedia tools As well as gaining advantage from the new instructional materials made available by multimedia technologies, students can also gain considerably from learning to use the new technologies to produce their own multimedia products. Consider the following description of a local primary school using these technologies.

Ian, a teacher at a primary school, has installed a number of Amiga computers with a multimedia capacity. This equipment is supported by a number of appropriate software products that students are taught to use. Students are instructed in the use of these technologies and encouraged to make personal use of the facilities wherever possible. It is not uncommon for students at this school to create multimedia presentations when submitting project work. Such presentations include video images combined with computer-generated graphics and animations, and dubbed voice files. Records of special events at the school such as concerts, school camps and presentations have also been recorded and presented in this fashion. All this is done by students 10, 11 and 12 years old.

Instructional materials The majority of multimedia instructional materials produced for schools are aimed at the early school years where sounds, pictures and animations are popular forms of teaching and learning. Sometimes it is difficult to distinguish between conventional computer-based learning materials and multimedia materials because the conventional materials frequently involve the use of multimedia. It is convenient to look at computer-based learning products available on CD-ROM and to consider these as typical of the new form of multimedia instructional materials. A common application is the electronic fiction book in which the multimedia application adds life to conventional text and images.

A popular title among these 'living books' is the program *Just Grandma and Me* (Broderbund, 1991). In this program, a story is presented to the reader as a series of screen images. The reader follows the story by clicking on objects within the picture on the screen. When objects are clicked, they come to life and the use of the book becomes an activity of exploration and discovery. Although it was written for readers aged four- to eight-years, many adults and older readers have had many hours of fun in the world provided by this book.

There are a multitude of instructional titles published on CD-ROM with varying forms of interaction and activity. As the technology develops and creative applications emerge, we should expect to see more of these programs in classroom use.

Issues arising from multimedia applications

Despite its strong potential, IMM has inherent problems in its use and application in educational settings (Ford and Ford, 1992). In the first instance, there are many forms of multimedia that must be considered, each of which has unique characteristics, applications and functions.

Hypermedia is the term used to describe multimedia applications built around a network of multimedia nodes. The user navigates through the information system by linking from one information node to the next. Typically, an information node is a window that displays information. Nodes can be of various forms and consist of text, animations, video, still images or sound or combinations of these. The hypermedia base on which they are designed relies heavily on a very low degree of program control and maximum opportunity for control given to the learner.

Many problems have been observed in user access to IMM and hypermedia. Collis (1991) describes the more serious problems as:

- disorientation: difficulty knowing where one is in the book;
- navigation inefficiency: difficulty moving from one point to another;
- cognitive overload: exposure to information that exceeds that required by the task or purpose.

Many potential users of hypermedia and electronic books have been found to lack the cognitive skills, the motivation and attitude to learning required to take full advantage of the medium (Heller, 1990; Trumbull, et al. 1992). Although many publishers build design metaphors into their interface and navigational structures,

naïve users are often unaware of this encompassing and potentially useful structure (Gay and Mazur, 1989). Trumbull, et al. (1992) found that novices typically tend to browse when seeking information and this was a very inefficient form of navigation when compared to indexing and using on-line guidance.

Navigation strategies are very difficult to plan when broad usage is required of a program. Keyword searching is a difficult task for novices, who often need to translate their information requirements to an unfamiliar language. Similarly, even alphabetic lists have been found to be difficult for novice users, especially when indices use bands of initial letters such as D-J and S-V. Novices tend not to recognise immediately, for example, that E is in one band of letters and not another (Fasick, 1992). Studies of the use of hypertext by novices have revealed that non-skilled users in these environments view more screens than skilled users and do so in a non-sequential and inefficient mode. Levels of learning and understanding are significantly less among novices than trained users. Although users prefer the control they are given over the media to the lower levels of user-control provided in other forms of computer-based software, they do not choose the best paths in information-seeking activities (McGrath, 1992). Despite these problems, however, comparisons of learning and information retrieval from conventional books and electronic books reveal gains and advantages for the electronic books (e.g. Saga, 1990; Riding and Chambers, 1992). It is possible with appropriate training and instruction to teach students to become better users of the hypermedia environments. Furthermore, as research informs us more about appropriate designs of electronic books, the more successful learner interactions can be expected to become (Barker and Manji, 1991).

Heller (1990) compares researching with hypermedia with discovery learning and suggests that many younger students may not have the capacity to be able to actively ignore non-essential information as they browse a hypermedia system. Several authors have suggested that different learning styles will influence the way in which hypermedia systems are used (Marchioni, 1989; Heller, 1990; Riding and Chambers, 1992).

Learner control

A critical difference between conventional computer-assisted instruction and multimedia is in the sequencing of the instruction and information. In the design of interactive multimedia materials, the learner is given a greater degree of freedom in choosing the information and activities that comprise the learning task. These

choices are typically non-linear in fashion (McGrath, 1992) and are controlled by a system of menus that enable the learner to navigate through the program. Learner control is an important consideration when considering learning applications of interactive multimedia. By their very nature the interactive applications provide a high degree of learner control possible.

There has been considerable research conducted into the effects of learner control of computer-based media on the acquisition of knowledge. Not all research has been conclusive. Murphy and Davidson (1991) describe a study in which the development of concept learning was studied in relation to varying levels of learner control. Learner control was not found to be an influencing variable. Other research on learner control clearly indicates that learners who are not skilled in the subject tend to learn more effectively if the control of the learning sequence is left to an external agent rather than the learner. While skilled learners choose more options and make better use of the instructional materials to achieve higher learning gains, less skilled learners make poorer choices, choose fewer items and perform less well (Goetzfried and Hannafin; 1985, Ross, Morrison and O'Dell, 1989). The findings from such research suggest a need for caution and concern in the application of interactive CD-ROM materials among novices and less skilled learners. The lack of any form of program control over the material that is presented to the learner could result in many students failing to access important information from the program. The non-linear form of information access could result in learners choosing inappropriate information sequences incapable of delivering the information being sought.

The lack of program control in interactive multimedia applications is one of its key attributes and main strengths (Scott MacKenzie, 1992). If it is the case that unskilled learners do not fare well with such instructional design, then it is necessary to consider changes to the way learners use the programs rather than changes to the instructional design of the application. If learners can be trained in the processes involved in navigation and appropriate navigation strategies developed, the potential for successful use of the application would appear to be enhanced considerably.

Cooperative Learning

The use of interactive multimedia frequently occurs in group settings to provide student access to what is often a scarce resource. The need for consideration of the students' discrete and combined actions in such settings would appear an important

consideration in determining the learning potential of such activities. In some instances, it may be that interactive software is not well matched to group learning activities.

At first glance, the use of interactive multimedia materials appears to have considerable potential as a facilitator and motivator of group activity. There has been considerable research conducted into the effectiveness of small-group learning activities. Johnson and Johnson (1989) report a significant improvement in effective learning among students engaged in group learning when compared to individual learning. Further, research indicates that computer-based instruction is often more effective when completed in groups, with the grouping able to yield improved achievement and attitudes over individual instruction (Dalton, Hannafin and Hooper, 1989; Hooper, 1992).

The achievement of improved learning outcomes through the cooperative use of computers is dependent, however, on the quality of the design of the computer-based learning materials. Hooper (1992) discusses the need for the software to enable all group members to be cognitively engaged at all times in the learning process. Dalton (1990) argues further that the design of instructional materials for group activities demands inherently different approaches to materials used by individuals. The instructional design characteristics of interactive multimedia products tend to reflect more the intention of individual rather than group use, in much the same way as printed material serves the single reader. The capacity of the materials to display and present information to the wider audience is a key factor in encouraging their group use. In assessing the utility and efficacy of the use of multimedia materials, the nature of the interactions and outcomes from group use would appear an important and necessary consideration.

Information seeking with IMM

In a study that sought to examine learning outcomes achieved through use of IMM systems, Frau, Midoro and Pedemonte (1992) found that their subjects often made ineffective use of the hypermedia in inquiry activities. They found the students chose to look mainly for facts in their interrogation of the system in constructing a mental image of the topic under investigation. The students were guided in their investigation by a task that directed their inquiry. It was found that the conventional method of inquiry practised by the students was an obstacle to exploiting the full potential of the system. The students' exploration was judged to be sequential and systematic (as if reading from a textbook) rather than thematic and hierarchical, the

more appropriate forms when accessing hypermedia information. Frau et al. (1992, p. 50) concluded that 'optimising the learning environment by the provision of hypermedia does not by itself produce a significant improvement in learning'.

A number of other studies have demonstrated the need for, and the advantages to be derived from, specific instruction in the use of multimedia materials (Perzylo and Oliver, 1992; Oliver and Perzylo, 1993). Investigations with upper-primary school students using a multimedia-based electronic book revealed that students retrieved very little information from the information source apart from textual information gained from hard copy printouts of essays. There was no evidence of students making use of the many forms of information available through the media other than text with which they were familiar. The program that they were using contained sound files, colour images, graphics and video-clips as supplements to the conventional text-based information. Although this multimedia information was attractive and appealing and accessed by students, in general little of this information was recorded and used in their project work.

A follow-up study with a similar information requirement was undertaken among a similar group of students. This time, specific instruction was given in information retrieving and recording to aid students to extract descriptive information from other than text-based sources. The results from this study clearly demonstrated the need for, and the advantage of, such instruction and teaching. The students were subsequently observed to make significantly more use of the extra information than their peers in the previous study. They listened, watched and studied the multimedia sources intently and incorporated this extra information into their notes. An examination of the submitted projects gave clear indications that students at this level are able to use to advantage the multimedia information sources given adequate instruction and guidance.

New skills for new technologies

Although use of IMM is in its relative infancy in school settings, there are obvious signs that effective use of the technology demands new skills and knowledge. The large differences between IMM systems and conventional teaching materials necessitate the use of different processes in the application of each. It is not sufficient to simply transfer the skills and knowledge from conventional information seeking and inquiry processes. Since much of the use of IMM applications is undertaken by students in an independent and unguided mode, the ideal place for the development of the new skills is in the inquiry and information process programs currently in

place in schools. The growing use of IMM applications in school libraries can serve the dual purpose of providing a vehicle for information and the improvement of children's overall inquiry and information processing skills.

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Evaluating what really matters in computer-based education

Tom Reeves

Abstract

This chapter describes fourteen pedagogical dimensions of computer-based education (CBE) that can be used as criteria for evaluating different forms of CBE. The pedagogical dimensions described in this paper are:

1. epistemology;
2. pedagogical philosophy;
3. underlying psychology;
4. goal orientation;
5. experiential value;
6. teacher role;
7. program flexibility;
8. value of errors;
9. motivation;
10. accommodation of individual differences;
11. learner control;
12. user activity;

- 13. cooperative learning;
- 14. cultural sensitivity.

An initial attempt to apply these criteria to two different examples of CBE is included.

Introduction

Systematic evaluation of computer-based education (CBE) in all its various forms (including integrated learning systems, interactive multimedia, interactive learning environments, and microworlds) often lags behind development efforts (Flagg, 1990). There are several reasons for this lack of evaluation. First, consumers of technological innovations for education seem to assume that because these innovations are advertised as effective, they are effective. The fallacy of this assumption should be clear to anyone familiar with the generally poor success of CBE in most educational contexts (Cuban, 1990; Siegel, 1994; Shlechter, 1991). Nonetheless, the dominant strategy of the business interests that underwrite the development of CBE has been and continues to be investing much more money in marketing CBE than in evaluating it.

Second, evaluation of CBE has often been reduced to a numbers game wherein the value of CBE is represented by: (i) the amount of money spent on hardware and software; (ii) the ratio of students to computers; or, (iii) the amount of time students have access to CBE within a school day, week, month, or year (Becker, 1992). The utility of such indicators in evaluating the ultimate effectiveness and worth of CBE is extremely limited, but their pervasiveness is obvious in the reports produced by national, state, and local education agencies around the world (National Centre for Educational Statistics, 1993). This type of quantitative data is relatively easy to collect, analyse, and report. Further, judgments concerning progress within a specific educational entity (school, district, state, or nation) as well as comparisons among different entities can be rendered with a 'certainty' that is untainted by the complexity of more ambiguous indicators such as measures of implementation, motivation, and learning.

A third reason for the lack of the evaluation of CBE is the inadequate utility of the evaluations that have been previously conducted. Evaluation reports are usually presented in the format of social science research reports, a format that 'is almost useless for most clients and audiences' (Scriven, 1993, p. 77). Further, evaluations of CBE are rarely carried out in a manner timely enough to have sufficient impact

on the decisions that must be made in the midst of significant development or implementation efforts. The inadequate utility problem will not be resolved unless educators create evaluation systems that are as integral to educational practice as student assessment systems are today (Reeves, 1992a). In addition, the results of evaluations must be communicated in formats that are accessible to as wide an audience as possible.

A fourth factor in the paucity of useful evaluations of CBE may be that evaluators often rely upon traditional empirical evaluation methods that compare an instructional innovation with another approach. Frequently, the results of these studies have been disappointing (Clark, 1992). A major weakness in traditional empirical approaches to evaluation is that the treatments being compared (e.g. interactive multimedia versus classroom instruction) are often assumed to be cohesive, holistic entities with meaningful differences. Berman and McLaughlin (1978) and other implementation researchers (Cooley and Lohnes, 1976) have illustrated the fallacy of assuming that meaningful differences exist between two programs just because they have different names. It is imperative to open up the 'black boxes' of instructional alternatives and reveal the relevant pedagogical dimensions they express if evaluations are to be meaningful and have utility. Pedagogical dimensions are the keys to unlocking the black boxes of various forms of CBE.

