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Issues in primary mathematics education Computers: Classroom practice and curriculum reform

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ISSUES IN PRIMARY MATHEMATICS EDUCATION

Computers: Classroom practice and curriculum reform

LORRAINE KERSHAW
KEVIN JONES
LEN SPARROW

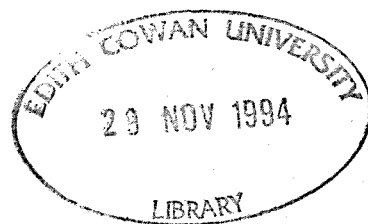


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Preface

Computers: Classroom practice and curriculum reform is one of a series of monographs on issues in primary mathematics education. It has been written to support initiatives in the development of student-centred learning programs at Edith Cowan University - programs designed to accommodate current views on effective adult learning strategies, as well as the development of professional and generic (key) competencies. Irrespective of the nature of individual learning programs, students and teachers working at undergraduate and postgraduate levels will find the series useful - either as a synthesis of currently available research findings and reference material, to identify potentially significant initiatives and developments in the area or as a classroom resource and guide.

The Contents and Introduction for this monograph have been designed for easy perusal, permitting rapid appraisal of its usefulness and relevance for a particular purpose. Although designed as a stand alone entity the monograph is part of a similarly titled self-contained module featuring videos/software/ print materials accommodating a wide range of teacher education programs. This independence has ensured a much wider appeal in a variety of teacher education applications.

While the content is not designed for direct utilisation as a classroom resource (these are listed separately), teachers would find the information, ideas, and examples presented, a valuable catalyst for both rationale and program construction.

Kevin Jones
Project Leader

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We firstly offer special thanks to the Committee for the Advancement of University Teaching for their strong financial and pedagogical support to produce this monograph series, and other student centred learning materials.

We greatly appreciate the contributions of the following institutions/organisations and people:

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1

Introduction

The advent of an interactive multimedia approach in teaching and learning has opened up yet another horizon to be explored in search of the perceived potential of the computer in primary mathematics education. Benefits promoted have included its use as a motivational aid, the developing of content knowledge and problem solving skills of children of varying abilities, its capacity to support an integrated curriculum, and to assist children in controlling their own learning. Many have doubts about the veracity of these assertions and disagree about the types of appropriate uses of the computer. For classroom teachers, software and hardware availability, degree of professional support and implementation of curriculum recommendations are additional concerns. Perhaps we should not be looking at ways in which the computer as a learning aid should be accommodated within the mathematics curriculum but how it may change the nature of classroom environments and activate curriculum reform in mathematics education.

Computers: Changes and challenges

"Anyone who presumes to describe the roles of (electronic) technology in mathematics education faces challenges akin to describing a newly active volcano" (Kaput, 1992, p. 515). Why should the task appear so fraught with uncertainties and what are these challenges?

Technological innovation in education is a term which can conjure up a bewildering picture. *Innovation*, for the teacher, has always been a frequent occurrence in education, as the inception of new ideas in the classroom seems to be a constant expectation of those who design and manage curricula. *Technology*, however, is seen by many as something new - something associated with silicon chips, hardware configurations, microprocessors and many other unfamiliar words and devices which seem to be part of a whole new world. Yet within our everyday world the tasks which these devices perform are common to our daily lives and we are dependent upon their efficiency. For example, we would expect an automatic teller to read and print an accurate balance of our account, respond quickly to our request for a withdrawal (most likely!) of funds and provide us with the correct sum - all tasks which various electronic devices are performing out of our sight.

Some clarification of terms is needed before we continue. In this monograph we have taken the UNESCO definition of technology referred to in the interim statement on Technology for Australian Schools (Department of Employment, Education and Training, 1992) which states:

...(technology is) the know-how and creative processes that may assist people to utilise tools, resources and systems to solve problems and to enhance control over the natural and made environment... (p. 1)

Technology has been used in education to create communication tools. "Changes (have) ranged from slates to paper; from quills to pens, pencils and ball-points; from blackboards to white boards and overhead projectors; from pictures to film-strips, films and videos" (National Institute for Educational Research (NIER), 1987, pp. 1-2). And now we have calculators and computers.

"Electronic" technology has produced calculating devices which have a source of power. A microcomputer, which we have called a computer, is one such device. Computers can be connected to other electronic devices such as video recorders, films and video discs, and this combination is often known as an interactive multimedia resource.

To return to our opening statement and question. *Newly active* is a propitious observation to make not just about computing technology in mathematics but about the very recent appearance of computing technology in our society. The early large mainframe computer system, as the forerunner to the microcomputer, was first developed just thirty years ago (Oliver, 1986). Since then the level of computer sophistication has changed dramatically e.g. size of storage for information, speed of operation and information access, graphics capabilities and portability (such as laptop computers). Nowadays in industry, in the workplace, in the home, in competitive sport and many everyday activities in which the average person is engaged, some form of computing

technology is used.