Pedagogical dimensions can be used to compare one form of CBE with another or to compare different implementations of the same form of CBE. Scriven (1993) maintains that there is an 'almost universal necessity to do comparative evaluations' (p. 58), despite the tendency of some evaluation theorists to deny the utility of such comparisons (Cronbach, 1980). The 'universal necessity' to conduct comparative evaluations is evidenced by the strong desire of most clients and audiences for such comparisons. Therefore, it is imperative that criteria for evaluating various forms of CBE be developed that will result in more valid and useful evaluations. That is the intent of this chapter.

Purpose

The purpose of this chapter is to describe fourteen pedagogical dimensions of CBE that have the potential to provide improved criteria for understanding, describing, and evaluating CBE. In physics, dimensions are used to describe a physical quantity or phenomenon in terms of certain fundamental properties such as mass, length, time, or some combination. For example, velocity has the dimensions of length divided by time as in 'the car has a maximum speed of 120 miles per hour.' Simi-

larly, the phenomena that are forms of CBE can be described in terms of pedagogical dimensions. Pedagogy is defined as the art, science or profession of teaching. Pedagogical dimensions are concerned with those aspects of the design and implementation of CBE that directly affect learning.

Pedagogical dimensions

Pedagogical dimensions refer to the capabilities of CBE to initiate powerful instructional interactions, monitor learner progress, empower effective teachers, accommodate individual differences, or promote cooperative learning. My first attempt to describe these dimensions was made at the 1992 Information Technology for Training and Education Conference, in Queensland, Australia (Reeves, 1992b). Since then, the dimensions have been revised based upon feedback from colleagues in Australia and the USA. This current set of dimensions is by no means final and further modifications are inevitable.

Pedagogical dimension 1 – epistemology

Epistemology is concerned with theories about the nature of knowledge. A dimension of CBE important to users of these systems is the theory of knowledge or reality held by the designers. Figure 1 illustrates a dimension of CBE ranging from an objectivist theory of knowledge to a constructivist one. Tobin and Dawson (1992) describe these two theories in relation to interactive learning environments.

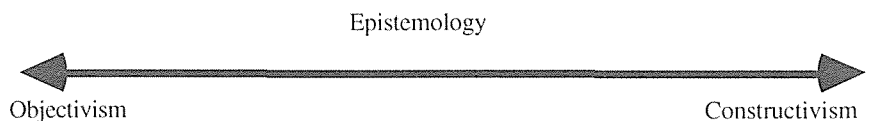


FIGURE 1. Epistemological dimension of CBE

Objectivist epistemology (Thorndike, 1913) encompasses the following facets:

- knowledge exists separate from knowing;
- reality exists regardless of the existence of sentient beings;
- humans acquire knowledge in an objective manner through the senses;

- learning consists of acquiring truth;
- learning can be measured precisely with tests.

Constructivist epistemology (von Glasersfeld, 1989) encompasses different facets:

- knowledge does not exist outside the bodies and minds of human beings;
- although reality exists independently, what we know of it is individually constructed;
- humans construct knowledge subjectively based on prior experience and meta-cognitive processing or reflection;
- learning consists of acquiring viable assertions or strategies that meet one's objectives;
- at best, learning can be estimated through observations and dialogue.

If the designers and users of CBE lean toward an objectivist epistemology, they will be primarily concerned with ensuring that the content of the CBE they create and implement is comprehensive and accurate with respect to ultimate 'truth' as they know it. They will seek to establish the definitive structure of knowledge for a given domain based upon the advice of the most widely accepted experts in a field. For example, in science education, they will seek to transmit to students the 'immutable laws' of any given field.

Advocates of constructivist epistemology, on the other hand, are much more concerned with assuring that the content in CBE reflects the complete spectrum of views of a given domain, ranging from the traditional academic perspectives to the views of the most radical 'fringe'. Constructivist epistemology calls for a multiplicity of perspectives so that learners have a full range of options from which to construct their own knowledge. In science education, constructivists might provide students with opportunities to rediscover the currently accepted theories of a given science as well as rival theories that may eventually replace the current positions. They might provide coaching or scaffolding to assist students in their discovery, but they would not overly direct the learning process. Constructivist pedagogy is increasingly popular in educational literature today, but few examples exist of its adoption in schools (Nix and Spiro, 1990).

Within education today, there is a tension between those who promote objectivist epistemologies and those who espouse constructivism. Within the context of CBE, the objectivist perspective is perhaps best represented by those who promote integrated learning systems (ILS), (Levinson, 1994), whereas the constructivist perspective may be best represented by those who promote electronic 'mind-tools'

Computer Education: new perspectives

Instructivists stress the importance of goals and objectives that exist apart from the learner. These goals and objectives are drawn from a domain of knowledge, e.g. algebra, or extracted from observations of the behaviours of experts within a given domain, e.g. surgeons. Once goals and objectives are delineated, they are sequenced into learning hierarchies, generally representing a progression from lower to higher order learning. Then, direct instruction is designed to address each of the objectives in the hierarchy, often employing instructional strategies derived from behavioural psychology (Rieber, 1992). Relatively little emphasis is put on the learner per se, who is usually viewed as a passive recipient of instruction. CBE based on instructivist pedagogy generally treats learners as empty vessels to be filled with learning. Direct instruction demands that content be sharply defined and that instructional strategies focus as directly on pre-specified content as possible.

Alternatively, constructivists emphasise the primacy of the learner's intentions, experience and metacognitive strategies. Rieber (1992) describes the constructivist view of learning as involving 'individual constructions of knowledge' (p. 94). In this view, learners attain a state of cognitive equilibrium through reconstruction of concepts, schema, mental models and other cognitive structures in the face of new information and experience that may conflict with earlier constructions. A major goal in constructivist pedagogy is to ensure that the learning environment is as rich as possible. Emphasis is placed on identifying the unique interests, styles, motivations and capabilities of individual learners so that learning environments can be tailored to them. Instead of an empty vessel, the learner is regarded as an individual replete with pre-existing knowledge, aptitudes, motivations and other characteristics that are difficult to assess, much less accommodate. Constructivists often argue for replacing direct instruction with self-directed exploration and discovery learning.

Different forms of CBE are based upon different pedagogical philosophies. Traditional computer-based tutorials, drill-and-practice programs, and contemporary ILS mesh well with instructivist pedagogies. Alternatively, interactive learning environments (Hannafin, 1992), microworlds (Rieber, 1992), and 'mind-tools' (Jonassen, in press) are forms of CBE that enable the implementation of constructivist pedagogy. It must be noted that the degree to which educators, parents, and community leaders emphasise one pedagogical philosophy over another appears to be strongly influenced by religious and political beliefs.

Pedagogical dimension 3 – underlying psychology

At the risk of ignoring a number of other important theoretical perspectives (e.g. developmental psychology), a dimension related to the basic psychology underlying CBE is proposed. Figure 3 illustrates this dimension with behavioural psychology at one end of the continuum and cognitive psychology at the other.

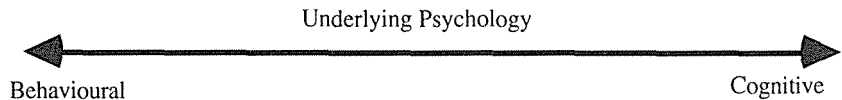


FIGURE 3. Underlying psychology dimension of CBE

Debunking behavioural psychology has become quite fashionable, despite a few staunch defenders (Gilbert and Gilbert, 1991). Therefore, it seems ironic that behavioural psychology continues to be the underlying psychology for many forms of CBE. According to classical behavioural psychology (Skinner, 1968), the important factors in learning are not internal states that may or may not exist, but behaviour that can be directly observed. Instruction consists primarily of the shaping of desirable behaviours through the scientific arrangement of stimuli, responses, feedback, reinforcement and other contingencies. First, a stimulus is provided, often in the form of a short presentation of content. Second, a response is demanded, often in the form of a question. Third, feedback is given as to the accuracy of the response. Fourth, positive reinforcement is given for accurate responses. Fifth, inaccurate responses result in either a repetition of the original stimulus or a somewhat modified (often simpler) version of it, and the cycle begins again.

Cognitive psychology, on the other hand, has captured the attention of many educators today, and virtually all self-respecting instructional design theorists now claim to be cognitivists (Gagné and Glaser, 1987). Without ignoring behaviour, cognitive psychology places much more emphasis on internal mental states than behavioural psychology. Kyllonen and Shute (1989) have proposed a taxonomy that represents the spectrum of internal states with which cognitive psychologists are concerned. Their taxonomy begins with simple propositions (e.g. stating that Japan sells more electronic products than any other nation), proceeding through schema, rules, general rules, skills, general skills, automatic skills and finally, mental models (e.g. analysing the potential of a trade war between Japan and the United States based on an analysis of balance of trade trends). The latter type of knowledge seems particu-

larly important because mental models are the basis for generic problem-solving abilities (Halford, 1993).

Cognitive psychologists recognise that a wide variety of learning strategies may have to be employed in any given instructional setting depending upon the type of knowledge to be constructed. Learning strategies include memorisation; direct instruction, drill-and-practice, deduction and induction (Schank and Jona, 1990). Different forms of CBE vary in their capacity to implement these different learning strategies. Whereas an ILS may provide adequate opportunities for direct instruction and drill-and-practice, some sort of mind-tools or microworld may be required to support deductive and inductive learning strategies.

Pedagogical dimension 4 – goal orientation

The goals and objectives of CBE can range from sharply-focused ones (e.g. following strict protocols for handling medical emergency situations) to more or less unfocused ones (e.g. learning to appreciate modern art). Figure 4 illustrates a dimension of CBE related to the degree of focus represented in the goals of an interactive program.

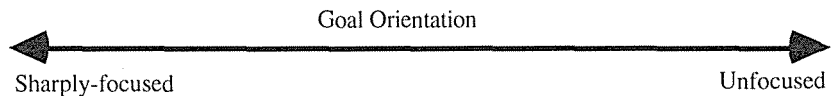


FIGURE 4. Goal orientation dimension of CBE.

Cole (1992) clarifies the relevance of different types of goals to the design of CBE. She maintains that some knowledge 'has undergone extensive social negotiation of meaning and which might most efficiently and effectively be presented more directly to the learner' (p. 29). In such cases, direct instruction, perhaps in the form of a computer-based tutorial, may suffice for learning. Other knowledge is so tenuous, creative or of a higher level (e.g. mental models) that direct instruction is inappropriate. In the latter cases, CBE programs that promote inductive learning such as microworlds (Rieber, 1992), virtual reality simulations (Henderson, 1991), and learning environments (Hannafin, 1992) are much more appropriate.

Although there are many advocates of discovery-based environments for the learning of social studies, science and even mathematics in schools, most of these people

would probably prefer their brain surgeons to be trained via direct instruction. However, there are examples of alternative approaches to learning being applied even in medical schools. Bransford, Sherwood, Hasselbring, Kinzer and Williams (1990) describe the sequencing problem in the context of medical education. Most medical schools follow a sequence whereby students memorise great quantities of factual information during their first two years of training and then spend the next two years in various clinical settings where they may or may not have opportunities to use the memorised knowledge. A few enlightened medical schools have begun to place students in clinical settings from day one while providing them with the pedagogical support to learn basic knowledge and skills as needed. Perelman (1992) describes medical schools in Canada and the Netherlands that successfully employ this innovative approach.

Although it might be tempting to delegate the teaching of sharply-focused goals and objectives to commercial ILS, tutorials and drill-and-practice programs, insufficient research has been conducted on which to base this decision. In addition, the infusion of mind-tools, learning environments and microworlds within traditional school curricula has been so limited that their effects on various types of learning goals and objectives are unclear.

Pedagogical dimension 5 – experiential validity

The earliest type of systematic learning activity probably involved some sort of apprenticeship whereby a novice worked side by side with a master. Apprenticeships have high, i.e. concrete, experiential value. More abstract learning activities, e.g. classroom lectures, were developed much later in history. A major criticism of much of our current dominant pedagogical schemes is that they are too abstract, removed as they are from 'real world' experience (Brown, Collins, and Duguid, 1989). Figure 5 illustrates an experiential value continuum ranging from abstract to concrete.

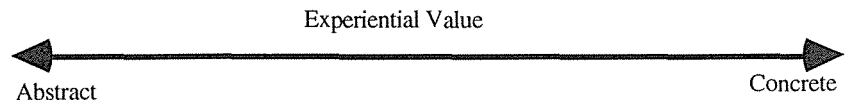


FIGURE 5. Experiential value dimension of CBE

An important concern for educators and trainers alike is the degree to which class-room learning transfers to external situations in which the application of knowledge, skills and attitudes is appropriate. The cognitive theories of Newell and Simon (1972), Anderson (1983), Brown (1985) and others support the fundamental principle that the way in which knowledge, skills and attitudes are initially learned plays an important role in the degree to which these abilities can be used in other contexts. To put it simply, if knowledge, skills and attitudes are learned in a context of use, they will be used in that and similar contexts. This principle is especially important in vocational education.

In traditional instruction, information is presented in encapsulated formats, often via abstract lectures and texts, and it is largely left up to the student to generate any possible connections between conditions (such as a problem) and actions (such as the use of knowledge as a tool to solve the problem). There is ample evidence that students who are quite adept at 'regurgitating' memorised information rarely retrieve that same information when confronted with novel conditions that warrant its application (Bransford et al., 1990; Perelman, 1992).

CBE can be designed to present a focal event or problem situation that will serve as an 'anchor' or focus for collaborative efforts among instructors and students to retrieve and construct knowledge (Brown et al., 1989). Cognitive psychologists at the Cognition and Technology Group at Vanderbilt University (CTGV) call this type of instruction 'anchored instruction' (Bransford et al., 1990; CTGV, 1992), because the process of constructing new knowledge is situated or anchored in meaningful and relevant contexts. They maintain that events and problems presented in CBE should be designed to be intrinsically interesting, problem-oriented and challenging. They have evidence that in response to these types of events and problems, students construct useful as opposed to inert knowledge (Bransford et al., 1990; CTGV, 1992).

Pedagogical dimension 6 – teacher role

CBE can be designed to support different pedagogical roles for teachers. Some CBE are designed to place teachers in the role of a 'facilitator'. Other programs are designed to support the more traditional didactic role of an instructor as 'the teacher'. Figure 6 represents a continuum of teacher roles ranging from didactic to facilitative.

The didactic roles of teachers are well-established. A quarter of a century ago, Carroll (1968) told us that 'By far the largest amount of teaching activity in educational settings involves telling things to students...' (p. 4). More recent analyses of teach-

ing indicate that little has changed since then (cf. Goodlad, 1984; Kidder, 1989; Perelman, 1992). Where teacher exposition is an appropriate instructional strategy, CBE can be designed to support, reinforce and extend teacher presentations.

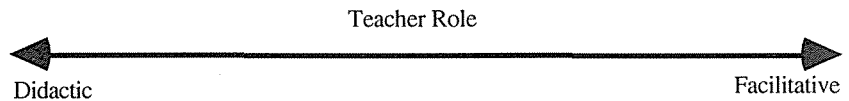


FIGURE 6. Teacher role dimension of CBE

It has become commonplace today in education circles to talk about changing the teacher's role from a traditional didactic one to that of a facilitator. The Cognition and Technology Group at Vanderbilt (CTGV, 1992) describe a shift in the teacher's role 'from authoritarian provider of knowledge to a resource who at times is consulted by students and at other times can become the student whom others teach' (p. 73). In addition to the constructivist learning environments such as the *Jasper Woodbury Problem Solving Series* (CTGV, 1992), producers of large-scale integrated learning systems (ILS) claim to assign teachers roles as facilitators. However, there may be important differences between the facilitator tasks of a teacher using *Jasper* and those carried out by a teacher implementing a commercial ILS. For instance, there is a danger that teachers using ILS may be so occupied with making sure the ILS are functioning properly and troubleshooting any problems, that they might not be able to conduct the one-to-one and small-group teaching that the systems were supposed to allow teachers to conduct.

Pedagogical dimension 7 – flexibility

A hidden agenda of some forms of CBE seems to be making them 'teacher-proof', perhaps because of a belief that earlier instructional innovations have failed as a result of teacher interference (Winn, 1989). Alternatively, other forms of CBE exist in which teachers have considerable leeway to modify program activities. Figure 7 represents a continuum of program flexibility ranging from 'teacher-proof', i.e. unchangeable, to 'easily modifiable'.

Teacher-proof approaches have fervent contemporary advocates. Some forecast the replacement of teachers with increasingly humanlike CBE. For example, Winn (1989) wrote 'Educational technology can only become a viable discipline and profession if it concentrates on developing alternatives to the teacher-based model of

public education rather than trying to alter it, improve it, or even just serve it' (p. 36). A new video created by AT&T as its vision of the future portrays students sitting in front of individual terminals interacting with computer-generated teachers while an adult stands nearby, seemingly in the role of monitoring their behaviour (AT&T, 1993).

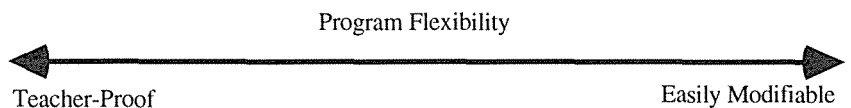


FIGURE 7. Program flexibility dimension of CBE

On the other hand, proponents of program flexibility must deal with the history of inadequate implementation that has hindered decades of educational innovations (Berman and McLaughlin, 1978). Modifying an innovative program has often resulted in insufficient fidelity in implementing a program's effective dimensions. Nonetheless, prohibiting local adaptation will lessen opportunities for creative modifications that may actually enhance effectiveness. The issue of program flexibility is a complex one that must be addressed by efforts to assess implementation very carefully during any evaluation. Forms of CBE must be designed to walk the fine line between being so 'teacher-proof' that they do not allow local adaptation (and may even encourage sabotage) and being so open or unstructured that they do not provide sufficient guidance and support for valid implementation.

Pedagogical dimension 8 – value of errors

The old maxim that 'experience is the best teacher' reflects a belief that we learn much in life through trial and error (CTGV, 1992). Although this approach is inefficient and even dangerous in some contexts, experiential learning is highly valued simply because it provides opportunities for us to 'learn from our mistakes'. On the other hand, some educational theorists, especially proponents of programmed instruction, have maintained that ideal learning involves no errors. These developers attempt to arrange the contingencies of instruction in such a way that learners can only make correct responses. Figure 8 presents a continuum of perspectives concerning the value of errors ranging from error-less learning to learning from 'trial and error' experience.

An example of a CBE program that prohibits errors is the *Principles of the Alphabet Learning System (PALS)* designed for the IBM Corporation by Dr. John Henry Martin (1986). *PALS* uses interactive videodisc technology to teach basic literacy skills to adolescents and adults. At specific intervals, learners are required to type in letters to form the words that on-screen characters say. However, only those keys that match an acceptable spelling of the words are enabled. Pressing the wrong keys puts nothing on the screen except more and more refined directions as to the desired response. This 'error-less' approach is also an element of IBM's *Writing to Read* program (Freyd and Lytle, 1990).

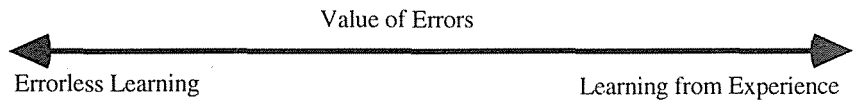


FIGURE 8. Value of errors dimension of CBE

Such an error-less approach contrasts sharply with forms of CBE that employ high fidelity simulation as an instructional strategy. In *The Case of Dax Cowart*, an interactive videodisc simulation created at the Centre for the Design of Educational Computing at Carnegie Mellon University (Covey and Cavalier, 1989), college students are placed in the roles of members of a hospital ethics panel that must decide whether a horribly burned patient can be allowed to die as he has requested or must undergo months of excruciatingly painful treatments. Regardless of a student's decision, he or she is confronted with the negative outcomes of that decision. In this simulation, each choice is treated as an 'error' from which valuable lessons can be learned.

Pedagogical dimension 9 – origin of motivation

Motivation is a primary factor in instructional models (Carroll, 1963). Rieber (1992) describes five design principles for CBE derived from constructivism. The first is to 'provide a meaningful learning context that supports intrinsically motivating and self-regulated learning' (p. 98). Intrinsic motivation has been held forth as the 'Holy Grail' to which all CBE programs should aspire (Malone, 1984). Figure 9 illustrates a motivation dimension that ranges from extrinsic (i.e. outside the learning environment) to intrinsic (i.e. integral to the learning environment).

Intrinsically motivating instruction is very elusive regardless of the delivery system, but virtually every new approach to come along promises to be more motivating than any that has come before. Interactive multimedia is the latest type of interactive learning system that is supposed to motivate learners automatically, simply because of the integration of music, voice, still pictures, text, animation, motion video, and a friendly interface on a computer screen. In practice, as Keller (1987) has specified, motivation aspects must be consciously designed into multimedia just as rigorously as any other pedagogical dimensions. An assumption underlying many commercial multimedia packages seems to be that students will be intrinsically motivated to explore these systems in search of new knowledge. Very little research exists that examines this assumption, but Harmon (1992) found that students using these programs were more likely to seek out confirmation of things they already knew than to seek new knowledge. It seems that the current state-of-the-art of CBE is such that extrinsic motivation will remain a critical factor in many educational contexts.

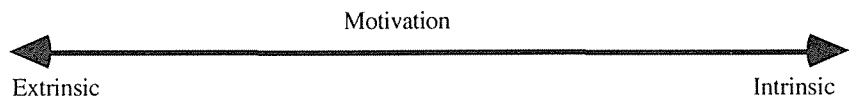


FIGURE 9. Motivation dimension of CBE

Pedagogical dimension 10 – accommodation of individual differences

Although it might be assumed that the main reason for employing CBE would be accommodating individual differences among learners, this is not always the case. Some CBE programs have very little, if any, provision for individual differences, whereas others are designed to accommodate a wide range of individual differences including personal, affective and physiological factors (Ackerman, Sternberg and Glaser, 1989). Figure 10 illustrates a continuum of accommodations of individual differences that ranges from non-existent to multi-faceted.

The impact of individual differences is a major factor in the effectiveness of CBE. Learning is a function of the learner, the content to be learned and the features of the instruction (Sternberg, 1985). Many theoretical models of learning treat individual differences among learners as the major predictor of differential learning outcomes (cf. Carroll, 1963). In most educational contexts, we cannot be guaranteed that learners will be homogeneous in terms of aptitudes, prerequisite knowledge,

motivation, experience, learning styles, eye-hand coordination etc. Therefore, we must provide scaffolding, cognitive boot-strapping and other types of metacognitive support to promote learning (Resnick, 1989). Examples of CBE that provide comprehensive metacognitive support are difficult to identify (Cates, 1992).

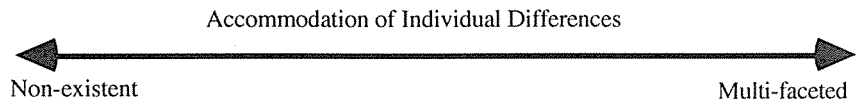


FIGURE 10. Accommodation of individual differences dimension of CBE

Pedagogical dimension 11 – learner control

Learner control has been one of the most heavily researched dimensions of CBE in recent years (Steinberg, 1989). Figure 11 illustrates a dimension of CBE that can range from complete program control to unrestricted learner control.

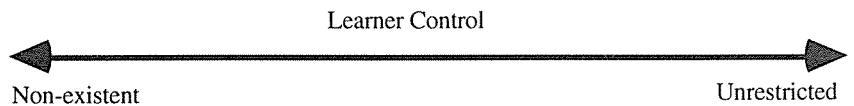


FIGURE 11. Learner control dimension of CBE

Learner control refers to the options in CBE that allow learners to make decisions about what sections to study and/or what paths to follow through interactive material. The popular wisdom is that learner control makes CBE more effective by individualising the instruction and making it more motivating, but all too often experimental studies have led to no significant results in terms of the predicted main effects (Williams, 1993). Reeves (1993) describes critical theoretical and methodological flaws in learner control studies. Ross and Morrison (1989) concluded that 'research findings regarding the effects of learner control as an adaptive strategy have been inconsistent, but more frequently negative than positive' (p. 28). Better research is needed before questions about the learner control issue can be answered (Reeves, 1993).

Pedagogical dimension 12 – user activity

Hannafin (1992) identified another important dimension of CBE, especially those forms of CBE that he and others characterise as ‘learning environments’. He maintains that some learning environments are primarily intended to enable learners to ‘access various representations of content’ (p. 59). He labels these ‘mathemagenic’ environments. Other learning environments, called ‘generative’ by Hannafin, engage learners in the process of creating, elaborating or representing knowledge. Figure 12 illustrates this continuum of user activity.

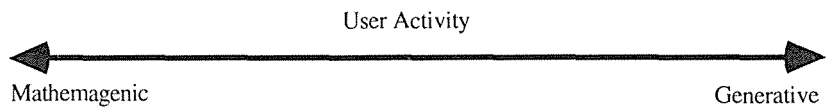


FIGURE 12. User activity dimension of CBE

Generative learning environments are aligned most closely with constructivist pedagogy whereas mathemagenic environments are often based upon instructivist pedagogy, but this is not necessarily always obvious. Contemporary CBE programs such as the *ABC News Interactive* series (ABC News Interactive, 1991) and the IBM *Ultimedia* programs (IBM Corporation, 1991) include generative capabilities nested within otherwise mathemagenic presentations of content. On the other hand, mind-tools such as HyperCard have great potential for enabling generative learning (Jonassen, in press).

Pedagogical dimension 13 – cooperative learning

Support for the value of cooperative learning is growing throughout education circles (Slavin, 1992). CBE can be designed to thwart or promote cooperative learning. In fact, some CBE programs require cooperative learning (IBM Corporation, 1986) whereas others make no provision for its support. Figure 13 illustrates a cooperative learning dimension ranging from a complete lack of support for cooperative learning to the inclusion of cooperative learning as an integral part of CBE.

Cooperative learning refers to instructional methods in which learners work together in pairs or small groups to accomplish shared goals (Slavin, 1992). Johnson and Johnson (1987) and Slavin (1990) present evidence that when CBE (and other instructional delivery systems) are structured to allow cooperative learning, learners benefit both instructionally and socially. Some commercial ILS have been

designed to be used by two or more learners working cooperatively. In addition, multimedia construction programs (such as *Authorware Professional* and *Macro-mind Director*) are so complex that they usually require team-based usage in school contexts.