In schools, the computer, as a mainframe system, first appeared about two decades ago ((Oliver, 1986). These have now been replaced by microcomputers, although their everyday use by children in schools is not common (Kaput, 1992). For young children's use, specially designed peripherals, such as the Logo turtle and the concept keyboard, also began to appear in schools. (The Logo turtle is a mechanical object which can draw a visible path on the floor upon instructions from a computer keyboard. The concept keyboard is a tablet which utilises overlays of pictures and simple symbols instead of the traditional keyboard to interact with a computer.) More recently in mathematics education, the use of interactive multimedia resources has emerged. Text, sound, graphics and video resources are integrated through the medium of powerful computer programs. The user can choose combinations of these resources to access information for visual and sound displays. Interactive multimedia resources involving laser technology, such as interactive video discs, have already had trials in classrooms (Caddy, 1993).

So at least two significant issues are apparent - the rapid changes of computing technology and its newness in society and schools. These are particularly obvious if this form of technology is compared to something like the technological development of the car which has had nearly one hundred years to reach its current stage of refinement (Kaput, 1992). Some of the uncertainties for computing technology and mathematics learning lie in what form the technology might take next, how soon new ideas will emerge and the recurring impact on the curriculum.

Consider some of the challenges to the curriculum. Education authorities and teachers faced considerable pressure from the community and parents to incorporate available computing technology into the school curriculum. Unlike their fears about calculators being harmful to children's mathematical skills, parents believed their children needed to understand how to use computers as tools in today's society, and that subsequent employment opportunities would be greater (Fitzgerald, Hattie & Hughes, 1986; Collis, 1988; National Research Council, 1989). Early uses in primary mathematics were for drill and practice or as a reward (and indeed this type of use is still quite common today), and the mathematics curriculum remained as it was (Collis, 1988). That is, until interested mathematics educators and organisations began to question and challenge the curriculum as a consequence of computing technology being available to schools (National Mathematics and Statistics CBL Review Panel, 1987; National Institute for Educational Research, 1987).

Questions were asked about how the computer could be used well in teaching and learning mathematics and whether it was appropriate to do so. For example:

- how might mathematics content need to be changed?
- would children learn mathematics in different ways?
- would classroom environments be changed?
- what kinds of software would be most useful for problem solving contexts?
- are simulations useful
- could investigation skills be developed through the medium of computers? (NIER, 1987)

Responses to some of these questions began to be reflected in curriculum documents and resource materials. Education organisations, such as the National Council for Educational Technology (NCET) suggested that the computer:

- can be used to promote the enjoyment of mathematics, encouraging independence and exploration ...
- can help us do many of the things we already do, more effectively ...
- provides the opportunity to do things that were not previously possible in the evolution of new content and methods within the mathematics curriculum. (NCET, 1989, p. 3)

Developers of educational resources became more specific in their suggestions. For example, Lovitt and Lowe (1993) in their work on chance and data investigations recommended that the computer's database and spreadsheet functions be used in primary mathematics. The computer enabled data to be easily managed and examined by generating, analysing, manipulating and displaying it in graphical form, and through the simulation and display of events. It could also help children to explore new ideas and concepts.

As Willis (1990) said:

Computing technology has changed the way mathematics is produced and also the way it is applied at all levels of mathematics sophistication. (p. 12)

It would appear then that many feel the computer has an increasingly significant part to play in the lives of adults and children as they use and apply mathematics. But this has led to doubts being raised about the appropriateness of the current expectations we have of children's mathematical knowledge and the kinds of experiences we are providing for them as they learn mathematics (Harel, 1990). The call to change curriculum as a consequence of computing technology is gaining momentum though the direction appears unclear (Kaput, 1992). So too is the stability of any repercussive changes which might be made to the curriculum because the technology itself is constantly changing. The dilemma for mathematics educators, curriculum developers and teachers is whether change is really warranted, and if so, what the nature of those changes might be and on what acceptable grounds they might be based.

About this reading

An exploration of the above issues could take a number of different pathways and yet still conclude with many unanswered questions. We have selected a range of aspects and perspectives which we consider helpful in the search for responses and courses of action which may not only meet educational goals but also direct them. However, we would encourage readers to pursue other viewpoints of the many diverse issues involved.

To establish a mathematics education context for discussion of this topic on computers, some ideas about how children seem to learn mathematics and some apparent influences on their learning will firstly be reviewed. Reference will be made to classroom cultures and learning contexts. A computing context will then be described by summarising the historical development of

computer use in primary schools and some associated problems. Within this framework recommendations and teaching suggestions about their use in primary mathematics curricula will be outlined. Examples of classroom practices will be examined with particular reference to research in the area. Finally two innovative projects, involving interactive multimedia in primary mathematics, will be described.

2

Mathematical learning, culture and context

As indicated earlier, to describe and understand the potential roles and influences of computers in primary mathematics education is a complex task. Because computing technology is relatively new and may be unfamiliar to some, our intention is firstly to retrace some pathways which will be known to many: pathways about mathematics learning. We will therefore review some well-known ideas as well as introducing some recent perspectives on learning mathematics. This approach will help to shape a framework of ideas about mathematics learning in which questions raised earlier about computer use can be examined in a relevant way. This framework will include a brief look at some goals for learning mathematics, some ideas on how young children learn mathematics and some significant influences on their learning, such as cultures of mathematics classrooms, contexts for learning and learning strategies.

Goals for learning mathematics

It would be a most difficult task indeed to compile a comprehensive list of goals for learning mathematics to satisfy all interested groups, such as teachers, parents,

employers, policy makers or curriculum developers. It is obvious that children have been omitted from this list. Our reasons are twofold. Firstly, although we do not lack sensitivity to the significance of children's personal goals, it is beyond the scope of this reading to pursue the complexities of this little researched aspect. Secondly in this section we are more concerned with the viewpoints of those groups who currently are largely responsible for influencing, formulating and delivering the mathematics curriculum. Our aim is therefore to identify goals which would be representative of their recent viewpoints.

The following goals focus on children's learning outcomes:

1. Having the knowledge and skills to deal confidently with mathematical situations and problems.
2. Interpreting and communicating mathematical ideas in forms appropriate to the situation.
3. Thinking and reasoning mathematically.
4. Enjoying mathematics and appreciating its usefulness and power.
5. Developing mathematical knowledge with understanding.

(Australian Education Council, 1990; Greeno, 1991; Hiebert & Carpenter, 1992; Caddy, 1993; Campbell & Stewart, 1993)

How children learn mathematics

Knowledge about how children learn mathematics is not an immutable body of information. It is constantly being shaped and re-shaped by building upon or modifying

existing knowledge. New dimensions are added as differing perspectives are explored. Beliefs are discarded or reaffirmed as research and classroom practice refute or confirm ideas. Summarised below are some perspectives which are regarded as significant for any reflection upon computing in a mathematics environment.

Piaget's research opened many avenues for investigating how children learn mathematics. He described learning in the primary years and beyond, in terms of reversible processes he called operations. Since addition, subtraction, multiplication and division are operations, his work has had great import for mathematics learning in primary schools. For young children, operations (ideas) are formed by physical interaction with the environment; later, ideas can be constructed abstractly, without the need for concrete materials. He asserted that children acquire new knowledge as they assimilate and accommodate ideas, by reaching a state of equilibrium between the old and the new. That is, old knowledge may be modified or even discarded as the child attempts to make sense of the new knowledge (Ginsburg & Opper, 1988).

The use of language in the learning environment was examined further by Vygotsky (1962). He suggested that children actively construct knowledge in a social context through the use of language. This required children to think about and negotiate language meanings with others as they developed, explained and communicated their mathematical ideas.

The above views and ideas of others were utilised in A National Statement on Mathematics for Australian Schools (Australian Education Council (AEC), 1991) as a basis for describing a set of learning principles. Learners are viewed as constructing their own meanings through active participation in physical and social experiences. They take risks, question existing knowledge and reflect

on their experiences to build new knowledge (pp. 16-17).

Hiebert and Carpenter (1992) associated development of knowledge with understanding, where ideas have meaning as mathematical relationships are formed and linked. They claimed that understanding is needed by the learner to construct internal representations of ideas which are organised into cohesive networks of information. Thus existing knowledge can be expanded or new knowledge generated.

The ideas outlined above are seen as critical to evaluating some later descriptions of *mathematics learning / computer environments*, and to lend support in continuing the debate on the future of these environments. In summary the main points are the:

- active engagement of the learner in the learning environment;
- links between the computer and learning with concrete materials;
- social nature of learning;
- ways in which language is used;
- fact that learners construct their own knowledge; and
- ways in which mathematical understanding is developed.

Influences on learning mathematics

It is also recognised that the development of mathematical knowledge can be affected by many factors. These include:

- learner characteristics and beliefs e.g. age, cultural background, what the learner believes about the difficulty of the task or personal abilities in performing the task;
- the nature of the context in which the learning takes place e.g. whether the mathematical task is carried out in the classroom or in an everyday situation such as shopping;
- learning and thinking strategies e.g. strategies used by the learner to classify and organise information or assist in monitoring and managing personal learning;
- the culture of the mathematical setting e.g. a setting where learners are viewed as apprentices and learn procedures from experts or where risk taking and making mistakes are valued.
- (Lave, 1988; Brown, Collins & Duguid, 1989; Greeno, 1991; Wong & Herrington, 1992).

Ideas about context and culture of mathematical activity, in particular, need further clarification as we also intend to examine the use of computers from a similar perspective. Quite a number of prominent researchers have argued that the nature of the context and culture of a learning activity are interdependent and determine the nature and usefulness of the knowledge gained (Lave, 1988; Brown, Collins & Duguid, 1989; Greeno, 1991). That is, the particular mathematical activity in which the individual is engaged provides a frame of reference for the learner. The child learns about and makes purposeful use of the language, actions and tools needed for that task.

The following mathematical example is used to clarify this view. A shopping task has been devised by two teachers but the contexts chosen are very different.

Context of the mathematical task

Task A: The children are presented with a set of ten text book word problems which involve multiplication and addition. The teacher uses the blackboard to reinforce the procedures required for the calculations. One of the problems reads: "What is the total cost of 4 apples worth 27 cents each and 3 bananas at 18 cents each?"