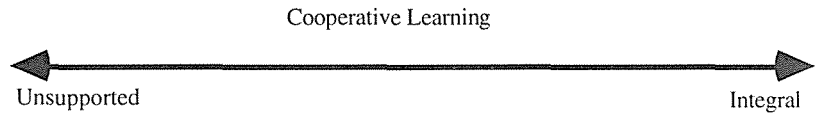


FIGURE 13. Cooperative learning dimension of CBE

Pedagogical dimension 14 – cultural sensitivity

Henderson (1994) provided a valuable critique of an earlier version of these pedagogical dimensions (Reeves, 1992b). Henderson maintains that the assumptions underlying a specific point on any of these dimensions have a cultural element that should not be ignored. For example, whereas a constructivist pedagogy advocates, indeed demands, persistent questioning on the part of learners, questions, especially ‘why?’ questions, are inappropriate in cultures such as the Torres Strait Islanders of Australia. Although CBE may not be able to adapt to every cultural norm, they should be designed to be as culturally sensitive as possible (Powell, 1993). Figure 14 illustrates a cultural sensitivity dimension ranging from non-existent to integral.

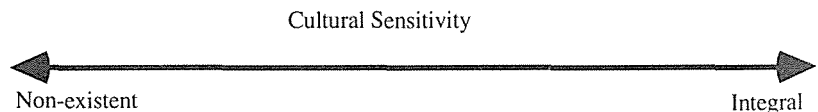


FIGURE 14. Cultural sensitivity dimension of CBE

Powell (1993) revealed that few instructional design courses include cultural diversity as an important factor in designing effective instructional programs. Therefore, it should not be surprising that few CBE programs have been developed in which cultural sensitivity is integral to their design. To be sure, a few instances of CBE include what Henderson (1994) labels ‘tokenistic gestures’ by allowing an occasional minority role for an actor or perhaps by including culturally diverse, albeit

safe, references in terms of music, location or other cultural aspects. It is difficult to describe what comprehensively culturally sensitive CBE would be like, but at the very least such programs would accommodate diverse ethnic and cultural backgrounds among learners.

Application of the dimensions in CBE evaluation

To illustrate the potential utility of the pedagogical dimensions of CBE described above, the last part of this chapter presents an analysis of two examples of CBE employing these dimensions. Experienced developers and users of CBE possess the necessary background and objectivity to provide a reliable and valid assessment of the pedagogical dimensions of these systems. Although the final ratings reported below are mine, they have been influenced by colleagues in Australia and the USA with whom I have discussed these programs. There is an inevitable degree of subjectivity in this analysis and additional applications of these dimensions involving experienced personnel in other education contexts are invited.

The two examples of CBE used in this application are the *Writing to Read* program designed by Dr. John Henry Martin and widely disseminated by the IBM Corporation (IBM Corporation, 1985) and the *Jasper Woodbury Problem Solving Series* developed by the Cognition and Technology Group at Vanderbilt University (CTGV, 1992). The *Writing to Read (WTR)* program is intended to improve the reading and writing performance of students in kindergarten and first grade. During *WTR* periods lasting an hour per day, children rotate among five workstations, two of which involved CBE. The primary computerised workstation in *WTR* provides students opportunities to learn and practise phonics skills. Computer-guided activities include keying-in sounds, words and eventually sentences. The program emphasises the learning of 42 phonemes, letter-sound combinations that can be used to 'spell' any words in the English language. Often, the computer requires verbal as well as keyed-in responses, and occasionally students are prompted to clap or stomp their feet in time with computer presentations.

Few examples of CBE have been more extensively evaluated than *WTR* and few programs are more controversial. Slavin (1990b) concluded that the results of *WTR* are disappointing. On the other hand, Chira (1990) described the enthusiastic reception of *WTR* as a statewide program in Mississippi. Estimates are that more than 10% of the kindergarten and first grade students in the USA used *WTR* in the 1992-93 academic year, making it one of the largest implementations of CBE in any setting.

The *Jasper Woodbury Problem Solving Series* (CTGV, 1992) was created in an academic environment within the context of a long-term research and development program. Its use until recently has been confined largely to a few dozen schools in the south-east section of the USA, but it is now commercially available. The *Jasper Series* represents an attempt to implement constructivist learning principles. These programs (which are provided in both interactive videodisc and linear video versions) provide students with opportunities to develop advanced mathematical problem-solving skills within the context of a series of high-interest video adventures. Students discover the need to develop mathematical skills within the context of flying planes and operating motor boats to solve simulated dilemmas. Numerous studies have been and are being conducted using the *Jasper Series* of programs (Bransford et al., 1990).

The *Jasper series* is an example of what Hannafin (1992) calls a 'generative' learning environment; i.e. a program that requires students to construct or generate their own knowledge as opposed to one that requires them to select knowledge from pre-packaged options. Knowledge constructed in generative environments is more likely to generalise than the inert knowledge acquired in traditional passive learning environments (CTGV, 1992).

Figure 15 presents a profile of the *Writing to Read* and *Jasper* programs using fourteen pedagogical dimensions. My ratings of these programs are based on limited observations in schools, demonstrations of the programs at professional conferences and reading several extensive reports about them, but not first-hand experience in implementing the programs myself. My analysis reveals that *WTR* is based on objectivist, instructivist and behavioural foundations. It is a highly structured program. One of its most notable features is its provision for error-less learning, e.g. students are not allowed to key in incorrect responses to questions. Alternatively, the *Jasper* programs are grounded in constructivist and cognitivist foundations. Teachers are integral facilitators in implementing *Jasper*, and they are encouraged to modify it according to their local needs. Collaborative learning is strongly supported in this program. It appears to be an advanced example of a generative learning environment.

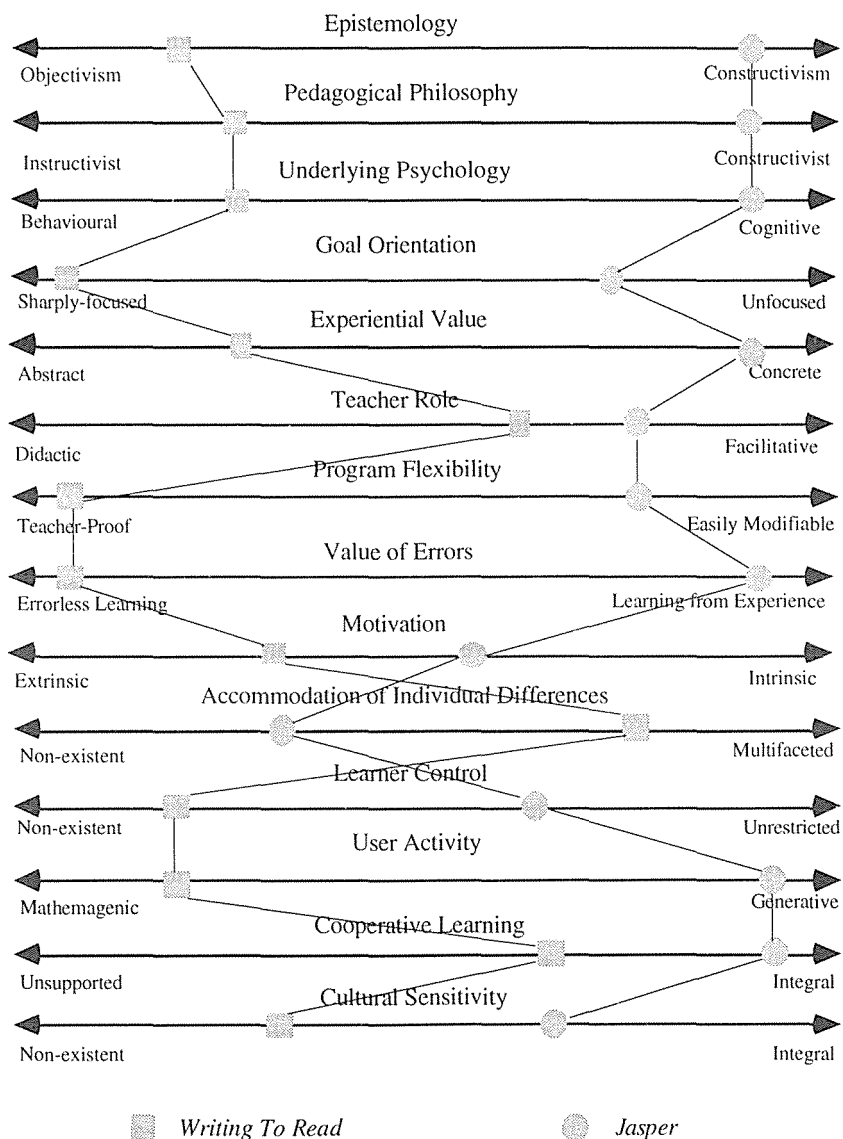


FIGURE 15. Pedagogical dimensions of *Writing to Read* and *Jasper*

Conclusion

The preceding analysis is an admittedly preliminary investigation into the value of these pedagogical dimensions. Hence, the following recommendations are made for improving their utility. First, the dimensions should be subjected to rigorous expert review by leaders in the design and application of CBE. Second, once there is evidence for the qualitative validity of the dimensions, quantitative scales should be integrated into each dimension, e.g. a ten-point rating system. Quantitative values have not been added to the dimensions up to now for fear that reviewers might get too distracted by the numerical values to concentrate on the qualitative aspects of the dimensions themselves. However, there is certainly merit and utility in eventually grounding the ratings in quantitative values. Third, the validated dimensions should be applied to many different forms of CBE in a wide variety of educational contexts to provide evidence for their utility. Fourth, research should be initiated into the relationships among ratings of the pedagogical dimensions of CBE and actual data regarding the instructional effectiveness and impact of these same programs.

The fourteen pedagogical dimensions described above are by no means the final answer to improving evaluations of CBE in education. A comprehensive approach to evaluating CBE requires multiple levels of design, data collection and interpretation. We must explore many alternatives. Each month sees the introduction of new commercial CBE packages advertised as effective instructional systems. Yet systematic evaluation of the implementation and efficacy of these systems is sadly lacking. In addition, many evaluators continue to employ outmoded experimental designs. Papert (1993) sums up the inadequacy of these traditional evaluation designs: 'The method of controlled experimentation that evaluates an idea by implementing it, taking care to keep everything else the same, and measuring the result, may be an appropriate way to evaluate the effects of a small modification. However, it can tell us nothing about ideas that might lead to deep change' (p. 27).

In education today, we need 'deep change', and therefore improving evaluation of CBE has never been more important. Technological advancements are increasing at an ever faster pace, especially with respect to telecommunications and multimedia. At the same time, few teachers feel confident and competent with respect to the goals and functions of CBE in their classrooms (Becker, 1992; Siegel, 1994). Despite some efforts to introduce pre-service teachers to computer education in their teacher preparation programs, Becker (1992) found that over half of the future teachers he surveyed never used a computer in any of their college courses. At least part of the problem may stem from a restricted vision of CBE as simply an alternative delivery system for traditional pedagogy rather than as a tool for implementing

alternative pedagogical dimensions. Evaluation approaches based upon clearer delineation of the pedagogical dimensions within different types of CBE will surely be a step forward.

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Using information technology with low- performing students

David Evans

Abstract

The role of media (e.g. television, computers, innovative technology) in education has promised much over the past years. This has particularly been the case for low-performing students in regular schools and education support or special education settings. The promises of the media in the 80s were never met, and cynical views are held of the promises being made about the use of computers and innovative technologies of the 90s. This chapter will review the use of technologies in catering for low-performing students and make recommendations as to how technologies of the 90s can assist teachers to cater for all students in the regular education setting.

Introduction

The use of computer technology in special education has grown rapidly over the past decade (Blascke, 1985; Ellis and Sabornie, 1986; Hasselbring, 1986). In 1983 Blascke reported that 6000 microcomputers were used in special education settings. By 1986 this had grown to approximately 150000, an increase of 250% in three years.

This explosion in computer technology has created a new, rich strand of media for regular and special education teachers to use with low-performing students. This richness is enhanced through not only microcomputers, but the use of related technologies (e.g. videodiscs, computer networking, multimedia technology).

The expansion of computer technology has brought with it the promise that teachers will be assisted in the provision of appropriate education for special education students. This assistance includes the individualisation of students' programs, greater amounts of teacher-student interaction, and use of technology tutors to instruct students in new skills (Ellis and Sabornie, 1986; Reith and Frick, 1982).

However, the promises of computer technology have only been partially fulfilled (Maddux, 1987, Ellis and Sabornie, 1986). The current path of computer technology development is paralleled by the troubled and rocky road of other classroom technology such as television. Computer technology has failed to meet the expectations attributed to it when it first entered classrooms. Tyack and Hansot (1985) state:

The history of technology in the classroom gives one pause. Too often, inflated promises have been followed by a burst of enthusiasm and partial implementation, and then by discouragement and disrepair, broken morale and broken machines. (p. 40)

Attempts to repair broken morales and machines need to focus on analysis of the use of computers in the classroom. The use of technology has been hindered by inappropriate matching of software to instructional objectives and inappropriate use of technology for class instruction. That is, the ailments afflicting technology use in the classroom are due to the uses made of the technology rather than to the technology itself. Maddux (1984) summarised this concern in the following statement:

The major obstacle is to get people to understand that the things we don't comprehend are fundamentally not technological. They're fundamentally where kids have trouble learning which is not a new question: it just happened to be a new context for asking the question. (p. 42)

Adding to this dilemma is the pace at which technology is changing. If technology is to assist teachers in catering for students with learning problems, teachers must be sure as to what will be of greatest benefit to their students. The purpose of this chapter is to review the use of technology with low-performing students, and then make recommendations regarding ways of selecting and using technology so that it assists teachers to cater for low-performing students in their classrooms.