In this context the children are learning to understand and interpret the particular language patterns which are unique to this text book setting, in order to complete the task. An understanding of some of the words and phrases in the text book may be useful only in this setting and not relevant to other settings e.g. in an everyday setting a customer is more likely to ask "How much is that ...?", rather than using the words "What is the total cost...?"

Task B: Children have to purchase some fruit to take on an excursion.

Here different language patterns would be required to Task A, e.g. some everyday shopping language. Additional mathematical operations could also be used e.g. subtraction and division as children calculate change and how much each child would need to contribute to the cost of the fruit.

Culture of the classroom

Culture A to match Task A: Children have access to pencil and paper only. They are expected to set out each example in a prescribed way - a standard procedure which has been taught by the teacher. The teacher prefers children to work these types of examples on their own. Each correct answer is rewarded with a tick and a score, incorrect answers with a cross and no score.

Children do their corrections for homework. Children with all ten correct earn a point for their team.

The culture in classroom A is one where the tools, procedures and the social context are prescribed, correct answers are valued and mistakes are punished.

Culture B to match Task B: Children have access to calculators, pencil and paper or whatever tools or objects (e.g. multibase arithmetic blocks - MABs) they wish to use. Estimation, approximation and discussion are encouraged by the teacher, for example, as children decide on the best buy.

The culture of classroom B supports differences in learning styles, as children make their own choices about the tools and strategies to use. Accuracy in making calculations is valued, so also is risk taking as children estimate and provide different solutions.

Compare the differences in the contexts of the two tasks and the cultures of the classrooms. The real life task would have a different meaning and a different purpose for the children compared to the text book problem. It takes little imagination to ascertain the different beliefs about mathematics that the children might learn in these two settings, what mathematical knowledge might be gained, how useful that knowledge might be, as well as its appropriateness in meeting some of the educational goals listed earlier.

As Nickson (1992) has suggested, scenarios like the one described in Task A above are changing, with more choices now becoming possible e.g. choices of tools and strategies, choices in purpose, choices in the kind of support sought by the learner and offered by the teacher. The effect of these choices will be seen in the emergence of non-traditional classroom cultures where each classroom culture will continue to embody the particular values and beliefs of children and teachers. The difference will be in

the changed values and beliefs of the actors in that culture. It is this perspective which we will consider again later but with a focus on some contexts and cultures in computing.

3

Computers in primary schools

We have reviewed some recent ideas on mathematical learning in terms of educational goals, how children learn and influences on learning, including context and culture. Before we relate some of these ideas to computing we need to consider the changing context of primary school computing. This would best be introduced by an overview of computer use in schools over the past two decades. A brief summary of issues affecting successful implementation of this innovation in education will follow. In this way some significant elements of computing contexts will be evident for later reference to mathematics teaching and learning.

Implementation review

The development of computer use in schools did not occur at the same rate and in the same way in each of the Australian states nor in other countries. For example, computer use was supported in some Australian states for a greater number of years than in other states. In most cases support for professional development and hardware acquisition tended to be centralised (Fitzgerald, Hattie & Hughes, 1986). This centralised model was adopted by the Education Department in Western Australian. A

description of some key events leading finally to the present decentralised system in Western Australian schools will be useful in charting an example of an implementation timeline for one Australian state.

The first computing facilities were made available to secondary schools in Western Australia in 1971 and consisted solely of providing computer programming experiences. This gradually changed to the development of courses on computer literacy (Sully & Young, 1990). Topics in typical literacy courses included the study of computer systems, applications (such as storing large amounts of information), implications (such as ethical and privacy issues) and ways in which the computer could be used as a tool e.g. word processing and spreadsheets (Oliver, 1986).

Pressure from parents, the community, some teachers and the suppliers of computer hardware and software forced the Education Department to consider their position on the use of computers in primary schools (Schibeci & Beckett, 1990). In 1981 a policy paper outlined uses which would be centrally supported. These included the integration of computer use into suitable areas of the curriculum, as a tool for problem solving activities, in computer-assisted instruction (such as drill and practice) and its use as a motivational aid.

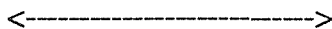
Later these ideas were translated into a policy document - *Computer use in primary education policy* (Ministry of Education, 1989). The policy set out some major goals for teachers and children to achieve. In summary these referred to:

Teachers	using a computer regularly to achieve teaching/learning objectives
	being sufficiently knowledgeable to choose educationally sound software
	using a computer for personal tasks

Children	being confident to use a computer in their learning
	using a computer in all subject areas and for solving problems

Sub-goals were set out on a continuum and attainment measurable through a set of outcome indicators. Indicators point to the degree to which major goals have been met. An example of an outcome indicator on the sub-goal continuum is shown below. It is related to a goal about children's confidence.

no problem solving use of the computer



computers used for problem solving across the curriculum e.g. ... Logo ... information processing ...

Meanwhile national funding, and later state funding for government primary schools, was made available to purchase computers (Kershaw, 1990). This meant that by the end of the 1980s all government primary schools had at least one computer. Initially central support was directed towards the implementation of the policy document. Later, computer related resource materials were provided for schools in support of special projects,

such as the First Steps program. Centralised support then gradually decreased and with the disbanding of the Computers in Education Project in 1990 it was left to the regional offices to provide support as they saw fit.

Late in the 1980s syllabus documents began to reflect the expectations of policy makers that computers be used in the primary curriculum. The primary mathematics syllabus made suggestions about classroom organisation and the purposes for which a computer could be used in mathematics activities e.g. in a whole class situation with one computer it was recommended that children discuss and trial how to "develop(ing) winning strategies by playing against the computer at increasingly more difficult levels of performance" (Curriculum Programmes Branch, 1989, p.33).

These initiatives promised much but implementation has been slow as schools struggle to adopt new ideas.

Issues influencing implementation

Fitzgerald, Hattie and Hughes (1986) conducted a survey of 1 000 Australian schools to gain information on computers in schools, including data on advantages and problems, types of use and attitudes towards computer use. They found that teachers reported insufficient numbers of computers and funds for the purchase of equipment as the two most important factors affecting their use. These were closely followed by concerns about the lack of teachers who had specialised training in using a computer (see Table 1). Similar results were reported in the U.S.A. in a 1988 study (Olive, 1992).

Figure 1. Major problems of introducing computers

Problem	School		Teacher		Parent	
	Rank	Mean	Rank	Mean	Rank	Mean
There are not enough computers available in classrooms	1	5.3	1	4.8	1	4.6
Insufficient funds are available for the purchase of appropriate equipment	2	5.1	5	4.2	3	4.4
There are not enough teachers with both teacher training and specialised training in using computers to act as key resource people in our school	3	4.7	3	4.4	1	4.6
Teacher education institutions are not providing adequate preparation in the educational use of computers	4	4.4	2	4.5	4	4.3
Very little is known about how children learn when using computers in the classroom	5	4.0	4	4.3	5	4.0

(Fitzgerald, Hattie & Hughes, 1986, p. 31)

Other relevant influences here are:

1. Teacher factors

There is a considerable body of literature relating to teachers and the level of success in implementing computer use in schools. Some of the main factors and teacher characteristics influencing implementation have been summarised by Kershaw (1990) as follows:

- the commitment of the teacher to the innovation;
- teachers' attitudes towards the imposition of policy statements and curriculum expectations;
- teachers' resistance to change and difficulties in changing well-known practices;
- time taken for teachers to become familiar with the hardware and software;
- teachers' degree of computer anxiety;
- teachers' general attitudes towards computers and their perceived educational value; and
- teachers' levels of background knowledge e.g. age, experience and training.

Gender differences also affect successful implementation. For example, in their Australian study Fitzgerald, Hattie & Hughes (1986) reported that female teachers were more strongly opposed than males to the belief that computers were more useful for boys than girls.

2. Software concerns

Software is another area which has drawn a great deal of attention in analyses of classroom computing environments. The following summary indicates some of the concerns held by teachers as they endeavoured to implement curriculum recommendations:

- good quality software was hard to find;
- drill and practice programs prevailed;
- it was not easy to find software that related well to curriculum objectives;

- software appropriate to children's level of understanding and educational need was rare;
- content often lacked meaning and relevance to the children;
- text-based materials were more adaptable, had more variety and cost less than software packages;
- the amount of time available to a child to use a software package was limited when class sizes are 25 and only one computer per class is allocated;
- many software packages lacked imaginative ways of helping children learn and ideas were often presented in well known book formats;
- software often showed gender or cultural bias.

(Folds, 1986; Ediger, 1988; Kaput, 1992)

3. Deployment of computers

During the 1980s many schools had limited funds for the purchase of computer hardware and therefore the number of computers in a school significantly affected their deployment. Since then most schools have gradually been able to increase their pool of computer systems. But regardless of the number of computers now accessible to each classroom, careful deployment is still essential in making the best use of this resource. When educational goals are also considered, many placement configurations present themselves and teachers are unsure of the most beneficial option, as reasons for choices vary.

The following list sets out some of the issues which could be considered before decisions are made about the placement of computers in the school/classroom:

- accessibility of a computer whenever it is needed by the child for undertaking a task;
- time allocated for each child's use of a computer;
- whether the tasks carried out in a laboratory setting by the child will be associated with classroom activities;
- the basis for devising individual children's use of a computer e.g. use in free periods, as a reward, rostered as single sex groups, suitability to learning style;
- whether the task would be more appropriately carried out by a single child, pairs of children, small groups or the whole class;
- availability of a computer work station as a learning centre; and
- accessibility of computers for staff

(Gallagher & Nowak, 1987; Kinnear, 1990)

Summary

Having looked at some of the significant issues facing the implementation of computers in a general educational context it is now appropriate to examine a specific aspect of that context, namely, primary mathematics education. Curriculum developers noted many of these influences affecting successful implementation in making their recommendations about suitable mathematical activities with the computer. Some general classroom strategies were often outlined, while the need for teachers to select good software was consistently emphasised. Deployment of computer resources was identified as a critical factor in determining their educational value.

4

Primary mathematics and computers

Like the overview of computer use in schools the observations and suggestions of curriculum developers and mathematics advisers have been ordered chronologically. This approach should enable the reader to reflect upon the evolving nature of computer use in the context of mathematics education.