Review of technology use in special education

This review will focus on the use of technology in special education. Technology use will be discussed under the broader model of media or instructional media (Reiser and Gagne, 1983). Instructional media, 'the physical means by which an instructional message is communicated', include various types of technology such as television, computers and multimedia. Particular emphasis will be given to the relationship between media and learning, with specific reference to computer and multimedia technologies.

Learning from media

Clark (1983) argued that media does not benefit learning and summarised his ideas:

The best current evidence is that media are more vehicles that deliver instruction but do not influence students' achievement any more than the truck that delivers our groceries causes changes in our nutrition. Basically the choice of vehicle might influence the cost or extent of distributing instruction, but only the content of the vehicle can influence achievement. (p. 445)

The basis for Clark's argument is a review of studies and meta-analyses investigating the influence of media on learning. Two points of contention were raised by Clark regarding claims for the positive effects of media in education. First, the effects of novelty-motivation on student performance, and second, the lack of empirical rigour used within studies of media in education.

Novelty

Novelty can be viewed in two ways. First, novelty can be viewed in relation to the amount of time spent on task (Ellis and Sabornie, 1986; Semmel and Lieber, 1986), and second with reference to how technology motivates students (Ellis and Sabornie).

On-task behaviour can be measured by the amount of time spent engaged with a set task. Reith (1986), in a survey of teachers and administrators, reported that students in classes using computers tended to be on-task for a greater amount of time than students not using computers. Semmel and Lieber (1986) supported this by reporting that handicapped students were on-task at least 90% of the time during the use of microcomputers.

Increase in motivation has been attributed to the use of arcade game-style programs with microcomputers. Chiang (1986) concluded, however, that non-arcade-styled

games are just as, if not more, beneficial with learning disabled students than arcade-type programs (Chiang, 1986). Ellis and Sabornie (1986) in acknowledging the concerns of Chiang countered this concern, stating 'any form of academic engagement may be welcome for students who are extremely reluctant learners' (p. 3).

Microcomputers have also been used as secondary reinforcers (Reith, 1986). For example, students upon completing class work were permitted to play a game on the computer. Ellis and Sabornie (1986) acknowledge the value of this use of microcomputers as beneficial, especially for low-performing students. However, they raised two concerns about this practice. First, that use of the microcomputer as a reinforcer was 'a great time thief' (p. 4). Secondly, this type of activity does not promote an internal locus of control. Ellis and Sabornie (1986) listed three ways of overcoming their concerns:

- ensuring that students complete independent work that requires a high level of success;
- have students chart their progress;
- have students predict their score on the next performance of a skill.

Lasting benefits of media applications were viewed by Clark (1983) with scepticism. Studies which lasted one to four weeks had an effect size of .56 standard deviations. However, studies lasting from 4 – 8 weeks, and more than eight weeks in length, had effect sizes of .3 and .2 respectively. Clark concluded these effect sizes were not strong evidence of lasting positive effects of learning through media.

Instructional methods

In reviewing the effects of media on learning, Clark (1983) was critical of studies that did not control experimentally for instructional methodologies. A common weakness in experimental studies involves the comparison of the treatments in which many elements (e.g. subject matter, content and method of instruction) are not identical, making interpretation difficult.

An example used to support this point was the hypothesis that computers are time savers. Clark (1983) argued that studies that investigated this hypothesis could have several rival hypotheses. For example, the program that required the greatest amount of time to design (e.g. videodisc) will be more effective than a program that required less time to design (e.g. teacher-prepared lesson using overhead transparencies). Clark compared this type of study to a race between a precision engineered racer and a family car.

Acknowledging the concerns of novelty effects and confounding research materials, the role of media/technology in special education cannot be dismissed. For example, videodisc technology is capable of presenting concepts in an interactive manner, allowing them to be highlighted and presented dynamically. Previously this has been beyond the means of the teacher.

The ensuing discussion will highlight the use of three types of technologies for learning disabled students. Emphasis during this discussion will be given to the types of software designed for these technologies, how this software is used in instructing special education students and the role of the teacher in using software in the classroom.

Computers

Four major applications of computers are made in special education settings. These applications are listed in Table 1. The application, computer-based instruction and computer-managed instruction, will be the focus of this discussion. Discussion will then focus on the research surrounding the use of videodisc technology.

TABLE 1. Applications of computers in special education settings

Application	Main Use	Major User
Tools (e.g. a word processor)	For personal assistance with specific tasks (e.g. writing)	Physically and sensorially handicapped students
Computer-Assisted Instruction	For instruction — often using practice and tutorial approaches	Students
Computer-Managed Instruction	To manage instruction-related information	Teacher
Computer literacy	To provide knowledge and skills required to function in an information-based society	Teacher and students

Computer-assisted instruction Computer-assisted instruction (CAI) has traditionally been divided into two components: tutorial, and drill and practice programs. Drill and practice programs are those most commonly used with low-performing students (Ellis and Sabornie, 1986; Hofmeister, 1984). They are also the programs that are the focus of most criticism. These criticisms include poor presentation of material, resulting in trial-and-error learning (Le Blanc, Hoko, Aangeenburg and Etzalm, 1985); poor matching between the software and the curriculum in classrooms (Ellis and Sabornie, 1986); and passive integration between teachers and students (Maddux, 1987).

Drill and practice CAI programs are theoretically better suited to the development of proficient skill manipulation than to teaching students new skills. Before students use drill and practice programs to establish proficient skill use, they need to be able to complete the skill accurately. Following the development of proficiency, generalisation of the skill to other settings is not recommended through use of drill and practice programs (Carlson and Silverman, 1986; Hofmeister, 1984).

Drill and practice programs used to develop automaticity in basic skills are useful for teachers of low-performing students. This benefit is maximised when the drill and practice program and teacher's instruction are closely matched in terms of the content (Ellis and Sabornie, 1986) and when programs provide feedback and help manage data on student performance.

Tutorial programs used in special education settings may be either simulation programs or programmed learning. Simulation programs allow the teacher to present materials and situations in the classroom which may be too dangerous, too expensive, or inaccessible in real life. Programmed learning advances students through material in a given sequence, providing corrective feedback, repeat cycles and hierarchical branching if students fail to attain mastery.

Tutorial programs can also be used to teach new skills. The effectiveness of these programs in teaching new skills has been questionable (Carlson and Silverman, 1986). Recent empirical studies, however, have shown that tutorial programs can teach new skills effectively (Collins, Carnine and Gersten, 1986; Johnson, Carnine and Gersten, 1986). The tutorial programs studied presented information in small chunks, accompanied by a cumulative review of previously mastered material, and taught new material directly followed by practice to mastery.

Computer-assisted instruction has borne the brunt of much criticism (Ellis and Sabornie, 1986). This criticism has been warranted in part due to poor instructional design features and the failure of evaluation to inform this design. CAI programs

can be effective, but this is dependent upon how well teachers match program content to instructional objectives, how teachers use programs, and the instructional features of programs.

Computer-managed instruction

Computer-managed instruction (CMI) encompasses the educational goals, the curriculum goals, the curriculum, the instructional model, and an information management system to assist teachers in tracking pupil progress and scheduling students' learning activities. (Baker cited in Fuchs, 1988, p. 294)

Computer-managed instruction has been credited with saving time in the management of student performance data (Krivacska, 1987) and with assisting teachers in designing instructional programs that are beneficial to low-performing students. Empirical support for CMI, however, is minimal, raising doubts about how useful CMI is in assisting teachers to cater for low-performing students.

Fuchs (1988) compared CMI and traditional teacher management of student monitoring. CMI was shown to benefit teacher decisions, and consequently benefits to students were postulated. Fuchs concluded by hypothesising that CMI could assist teachers to overcome their reluctance to perform frequent monitoring of student performance.

Despite the apparent value of CMI, the potential for misuse by teachers is apparent (Krivacska, 1987). For example, a failure to match CMI to required instructional objectives would negate the benefits that CMI can deliver.

Videodisc instruction

The potential of videodisc technology in special education and regular classrooms has not been realised, despite some of its attractive advantages over other technologies. Videodiscs are LP record-sized compact discs that can have up to 54000 high resolution video frames stored on them. This information can be viewed as a dynamic presentation, or frame by frame. The user is able to control the videodisc via a basic remote control mechanism or via a computer (Carnine, 1989).

This autonomy from the machine, and preprepared instruction, frees the teachers from regular class instructional duties (e.g. chalkboard demonstrations, explanations of concepts via two-dimensional, static displays). The teacher is able to use effective teaching strategies like regular monitoring of students' work, brisk pacing of instruction, and ensuring lower-performing students master each step in instruction (Rosenshine and Stevens, 1986).

Teachers still need to ensure that the videodisc software content matches curriculum and Individual Education Plans (IEP) objectives. Teachers also need to select software that follows instructionally sound principles such as concise explanations and demonstrations of concepts, cumulative review of concepts and teaching to mastery (Hofmeister, Engelmann and Carnine, 1986).

Videodisc instruction in special education settings following effective teaching principles and sound instruction principles has been shown to have positive results. Using videodisc instruction, Kelly, Carnine, Gersten and Grossen (1987) taught fraction skills to eight, integrated Year 7 learning disabled students. The integrated students performed on the post-test only marginally below that of their peers, although they did require extra time to complete the same amount of work.

The use of well designed videodisc materials can lead to frequent teacher performance of teaching behaviours correlated with effective teaching outcomes. Evans and Summers (1992) found that teachers when using videodisc technology asked more lower order questions of students and monitored students, especially lower-performing students, more frequently than when they were not using this technology.

Conclusion

Studies investigating the effect of technology have failed to address concerns of confounding variables (Clark, 1983). The empirical studies reviewed did not address the effects of novelty, and only a few studies matched procedures for control and experimental groups (Fuchs, 1988).

Without dismissing these issues, successful use of technology has been shown to be dependent on several factors. First, instructional objectives need to be considered when selecting software. If selecting software for drill and practice, teachers need to consider whether the skills practised by use of the program match those the students have already been taught. Failure to do so could result in wasted instructional time.

Second, the design of instructional strategies used in software needs to be considered. Programs teaching new skills are more efficient if the skills are taught directly in small chunks, practised to mastery, and reviewed cumulatively. Students using drill and practice programs need to receive regular feedback, and recommendations when necessary.

Third, teachers need to use teaching strategies, and classroom management strategies, already identified as being effective during non-technology-based classes. These strategies include regular monitoring of students' work, brisk pacing of instruction, and frequent provision of feedback.

In the following section recommendations will be made on how to select appropriate software to assist in catering for low-performing students in the regular and education support classroom. These recommendations can be used in selecting computer software, videodisc software, or combinations of media.

Recommendations for using technology with low-performing students

In making recommendations for using technologies to assist teachers in catering for low-performing students, the points made above need to be considered. Also, the following recommendations are based on the assumption that ALL students can learn. To support all childrens' learning, teachers need to take responsibility for selecting the best instructional program and for making decisions on what is the most appropriate instructional program to meet the needs of individual students.

In making decisions on what is the best technology, both hardware and software, the teacher needs to consider a number of factors. The teacher first needs to be sure that technology will assist students in achieving the stated learning objectives. In making this decision the flow diagram of decision-making procedures outlined in Figure 1 may assist in a sound decision being made. The decision-making model in Figure 1 brings together a number of the points made previously, as well as drawing upon a number of elements from the effective teaching literature (e.g. Rosenshine and Stevens, 1986).

In using technology to cater for all students, an important consideration for the teacher is whether the materials being considered are to be used to introduce new concepts or experiences. As part of making this decision, the teacher must be sure about the essential pre-skills required for the technology to be used. This may require the teacher to evaluate the program being considered and identify those skills required to operate in a program. (Many programs will have already identified these skills.) Having identified these skills, teachers must then assess students, especially the low-performing students, to ensure they have attained these skills.

Critical skill instruction If the objective of the program is to introduce or teach a new skill, it is necessary for the teacher to determine whether the skill is critical to further learning. If the skill is critical to further learning, it may be appropriate that the skill is taught using a teacher-directed strategy (e.g. direct instruction, direct

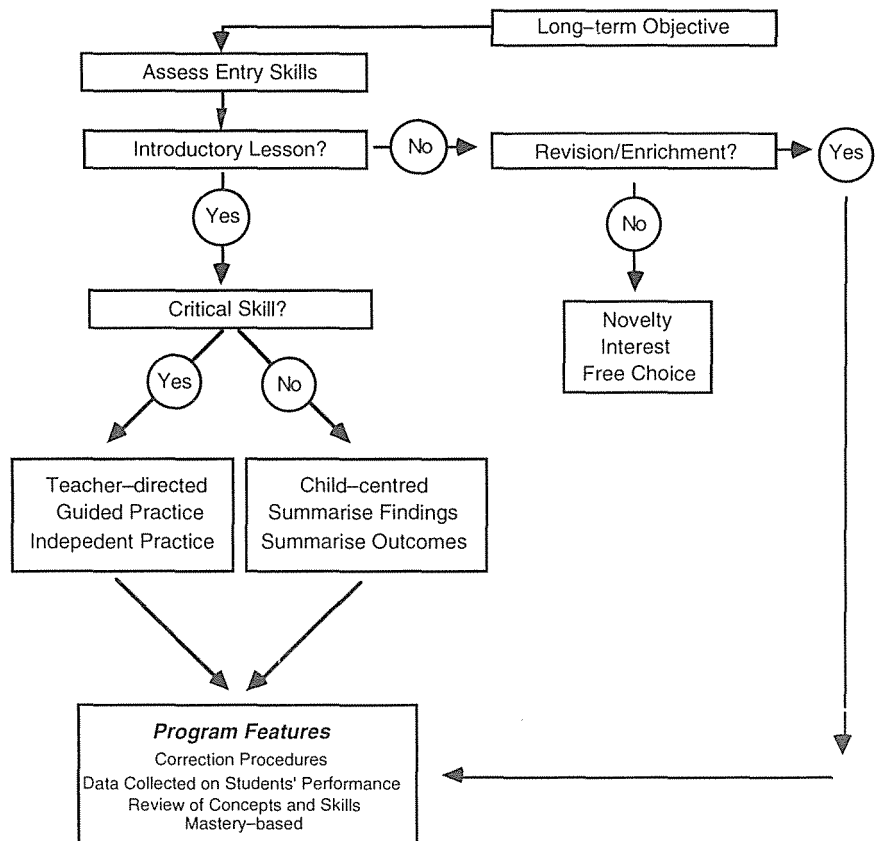


FIGURE 1. Making decisions about best uses of technology for low-achieving students

teaching). This will benefit low-performing students by ensuring that critical skills or concepts are made explicit to them. More able students can still achieve the planned learning outcomes, but this approach ensures that all students are given the optimum opportunity to achieve mastery.

The type of instructional features in a teacher-directed program are closely related to the teacher behaviours associated with effective teaching. Initial introduction of skills needs to be teacher-centred, moving to guided practice of skills to independent practice. The videodisc programs *Mastering Decimals and Percents* (Systems

Impact) and *Conquering Fractions* (Minnesota Educational Computer Corporation) are excellent examples of teacher-directed programs. It should also be noted that there are very few technology-based programs that allow the direct teaching of skills and it is recommended that teachers introduce new material initially, using technology to facilitate guided practice and independent learning (Malouf, Jamison, Kercher and Carlucci, 1991).

During guided practice students should be challenged to extend the work covered in teacher-directed sessions with less direct intervention. Students' performance on a skill is characterised by slow but accurate use of that skill. The use of technology allows the student to enhance the proficiency of the skill. This stage should lead to students completing work with increasingly less assistance from the teacher.

Child-centred learning Programs that are designed to teach non-critical skills can be more child centred. For low-performing students, these programs need to be set up so the students know clearly the steps they need to take to achieve the learning outcomes. Teachers may need to supplement programs so that findings are summarised and expected learning outcomes are the focus of final work submissions.

Whether programs are teacher-centred or student-centred in their approach to teaching skills and concepts, a number of program features are worth identifying if they are to assist in catering for low-performing students. The quality of instruction and the match with curriculum goals are important. Programs that represent skills and concepts dynamically (e.g. *Mastering Decimals and Percents*) also assist students in making connections with previous learning (Kozma, 1991).

Programs that record student information make it easy for the teacher to check on students' progress at regular intervals, an important consideration for teachers of low-performing students. The form in which information is presented needs to be considered (e.g. totals scores are not as useful as results given for each skill; percentage of correct responses versus number correct).

Programs that review concepts and skills tend to be more effective. This review ensures that skills are maintained. This is important to consider if the skill is used again as the component of a higher order skill. This also assists in achieving another important goal of good technology programs and that is teaching to mastery. Programs that teach to mastery and check that mastery is maintained are more effective at catering for low-performing students.

Finally, built-in correction procedures, ones that correct at the point of error, assist greatly in catering for low-performing students. Students need to be alerted to

errors and taken through correction procedures if they cannot work out the correct response. Correction procedures may require students to seek the assistance of the teacher. If this is a frequent occurrence with a program it may indicate the program is unsuitable for the students at this level of instruction.

Enrichment materials If technology is being used to enrich the teaching environment or to provide revision of skills, similar program features to those discussed above are beneficial. Programs need to provide students with correction procedures, review of recently learned as well as older material, and require students to perform to mastery. Data collection procedures for each student are necessary, as many of these programs require students to operate by themselves. For low-performing students, the more specific the information collected the better.

Conclusion The advent of technology in classrooms has been a painful process. The signs of this ongoing pain appear to be diminishing and these advances in technology use are being accompanied by evidence that students can receive appropriate instruction via technology-based instruction. Research is beginning to show that the effects of novelty and instructional strategies can be controlled to provide valid evidence of the power of technology in catering for all students in classrooms (Kozma, 1991). However, it should be noted that teachers need to consider a number of questions when selecting materials and be reflective on the way in which they use the technology in their classrooms. If these considerations are addressed in some way, the use of technology can become a powerful tool which will assist teachers to cater for all students in their classroom (Hannafin and Savenye, 1993).

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Planning for appropriate information technology environments for schools

Brett Clarke

Abstract

This chapter will explore the issues that need to be considered when planning for the introduction of information technologies (IT) in schools. It will describe the historical development of policies relating to the central provision of computing hardware in Western Australian government schools. Examination of the evolution of IT policy in Western Australia highlights the early mismatch between recommended practice and the results of policy. There are clear links between centrally-determined policy and what eventually occurs in schools and classrooms, and the changes which are discussed reflect changes in philosophy about the role of IT in learning and education.

The experiences of Western Australian schools highlight the need for informed planning at school level to ensure that policy supports best practice, and this chapter proposes models by which effective planning can occur. A case study of one Western Australian senior high school is presented to demonstrate how one school planned and implemented a policy which focused on IT to achieve school goals.

Introduction

For over a decade, IT and more specifically, the personal computer, has promised much as an educational resource in our schools. As a result of the experience gained over this period, educators have become more aware of the computer's applications across the curriculum rather than simply as an object of study.

However, during the early eighties when 'computer education' was recognised as a priority by the Federal government, it was the latter, narrower view which was widely held and supported by financial programs such as the Commonwealth CEP. In so far as the money stretched, its expenditure on hardware purchase (dollar for dollar subsidy) and basic teacher training concentrated mainly on secondary schools and addressed only a fraction of the needs.

Similarly, later programs such as the Western Australian government's 1987 Computer Education Project, provided funding for hardware to a ratio of between 1:40 and 1:90 computers to students (depending on size and type of school) and a small team of support personnel aimed at encouraging wider curriculum application in primary schools.

In the current economic climate, where accountability is a word one hears increasingly often and schools are more responsible for their own planning and decision-making, something seems to have slipped past many of those involved with IT in education. It is the question of 'what kind of IT resource is appropriate and can be justified in a school and how can it be managed so as to provide a continuing and ongoing service with regard to changing needs and technological obsolescence?'.

The best teaching strategies and philosophies related to the use of computers in education flounder if the technology is not available to be used. So it is not surprising to hear complaints of lack of equipment, when for the most part its planned provision has not occurred, leaving schools trying to apply 90s computer education philosophies in environments that were provided and funded within the context of the early 80s.

What is required is that today's decision-makers recognise the value and changing nature of the contemporary IT environment in education and plan for its continued provision in a programmed way. To put much of the suggested strategies and ideas into context, one needs to have an appreciation of how computer education and its facilities have developed over recent years.

This chapter begins with an outline of this development, giving some sense of the directions taken up to the present time and the motivations behind them. It concludes by reflecting on this experience in the context of contemporary opinion in this area and some strategies by which current challenges may be approached.

A history of computer education provision in Western Australian schools

1971 Secondary schools used 'off-site' facilities at the University of Western Australia (UWA) to batch process MINIWAFT cards that students had hand-punched to represent computer programs as a part of mathematics extension classes.

1975 Secondary schools used the facilities at UWA to provide 'interactive' processing of BASIC computer programs for the first time, taking turns via a single 'dumb' terminal in their classroom connected to a dial-up telephone link.

1977 The dial-up service provided by UWA to secondary schools was transferred to another DEC mini-computer system housed at the newly formed Schools' Computing Centre in Nollamara to cope with increased demand from more schools, but still, generally, only one terminal per school existed. Later, a few 'CP/M Vector Graphic' microcomputer systems were purchased through the Schools' Computing Branch. Many of these were made available on a rotational basis to secondary schools to augment the restrictive dial-in facilities.

1981 Computing activities in Western Australian primary schools were officially recognised for the first time with the release of the Director General's *Policy Paper No. 34: Computers in Primary Schools*. The emphasis was not on programming, as it was in secondary schools, but on the use of computers as a teaching aid across the curriculum for Computer-Assisted Learning and -Instruction (CAL/CAI), and as a motivational aid.

1982–1986 The first specification for microcomputers 'approved' for purchase by Western Australian schools (BBC Acorn for primary and Microbee for secondary use) was released as the result of a contract in 1982, and purchase had to be arranged through the Schools Computing Branch who made the purchase, checked the equipment and provided initial training. Such practice was encouraged through a centrally-funded 'lifetime' maintenance agreement and 'dollar for dollar' subsidy to augment the schools' own funds, effectively halving their price to schools. The centrally-funded 'lifetime' maintenance provision literally meant that if they ever

broke down they would be fixed at no cost to the school, and if they were not repairable, they would be replaced with a similar or new model.

This was generally the first time that schools had their own 'on-site' computing facilities and coincided with the availability of relatively cheap microcomputers. During this period, most schools had purchased at least one computer under this scheme and some pioneering secondary schools had as many as 12 or 16 Microbee computers using a star configuration of a Local Area Network (LAN). Much of the activity during this period was still in secondary schools, encouraged by the focus and funds of the Federal government's CEP which broadened use to developing general computer literacy through contact with productivity applications such as word processing, spreadsheets and databases, rather than simply learning to program them.

1987–1989 By this time the dollar for dollar subsidy and the Schools' Computing Centre ceased to exist and their advisory function was devolved to the newly created District Offices as part of the Education Department's overall devolution policy. But as part of an election commitment, the Western Australian government undertook to provide funds (approximately \$5 million) to ensure all government schools had sufficient computer hardware to meet a minimum agreed ratio dependent on school type and size of student population (e.g. an average primary school of 350–400 students received funds for five computers while a secondary school of 1000 students received enough for 25 computers). The provision of the funds rather than the machines themselves was a departure from previous practice and was a recognition of the new model of devolved decision-making to schools.

A new specification was written as the basis for a contract for the 'approved' microcomputers for purchase by schools as part of this initiative. This contract was still restrictive given that schools were now making the purchasing decisions, but did recognise new models of the already endorsed Microbee and BBC Acorn platforms, and added specific configurations of Apple Macintosh and IIGS computers, as well as one local brand of IBM-PC clone. The centrally-funded 'lifetime' maintenance provision continued to apply to these machines.

This list recognised the changing applications for computers in schools to some extent but changes were largely a reflection of a move from 8-bit towards 16-bit hardware. There was no longer a set computer for use in either primary or secondary schools, but most primary schools continued to buy BBC Acorns with a few IBM-PC clones and Apple II GS models, while most secondary schools purchased IBM-PC clones and, to a lesser extent, Apple Macintoshes.

The current 'Computer Use in Primary Education' policy was launched by the Education Department and included a small support team to help implement the policy in primary schools through in-service courses with the newly provided machines. The emphasis was firmly on the use of the computer as a general aid and not on the study of the computer itself. The new unit curriculum courses in secondary schools continued to de-emphasise the programming aspect and concentrated on computer literacy, productivity applications and an appreciation of the social impact of technology.

After the initial allocation of funds in 1987, schools continued to purchase additional computers to meet their needs from their own funds. In most primary schools this provided, in approximate terms, one computer per teaching area (i.e. between two and four classes); in secondary schools, the provision was for an extra computer laboratory or for one computer for each of the remaining faculties (e.g. business).

A contract was also let for the supply of administrative computer systems for all secondary schools (MAZE) and the Schools' Administrative Systems Branch was born. Unlike the devolved structure which seemed to be required of curriculum computing, administrative computing spawned a highly centralised structure, surprisingly similar to that which curriculum computing had during the time of the Schools' Computing Branch. Administrative systems were tightly controlled in terms of hardware and software and were purchased, installed and supported by Ministry officers from central budgets.

1990–1992 The three-year contract which had been let for the supply of computers in the 1987 State Computer Education program ended, necessitating a review of hardware specifications and provision policies. Devolution was in full swing, the Computers in Education project ceased, and its function was also devolved to a dwindling number of Districts where computing was seen as a priority.

After much debate, it was decided that a new contract should be let for the supply of microcomputers as there were issues related to audit requirements and many schools were still unable to provide sufficient expertise to make their own choices regarding computers. However, a growing number of schools did have considerable experience and expertise by this time and many teachers complained of insufficient choice (particularly in brands of PC clones), and high contract prices.

As a result, the 1990 contract process contained a significantly expanded list of contractors which was published in a unique document, *Microcomputers for Education Use in Schools: 1990*. While outlining the particular equipment currently

available on the contract, for the first time it endorsed 'notebook' portable PCs and 'families' rather than models of computers, allowing it to better reflect the rapidly changing technology and pricing structures and allowing schools more choice in the specification of their equipment.