Curriculum perspectives

1. An agenda for action (U.S.A.)
(National Council of Teachers of Mathematics, 1980)

Recommendation 3 of the agenda referred to the need for all students to make use of the power of computers. Schools were advised to make increased provision for their students to have access to computers. Integration into the core curriculum and the production of suitable materials, such as quality software programs, was suggested. Computer literacy for students, teachers in training and mathematics teachers was advocated.

2. The impact of computing technology on school mathematics (U.S.A.)

(Corbitt, 1985)

This report suggested that computers had the power to change the focus of mathematics instruction, for example, by facilitating a move away from an emphasis on paper and pencil computational skills to experiences which promoted thinking and reasoning skills. It also predicted a consequent change in the nature of mathematics classrooms and the role of the teacher in responding to this technology.

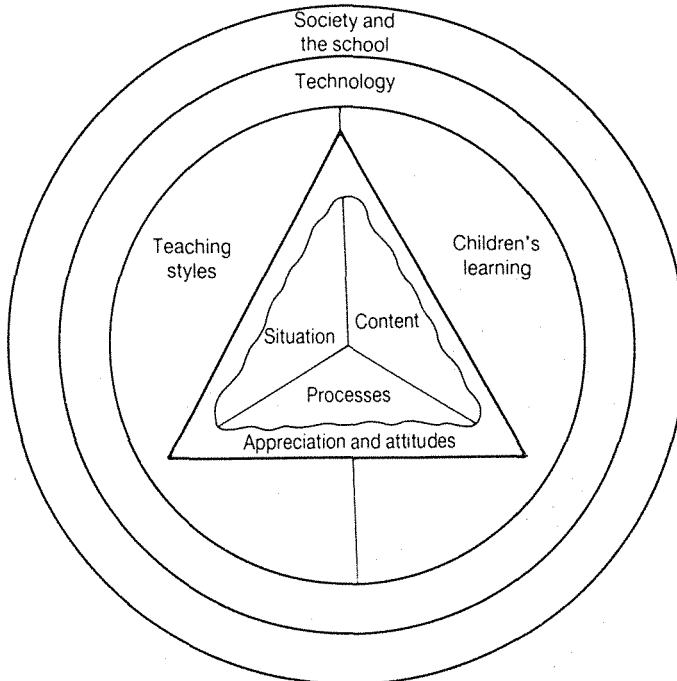
At the elementary school level the use of manipulative materials was still advocated, but computers were seen as enabling children to explore some concepts at an earlier age than previously thought appropriate. Logo programming activities, such as exploring and applying geometrical ideas about angles and attributes of shapes, could be part of this type of investigation.

The middle school curriculum should accordingly take into account the earlier introduction of some concepts and expand their curriculum expectations. Using graphing and other computing facilities for a clear display of data and more advanced statistical work were seen as possible curriculum inclusions. The ease with which some investigative hypotheses could be tested using the computer's speed to test, check, estimate and approximate, was considered beneficial to children's learning. Some computer programming experiences were advocated as an introduction to algebra.

3. A model of primary mathematics for curriculum building (U.K.)
(Shuard, 1986)

The impact of technology was an important component of Shuard's model of primary mathematics for curriculum building (see Figure 2). Important different elements of primary mathematics are depicted in the centre of the diagram on the four faces of a tetrahedron. These components of mathematical activity are part of the wider contexts of technology and society in which children's learning occurs and which therefore impact upon the nature of their learning.

Figure 2: A model of primary mathematics for curriculum building



(Shuard, 1986, p. 32)

In her discussion of the roles of new technology in children learning mathematics she suggested that software could be utilised for a number of different purposes. These included software which:

- ✓ could be used by the teacher in an expository way with a large group;
- ✓ facilitated small group discussion;
- ✓ allowed individual children to practise skills; or
- ✓ required children to investigate mathematical ideas or apply their mathematical knowledge.

Content free software such as Logo, databases and children devising their own adventure games could also be useful tools of learning. Practical work and the use of physical materials, however, should still form a large part of children's mathematical activity.

Logo or turtle graphics, in her opinion, could expand problem solving horizons. However, the use of other kinds of short programming tasks, which may help children to connect logically some of their ideas, needed further investigation. The computer's ability to display quickly a range of well drawn graphs, particularly pie graphs, was seen as a distinct advantage over the time consuming and inexpert attempts of young children using their own drawing skills and implements.

4. School mathematics: New ideas with computers (Asia/Pacific) (National Institute for Educational Research, 1987)

This report emanated from a regional workshop which brought together participants from 13 Asian and Pacific countries including Australia. Practices in each country were described and future trends predicted for the mathematics curriculum and classroom where the

computer's presence was beginning to presage change.

A strong emphasis was placed on the development of mathematical processes (e.g. establishing relationships, generalising) needed by children in the near future, as opposed to the decreasing need for a wealth of content knowledge. It was suggested that some skills, for example carrying out lengthy paper and pencil computations on whole numbers and fractions would no longer be needed. This did not mean in this example that the concepts of addition, subtraction, multiplication and division would not need to be understood by children. Topics such as data analysis and interpretation would also occupy a greater part of the curriculum, as computing activities increased.