With the closure of the Computers in Education project and the consequent reduction of advisory support for computer use in schools occurring at about the same time, this document had several other important functions aimed at making schools more self-sufficient in relation to computer use. It was to give school personnel an appreciation of the wide range of applications of computers across the curriculum, educate them about the criteria to consider in making equipment choices in the light of their specific applications and a knowledge of the proper procedures for making purchases using government funds.

At this time many primary schools were attempting to provide one computer in each classroom and many secondary schools had more than one lab and at least one machine in science, maths or media/arts. Significant numbers of portable computers were being purchased to satisfy a number of different applications in different locations. LANs were becoming quite prevalent in most secondary schools, generally as an aid to serving software and lesson exercises rather than as a collaborative learning tool.

All purchases were then being made from the contract using school or other funds. Such purchases continued to attract the centrally-funded 'lifetime' maintenance provision with the notional value of a 'computer system' being documented as \$1650 (\$1300 hardware, \$200 software, \$150 training) for the first time. This became an issue as many of the computers purchased under the subsidy scheme in the early 80s could no longer be repaired and had to be replaced with new equipment.

During this period a contract was also let for the supply of library automation systems for schools (i.e. *Microfusion*) under the auspices of the School Library Automation project. The organisation of this project was placed somewhere between that of the school administrative system and that of curriculum computing. Only one hardware and software resource combination was selected, with all support to be handled by the equipment's supplier rather than the Education Department. New libraries had the system supplied and existing libraries could have the system installed at their own expense.

1993 The 1990 contract had again run out and, based on increased knowledge and experience, schools were pressing very hard to have an unrestricted choice of com-

puters. Technology and price changes were becoming so rapid that the previous contract could not be updated quickly enough to keep pace. Some sections of the industry also felt that the contract system was unfair and denied them access to a significant market. Also, it was becoming obvious that the borders between the three areas of computer use in schools — curriculum, library automation and administration — were becoming less distinct and the policies regarding their selection and provision had to be brought more into line. In response to these needs, alternatives were canvassed, but the *Financial Audit and Administration Act (FAAA)* and government 'Quality Assurance' policies required that there had to be some restrictions on the expenditure of government funds.

During the first term of 1993, a new document was released by the Education Department entitled *Information Technology in Schools, 1993: Standards and Guidelines*. This document followed on from its predecessor of 1990, but its title reflected two important changes. It recognised that IT in schools encompassed curriculum, library automation and administrative applications. Instead of a period contract with specified suppliers, it provided a way for schools to purchase any equipment from any supplier provided it had been certified to particular 'quality assurance' standards (AS3902), and met or exceeded the stated guidelines with respect of system specification and capacity (32-bit, 2Mb RAM, 40Mb disk). Since each purchase was in fact an individual contract between the government and the supplier, stringent requirements were outlined as to the correct and legal purchasing procedures for schools to follow.

This situation reflects the culmination of the gradual shift from a very narrow choice of equipment with central purchase and support mechanisms through a half-way provision of both from 1987–1990 to an almost unrestricted choice with almost entirely devolved funding and purchasing power, over the period of a decade.

Current school IT environments

Equipment Knowledge of just what equipment is out in Western Australian schools is difficult to obtain as a result of a number of factors. With the closure of the Schools' Computing Branch in 1987, the body charged with administering the supply of computers to schools up until that time ceased to exist, and any records of its activities are unable to be traced. Similarly, the records related to the State Computer Education Program (1987–1990) when the largest provisions of computers to

schools were made, are unavailable. Thus, it is impossible to know with any certainty, just how many computers/peripherals, and of what types, were obtained by which schools during this period.

Since 1987, when a process of devolved decision-making was introduced to Western Australian schools, there has been no centralised funding of computer purchase. Computer purchases which have been made since 1987 have been funded directly from school accounts, and there is no central record of these purchases either. This situation has been further complicated by schools trading equipment with one another on an ad hoc basis, and various computers being replaced when they became uneconomic to repair, as part of a centrally-funded maintenance program.

However, in 1992 as part of an overall review of its IT position, the Education Department commissioned a report which was to outline, among other things, the computing equipment which existed in schools. Despite its small sample size, which casts some doubts as to its accuracy, the report concluded that there were about 15 000 PCs in schools. This compares to the 5 000 PCs that should be there if one uses the Education Department's current entitlement formulas (unchanged since 1987) and current student numbers per school as the basis of the calculation. This would indicate that since 1987, approximately 10 000 PCs have been purchased directly from school funds, and more recently, retail sales promotions such as Coles Supermarkets 'Apples for the Students' scheme.

Given that there are approximately 250 000 students in approximately 800 schools, central funding would have provided an average ratio of 50:1 (students to computers) or six computers per school. The overall estimate of 15 000 suggests the ratios are more like 16:1 (students to computers) and 18 computers per school.

The reader could be forgiven for gaining an impression that the resource provision and management of computers in Western Australian schools over the past dozen or so years has been somewhat haphazard. Perhaps the most consistent policy during this time has been related to the maintenance of the computers once they have been purchased. Provided the equipment is of a type and specification 'approved' for purchase by the Education Department, it will be repaired for an indefinite period after the expiration of its warranty. In other words, regardless of where the school found the money to get the computer in the first place, it will be maintained virtually 'forever' under existing policy using a centralised (Education Department) budget. This policy extends to the point where when it became uneconomical to repair (often due to non-availability of parts — e.g. Microbee network controller boards), schools received a sum of money for its replacement. This is effectively a

‘new for old’ replacement policy, which has now been recognised as a significant financial burden on the Education Department’s IT budget.

What is clear is that ever since the first introduction of computer education in Western Australian schools in the 1970s, they have been viewed as an item of ‘capital expenditure’, with funding (either at the system or school level) only being considered on an intermittent, as needed or crisis management basis. This is in contrast to practice which appears quite common in industry and some tertiary institutions where computer equipment is now considered to be ‘consumable’ and appears as a recurrent budget item each year.

Organisation Though some laboratories or ‘banks’ of computers exist in some primary schools, current practice generally appears to favour the provision of sufficient computers for one in each classroom with some in the library for access to catalogues and CD-ROMs. In addition, the provision of some notebook style computers which can be ‘borrowed’ like a book to augment the other facilities, or for the student to take to the point of need rather than the student having to go off to the computer, is becoming increasingly common.

The computer ‘lab’ is the most common sight in secondary schools, typically containing about 15–25 computers (often on a LAN) and used for teaching computer studies and/or business studies classes. However, in the past few years a few stand-alone machines have found their way into other faculties. Similar to primary schools, most secondary schools have found that some computers in the library for access to catalogues and CD-ROMs are important and the provision of some notebook-style computers for ‘borrowing’ is becoming increasingly common.

The beginning of the 80s saw a move away from off-site, mainframe/mini-computers with remote processing power accessed via telephone lines, to localised processing using desktop microcomputers. The beginning of the 90s has seen a strong move from stand-alone desktop PCs toward LANs, WANs (Wide Area Networks) and portable notebook and palm-top computers and the reacquaintance with telephone lines, though not to access processing power but rather the information held on those remote computers.

Use From the single application of learning a computer language in the 70s, the use of computers in secondary schools in the 90s has moved firmly from students writing simple programs of their own to using highly sophisticated commercial software as tools to boost productivity (word processing, spreadsheets) and enhance creativity (desktop publishing, video and graphics or music). In addition, there is a

slow awakening to the computer's potential as a learning aid in areas such as science, mathematics and English.

With the increasing amount of reference material published on CD-ROM rather than paper, both primary and secondary school libraries are moving rapidly to provide the facilities to access these forms of information, as they are with remote, on-line information sources such as Telecom NEXUS.

In the primary school, while the emphasis has remained on the computer being an aid to teaching and learning, the mode of use has changed to a significant degree. During the 80s, CAL/CAI software was most common. The computer provided the information in response to the user. Now, more primary-age students are using open-ended software tools, to create information of their own, often to a greater extent than some secondary students. The use of word processing, desktop publishing and multimedia tools are being used more commonly to produce 'projects' to communicate and display a student's ideas.

Management Unfortunately, this is the area in which the least amount of change appears to have taken place, yet is probably the area most requiring it. Until the advent of microcomputers in schools in the early 80s, the facilities were off site. There was no choice to make or much equipment to look after, and use was usually limited to a specific teacher's single class. However, since then computer numbers have increased from perhaps one per school to as many as 20 per primary school or 120 per secondary school in some cases, with not one but a dozen or more teachers needing access and assistance. The choice has increased from only one possibility or approved machine, to literally dozens.

Although school-based decision-making groups with various committees operate in all schools now, in many cases the research, rationale and decision-making related to the number and type of computers to be purchased continues to rest with one keen, enthusiastic and usually knowledgeable teacher in the school, whether it be primary or secondary. Once delivered it is usually the same teacher who is charged with their upkeep, software selection and staff troubleshooting. At no time in the past decade has there ever been any recognition of this role or the time that it demands, yet in that time the number of computers to be administered has increased from zero to 15 000.

Planning Given the strain staff are placed under with regard to the management role touched on above, and that rarely, if ever, is adequate time made available for it, it is no wonder that little future planning for IT provision takes place in most schools. Unless a broader base of staff, with increased expertise are given the

opportunity to take the time to plan, further progress beyond simply buying more or otherwise updating the obsolescent equipment is unlikely to occur.

At the very least, strategic planning requires a strong understanding of the strategic issues, an understanding of the relevant medium and long-term goals based on a needs assessment and a reasonable assurance of continued access to the resources to put the plan into action. In most cases some, if not all, of these basic requirements are missing in the planning process even if it is undertaken in the first place.

This raises the issue of whether individual schools, given their current resources related to funds, staff time and expertise, are actually in a position to manage strategic planning in this area. While the nature of schools means they are all different, there is likely to be sufficient similarity in a number of cases to save the re-invention of a few wheels at least. In addition, a key point about such planning is that the plan is not a product in itself, and that even with limited resources, each school must participate in the process lest the key elements of ownership and commitment be missing.

In recognition of this situation, the Education Department's IT strategic planning is now beginning to encompass school needs, and independent planning consultants, who previously would have only considered corporate clients are now marketing their services to local schools. While most people recognise that schools don't have large funds to pay for such consultancies, companies use the uniform nature of schools to advantage in keeping fees down. Instead of a time-consuming intricate analysis and detailed review each time, general needs and requirements can be quickly ascertained and previous experience or general solutions/techniques applied. This is of course a compromise of cost, participation and result, but one which at least recognises the need and tackles the problem.

Needs assessment and future goals

Planning is about controlling and affecting changes or actions in a situation over time, in order to progress toward a desired result. Implicit in planning for something must be an understanding or a vision of what or where that 'result' or 'something' is and developing an idea of what will be needed to get there.

In schools it is vital that the focus remain primarily educational, not technological. Improvement of student learning and development must be the eventual goal, for they continue to be the major reasons for which schools exist. Therefore, IT plan-

ning and thus technological change within a school must be linked to desirable improvements in learning.

As many readers would know, there is a myriad of factors which contribute to learning. Many of them are not well understood, so the challenge is to make links between what the technology offers and the factors which can be manipulated through it, for improvement. For example, gains might be sought through more equitable and timely 'access' to information or through greater 'engagement' with learning, encouraged by increasingly interactive rather than passive/responsive alternatives.

In either case, students not being able to get the information they need, when they need it, where they want it, or not being interested or motivated to learn, are common educational problems for which IT can offer part solutions. This might translate into a school having a multimedia-capable computer in the library and a number of portable computers stocked with similar software available for general loan.

Strategic issues

Time is a critical factor, as not only is it the major dimension in which change takes place, but it provides a link to 'trends', which are simply descriptions of change over time. In the IT industry, technological progress is so rapid it is easy to be swept away by the latest innovation. Conversely, education is so conservative it is easy to stand by and do nothing.

Table 1 outlines some of the changes in the use of computers in schools over the last 20 years. By reading across the table, you get some sense of the environment at the particular time; by reading down, you can see how things have changed over time. These trends are significant, though by no means are they comprehensive.

It is also necessary to understand the current trends in both the IT industry and in education. What will be important in the future is linking the IT trends to those of education in such a way as to benefit student learning.

TABLE 1. Time-line of developments in computing in Western Australia

Period	Locus of Control	Nos.	Type	Use	Funding	Management
1971	external	1	mainframe	programming	central	
1975	external	1	mainframe	programming	central	Schools Computing Centre
1977	external	1-2	mini-computer	programming	central	Schools Computing Centre
1982	external; school	6-16	8-bit micros	programming; CAI	central	single teacher
1987	school	10-40	8/16-bit micros	CAL; CAI; learning tools	central	single teacher
1990	school	10-80	16/32-bit micros and notebooks	CAL; learning tools	school	single; few teachers
1993	school	15-120	32-bit micros	CAL; learning tools	school	several teachers
1996-	school; teacher; students	1:1	personal digital assistant	information organisation; data access	school; students; parents	school; students; parents

Increasingly, a school in the future is likely to have the following characteristics:

- independent in responding to the specific needs of the local community and accountable to that community for the delivery of quality educational outcomes;
- the local community will be diverse in terms of age, skill-base, disability, ethnicity etc.;
- a flexible curriculum in terms of coverage and access to meet community needs;
- independent and collaborative learning styles supported to meet the demands of a wide range of learners;
- competitive for students.