In the classroom it was suggested that computers would be useful for presenting information, providing drill and practice opportunities, testing and promoting children's application of their knowledge. The computer was also seen as a useful adjunct to work with concrete materials by allowing mathematical ideas to be represented in different forms. The ability of the computer to facilitate and complement oral, visual, written and practical activities, in addition to its logical presentation of information could but enhance the learning situation.

Suggestions were made about the type of software packages which would be suitable in whole class, small group or individual settings. It was felt that these arrangements and uses could not only precipitate a change in teaching style and teaching methods but also in the role of the teacher in the mathematics classroom. In this changed context children could then take greater responsibility for their own learning.

The conclusion was that "It will not be the case of enhancing mathematics education by using computers but that a new mathematics education will evolve" (p. 3).

5. Learning mathematics handbook: Pre-primary to stage seven mathematics syllabus (W.A.)
(Curriculum Programmes Branch, 1989)

Like the previous report, this document made suggestions about how the class could be arranged to make best use of different kinds of learning experiences. It too emphasised the computer as an aid in helping children to know about and use mathematical processes such as "modelling e.g. choosing appropriate mathematical representations by utilising graphing software, or solving problems using a simulated event against which skills can be tested " (p. 33).

6. The impact of new technology on the primary mathematics curriculum (U.K.)
(National Council for Educational Technology.(NCET),1989)

This booklet is part of a series of four designed to assist primary information technology advisers. It lists reasons such as enjoyment, enrichment and the evolution of mathematics education for making computing and calculator technology an essential part of the curriculum. It uses the Shuard model mentioned previously to discuss how the learning and teaching of mathematics may be affected. Advantages of computer use included the following:

- children having control of their own learning by making their own decisions;
- effective group work promoted by the need to collaborate e.g. when only one computer is available and the problems of an adventure game need solving;

- the use of mathematical language as discussion is needed in collaborative group work;
- the potential of the computer to enhance children's self-worth in the non-judgemental environment of computing where risks can be encouraged and mistakes accepted; and
- extending the horizons of the current mathematics curriculum.

Many of these benefits are associated with the type of software chosen by the teacher and the teacher's role. Software which contains an embedded problem (e.g. simulating a hot air balloon ride where decisions have to be made about heights, costs, fuel requirements, speed, directions etc.) and open-ended software tools (e.g. using a database to store, organise and retrieve information which could then be linked to a spreadsheet to test hypotheses and finally have results displayed in graphical form). Software which links mathematical ideas to real world problems and cross curricular activities can show the wide applicability of the uses of mathematics.

7. A national statement on mathematics for Australian schools
(National Council for Educational Technology,(NCET),1989)

Computers are mentioned briefly in this document. It suggested that applications such as databases and graphing packages could be utilised in the mathematics classroom. Children should become familiar with the tool facilities of a spreadsheet as this type of computational use is most commonly found in business and industry.

Summary of curriculum ideas

Only a decade separates the suggestions summarised above about the use of computers in primary mathematics, yet it is evident in this short space of time that ideas have changed.

Computer literacy (and there are many points of view about the meaning of this term) was seen as an important goal to achieve according to an early document (National Council of Teachers of Mathematics, 1980). This aspect was not mentioned in later recommendations. Soon the advantages of Logo became apparent to those interested in utilising the power of the computer in providing previously unaccessible mathematical opportunities for young children. More recently the power and ease of manipulating data and producing graphical displays for exploration and interpretation of mathematical ideas was noted as being particularly helpful for children learning mathematics. This meant that the choice of mathematical activities and software to promote children's development of mathematical processes was of critical importance.

Discarding the use of manipulatives was not recommended. Understanding of mathematical concepts and ideas was still considered to be a critical factor in children learning mathematics. Providing activities with a computer were perceived as making an additional contribution to other teaching strategies which could facilitate children's understanding and learning. The nature of the computing environment was seen as beneficial to children taking control of their own learning and to improving their attitudes to mathematics.

A number of organisations (National Institute for Education Research, 1987; National Council for Educational Technology, 1989) raised issues concerning

the current state of the mathematics curriculum and suggested that changes were warranted. Educators were urged to respond to the impact of computer use by extending the expectations they have of children's mathematical achievements and shaping the curriculum to meet children's mathematical needs in our society.

5

Classroom practices

The rapid changes in curriculum recommendations have understandably led concerned educators to seek compatible changes in classroom practices. The implications of these recommendations which relate to computer use can be traced by looking at:

- ✓ ways in which software design has developed to meet changing needs of mathematics education;
- ✓ some examples of how software has been used in classrooms; and
- ✓ some innovative projects and kinds of software which are pointing the way ahead.

Software design

In the early days of computer use in schools the practice was to focus on teaching and learning from a hardware/software perspective. Software was designed firstly to fit ideas people had about what the computer could offer rather than what the curriculum recommended or children needed. Programs were classified in computing terms of tool (e.g. spreadsheet for investigating number patterns), tutor (e.g. drill and practice of basic facts) and tutee (e.g. Logo for exploring

geometry ideas). Then the attempt was made to try and fit these categories of software into the curriculum, as though they were an addend to the curriculum rather than an integral component.