Therefore, what are the characteristics of an IT environment most suitable to support such a school?

- an extensive communications network to allow access to information by teachers from any point in the school, and via the telephone system, from anywhere outside the school;

- an information base of electronic resources and courseware available over the network and access via the WAN to the information bases of other centres;
- software to facilitate communication and collaborative working patterns allowing multi-user input, electronic mail capabilities etc.;
- availability of a range of data capture and display devices;
- availability of appropriate computer processing power at the point of need;
- staff who are well versed in the educational application of electronic resources.

Due to the varied nature and distribution of its likely community, which could involve adults as well as children, both local and across the state, access to learning will have to be available off-site as well as on-site.

Current use of telematics is evidence of how IT is being used to distribute education over a wider area. The increasing pervasiveness of communications technology and computer LANs and WANs must be harnessed to provide convenient access to educational opportunities. Improvements in communications technology will mean that regardless of location, students will have access to the knowledge base and facilities provided by the computer network and other information sources at any time.

The improvements in human-interface design are providing greater access to all students regardless of age, intellectual capability or physical disability, to experiences unavailable previously. Accordingly, the provision of school IT facilities should aim towards:

- ease of access (off-site via WAN/phone access and portable equipment; on-site via LANs, labs, location in classrooms and portable equipment);
- ease of use (powerful and consistent user-interfaces; plug-and-play usage);
- ease of interacting with the real-world (media integration through imaging/audio capability and interfaces to sensory/control systems);
- ease of production/implementation of electronically-based teaching resources/courseware or software which, while each being useful separately, can also be linked to form more complex learning environments.

Flexibility must be the key

If all that is available are computers and printers, consideration should be given to buying a scanner or camera instead of another computer. This allows so much more to be done with the computers that are already available, rather than just doing more of the same.

The idea of having 'lots of the same' is appealing to many as it seems to simplify the solution. In fact, it complicates matters as such expenditure does not efficiently address the myriad problems (which there always are and which change over time). A mixture of desktops, notebooks, colour and monochrome, simple and powerful computers is needed in conjunction with a wide range of peripheral devices, rather than simply a large number of printers.

Conclusion

This aim of this chapter has not been to teach the reader how to plan, but rather to encourage:

- an awareness of the need to plan;
- consideration of the type of IT environments that should be planned for; and
- understanding of some of the technological and organisational issues involved.

It has been said that 'if you fail to plan, then you plan to fail' — in the dynamic area of information technology in schools and with our students' education at stake, can we afford not to plan?

Appendix

A case study

Leeming Senior High School is a metropolitan school in Perth, Western Australia, catering for approximately 1000 students aged 13–17 years. The school identified IT as a mechanism for helping to facilitate the achievement of goals outlined in its development plan very early and as a result has had a staff member assigned to IT planning matters since the late 80s. Since that time, computer resources have increased from a 16-station Microbee network (CP/M) in a classroom, to three interconnected LANs which span the school, supporting curriculum, office publishing and staff productivity, in addition to other school administrative and library automation LANs. In total there are 120–150 computers in the school, ranging from IBM XTs to 486s, Macintoshes (desktop and notebook), and BBCs. There are also scanners, LEGO interfaces, dot-matrix and laser printers and oversize/A4 monitors.

Despite forward planning for IT since the school's opening, various factors have resulted in the school having large numbers of computers that are now well out of date. The school estimates that approximately \$40 000 has been spent per annum over the last few years to build up to current resource levels, the majority of which has been funded through appropriation of school grant monies and to a lesser extent, Education Department funded maintenance and replacement programs, as well as commercial promotional schemes.

To upgrade facilities (without increasing numbers) to contemporary standards, the school estimates costs at approximately \$250 000. For example, to upgrade the three computing labs (24 computers each) and keep them up to date by replacement every three years, would cost about \$75 000 per year.

As a result, alternatives are now being considered, including altering the mode of teaching/learning in these classes away from 1:1 student/computer ratios to a cooperative group and task-oriented approach, where larger numbers of students share relatively smaller numbers of machines on an 'as needed' basis. This involves providing a range of computers from a larger number of basic 'productivity machines' capable of simple word-processing, spreadsheet and database applications, to a smaller number of powerful, desktop publishing and media-integration/presentation machines. This encourages students to use the appropriate equipment for the task and minimises outlay on large numbers of highly specified computers when they are not needed.

Even so, budgets for this exercise were approximately \$60 000 in the first year and \$30 000 p.a. for the following three years, to eventually reach a point where all equipment had been upgraded and was less than four years old.

Given that inspection of school accounts showed that approximately \$40 000 p.a. had been spent on IT purchases in the previous few years, and still the school had out of date equipment, the option of leasing equipment was explored. Preliminary investigations of three-year lease agreements have shown that for between \$35–45 000 p.a., over \$120 000 worth of 'new' equipment can be available on a continuous basis. Leeming argues that not only will such a plan enable their school to become 'state of the art', but also to remain so. The provision of such an environment is at an approximate cost of \$1 per student per week (20c per day).

The key to achieving such results involves a shift from viewing computing resources as a fixed asset to be purchased at intermittent intervals, to such resources being a recurrent, consumable cost. Computers are long-term resources and should

benefit all students; it follows that the cost of providing these resources should be spread across the school community over time.

In the future, communications infrastructure will become the fixed asset that schools and systems will need to provide, with the 'interfaces' to that communications infrastructure likely to be increasingly provided or funded by students/parents themselves.

Julie Bowden

Over the past ten years Ms. Julie Bowden has faced the challenges of numerous roles within and outside the Education Department, Western Australia. As a teacher with 25 years of teaching experience, she has held various positions, including Superintendent (General) of a country District, lecturer at Edith Cowan University and more recently Superintendent overseeing policy and planning regarding the introduction of telecommunications into Western Australian schools.

Brett Clarke

Mr. Brett Clarke has been involved with computers in education for over ten years. For the past five years he has been working with teachers in schools in an advisory capacity as Senior Education Officer responsible for developing computer education policy for the Education Department, Western Australia. He is a chief examiner for computing for the Secondary Education Authority (SEA) and has recently been chairperson for the SEA Computing Syllabus Development Committee. Brett is an executive member of the Educational Computing Association of Western Australia and is editor of that association's quarterly journal, *Login*.

Judith Cousins

Ms. Judith Cousins teaches in the science education and early childhood education departments of Edith Cowan University and has a background of primary and tertiary teaching. She is one of the writers of 'Primary Investigations', a national primary science project produced by the Australian Academy of Science. Her research interests are teaching and assessing technology in primary classes and girls and science. She is a regular presenter of workshops related to teachers' professional development.

Paul Dench

Mr. Paul Dench works with students and teachers from Year 1 to 12 at Scotch College, WA. He emphasises the use of computers as everyday curriculum tools in the classroom; he is not supportive of the practice of using computers in specialised school laboratories and does not consider that the computer should primarily be the focus for a separate subject of study. He was previously Project Leader of the Western Australian Education Department's Computers in Education Project. His interests include developing tools with multimedia applications, Logo and other list-handling languages and the use of computers to develop literacy in Aboriginal languages.

David Elder

Dr. David Elder is Chairperson of the Department of Language Studies at Edith Cowan University. His research interests are in the French language and include teaching-learning methodology as well as French literature and translation. His latest project with the Universite de Paris-Dauphine involves telematics and the translation of texts for French journalists.

Nerida Ellerton

Professor Nerida Ellerton holds two PhD degrees, one in physical chemistry and the other in mathematics education. She has taught at primary, secondary and tertiary levels, and is currently Professor of Mathematics Education at Edith Cowan University. She has published widely in research journals, and has authored, co-authored or edited eight books. She is frequently invited to lead professional development programs for practising teachers, and is co-author of the professional development module 'Attitudes and Appreciations' which was produced as part of Maths Works for the Australian Association of Mathematics Teachers. Her research interests focus on language and cultural factors in the teaching and learning of

mathematics. She is editor of the *Mathematics Education Research Journal*, which publishes refereed articles on mathematics education research from around the world.

David Evans

Dr. David Evans teaches in the Faculty of Education, Edith Cowan University, in the area of children with special needs. He has been a primary school resource teacher in a number of Australian States and is actively involved in the education of students with learning difficulties in regular education settings. His research interests include the use of technology to assist in catering for students with learning difficulties, instructional design features in various instructional mediums, and issues in the education of students with disabilities and learning difficulties.

Bob Hart

Mr. Bob Hart is presently Director of Imagination Technology, a British company specialising in the design and management of innovative learning experiences and, in particular, interactive multimedia courseware. Bob has extensive experience in education, having been a Principal of primary schools, coordinator for the UK government's Microelectronics Education Programme (MEP) and Advisor for Information Technology for Sheffield Education Authority. He is author of a number of books and papers; his software credits include *Tombs of Arkenstone*, one of the first 'adventure generators' made available.

Stephen Heppell

Professor Stephen Heppell is director of ULTRALAB, Anglia University's learning technology research centre in the United Kingdom. ULTRALAB is a major educational producer of CD-ROMs in Europe and is at the heart of the developing debate about new learning environments; it is also home to the National Archive of Educational Computing. ULTRALAB houses an eclectic team. They have an international reputation for work at the 'cutting edge' with hardware and software companies, with publishers and information providers on projects encompassing the broadest possible definition of learning. Stephen has long experience of educational computing; he was originally with the UK government's Microelectronics Education Programme (MEP) and has been based at Anglia since 1984. His chair is supported by Apple Computer as European Fellow. Stephen delivers talks all over the world and is active in TV and radio, his philosophy of 'you can too' and 'learning really matters' being welcomed by teachers, parents and learners alike.

Ros Keep

Ms. Ros Keep is currently the Director of Information Technology at Christ Church Grammar School. She trained as a teacher of mathematics in the United Kingdom and has worked as teacher, programmer, educational software designer and educational researcher before moving to Perth in 1991. Ros has a particular interest in electronic communication and coordinated a major project in the UK in which schools used electronic mail and on-line databases to enhance the curriculum. Since arriving in Perth, Ros worked in the education team of the Perth AppleCentre in a sales, training and support role before joining Christ Church this year. Ros is an active member of the Executive of the Educational Computing Association of Western Australia, where she set up NEXUS mail-boxes for all members and is the Account Manager of the group. She is also a member of the Australian Council for Computers in Education.

Paul Newhouse

Mr. Paul Newhouse teaches educational computing, interactive multimedia design and computing courses in the Computer Education Department at Edith Cowan University in Western Australia. He has been a secondary mathematics and computing teacher and has produced many textbooks and a number of pieces of computer software for those curriculum areas. His research interests include computer-supported learning environments, computer literacy, software instructional design and computer-mediated communications in education.

Ron Oliver

Dr. Ron Oliver is senior lecturer in the Department of Library and Information Science at Edith Cowan University. He has a background in instructional technologies and has lectured in this area for many years. Special interests include children's information technology skills, using interactive technologies for instruction and training and the delivery of distance education and open learning programs.

Tom Reeves

Dr. Thomas Reeves teaches program evaluation, multimedia design and research methods courses in the Department Instructional Technology at the University of Georgia. He has developed and evaluated interactive technologies since 1974, and has been an invited speaker in Australia, Bulgaria, Finland, Peru, Russia, Switzer-

land, Taiwan and elsewhere. His research interests include mental models, electronic performance support systems, adult literacy, multimedia user interface issues, and instructional technology in developing countries.

Helga Rowe

Dr. Helga Rowe is a Principal Research Fellow with the Australian Council for Educational Research. She is the author of a number of educational and psychological test batteries. She has published six books and contributed numerous chapters and articles on a wide range of topics relating to individual differences in information processing and cognitive development. Her current research relates to the development of higher order thinking in educational, real-world and technological environments, and to implications of personal computers for learning and teaching. She has been a Visiting Professor in the Graduate School of Psychology, Yale and at the University of Hamburg. During 1992 she worked for several months as a consultant on cognitive science projects with the Max Planck Institute in Germany.

Ilana Snyder

Dr. Ilana Snyder teaches language and literacy education in the School of Graduate Studies, Faculty of Education, Monash University. Her research focuses on the use of electronic writing technologies in literacy education. She is particularly interested in issues related to equity of access to technologies and professional development for teachers to learn how to exploit the potential of technology in the English classroom. She is currently writing a book on hypertext and critical theory to be published by Melbourne University Press.

Sue Trinidad

Dr. Sue Trinidad teaches technology education to pre-service and post-service teachers with the Faculty of Education at Curtin University of Technology, Perth, Western Australia. Her interest in working with young children began with her work as a primary school educator. Further studies lead her to investigate the effects of computer-based learning on young children. She is currently researching the effects of the technologies of robotics and interactive multimedia programs as tools for stimulating problem-solving strategies in young children.



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Martyn Wild

Mr. Martyn Wild is a lecturer in the Department of Computer Education at Edith Cowan University, Western Australia. He has worked in universities and schools in both the UK and in Australia. His research interests encompass: teacher education and the use of IT to facilitate quality teaching and learning in pre-service education; the use of interactive multimedia to support learners at all levels; cognitive modelling; and human-computer interaction. He is currently working on a PhD in instructional design and multimedia and conducting a number of research projects — into, for example, the quality and type of talk generated by young learners using computers and the development and implementation of performance support systems.

S. Wild BSc