Later choices of software were based on the goals set out in mathematics curricula. As Finger and Grimmett (1993) advocated:

The program of acquisition of hardware and software should follow and complement rather than precede the development of the educational rationale. (p. 92)

Software packages which allowed children to model real world problems, solve non routine problems, investigate number ideas and engage in strategy games were considered appropriate.

Other beneficial uses of software were seen as those which emphasised the integration of the curriculum. This type of software often involved the use of adventure games and simulations where mathematics knowledge formed only part of the knowledge needed by the user to solve the problems encountered in the game. A heavy responsibility rested with the teacher to organise the material needed for this thematic approach where many activities were often conducted away from the computer.

The ideal characteristics of good software were seen as those where children:

- ✓ could easily manage the software operating instructions
- ✓ could control their own learning

- ✓ were confronted with powerful mathematical ideas
- ✓ could devise their own pathways to solve problems.

(National Mathematics and Statistics CBL Review Panel, 1987)

Thus some packages could allow children to use and learn about mathematics in context, some may focus on the development of mathematical processes and problem solving strategies, while others may provide opportunities for the development and practice of mathematical content knowledge (Kershaw, 1987).

Software use in classrooms

The following examples will illustrate some of the software uses outlined above. In selecting the following sub-headings, it must be emphasised that the intention here is not to adopt a software classification system but rather to approach software selection from a mathematics education perspective. It is obvious in most instances that more than one purpose for any particular software package is possible. The ultimate choice lies with the teacher.

Mathematical content

Children's mathematical content knowledge can be developed, applied, revised or practised through software which incorporates links with concrete manipulatives, provides practice opportunities or requires the use of mathematical content knowledge to solve problems.

1. Using concrete manipulatives

An interesting way for children to build mathematical content knowledge was described by Lewis (1993). A mirroring software model, he explained, was the basis for many software packages which use graphics to draw pictures of concrete manipulatives e.g. *Blocks Microworld*, where children manipulate pictures of MAB blocks to investigate place value ideas and carry out computational tasks. It is expected in this case that children would have firstly used the MAB blocks before moving on to the software package. It is claimed that children using these types of software packages are more readily able to link the concrete with the symbolic to form and use abstract mathematical ideas.

Another suggestion came from the Mathematics Curriculum and Teaching Program materials (Lovitt & Clarke, 1984) in a lesson entitled *Biggest Volume*. Squared paper is used to make different sized open rectangular boxes. Firstly a rectangle is cut out then the same sized square is cut from each corner. Lastly the sides are folded up to make the open box. The aim is to find the box with the biggest volume by predicting a result after just a few boxes have been made. The computer can be used to verify the results but also to explore the concept further. *Similar Objects* is another software package where volume is explored. Children make models using 1 cm or 2 cm cubes in conjunction with the computer to investigate length, area and volume as shapes are rotated, enlarged and reflected.

2. Drill and practice

There are numerous programs which could be classed as drill and practice where basic number facts are presented in the form of games to beat the clock or previous score.

Many use animation techniques and are seen as highly motivating, since good packages are able to provide immediate feedback and keep track of errors e.g. *Connections* (Sherston, 1991).

Caution is urged, however, in the use of drill and practice software. Research has found that individualised flash card drill is just as effective if the expectation is increased speed and accuracy of automatic response (Campbell & Stewart, 1993). For young children where understanding the concepts involved are of prime importance, the use of concrete materials is advised (Campbell & Stewart, 1993; Collis, 1988).

3. Using pictures

The graphics facilities of a computer can be used to pose a problem by displaying it in picture form and allowing the picture to be manipulated by the user. In *Halving*, for example, pictures of geometrical shapes are displayed and as the shape is continually halved discussion on symmetry, area, and attributes of shapes can take place (Downes, 1987).

4. Playing games

Other programs, such as adventure games, are organised in such a way that mathematical problems have to be solved before the user can proceed to the next stage. Depending on the sophistication of the program, the content knowledge required to solve the problem can often be selected from a range of levels.

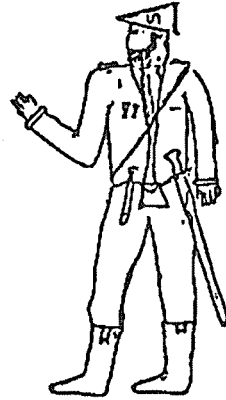
For example, *Martello Tower* is an adventure game where children are "imprisoned" at the top of the tower and have to use mathematical content knowledge and make decisions to find an escape route. Figure 3 shows an

eleven year old's explanation of how one of the problems was solved.

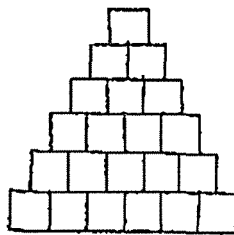
Figure 3. Explanation of a solution to a Martello Tower problem.

Triangular Hat

In Martello Tower there rooms a guard with a triangular hat. To tell the truth he has many hats but he wears them one at a time. Each hat has a number on it. If you meet him he will ask you the triangular number of the number on his hat. If the number on the hat is 10 you have to add 1,2,3,4,5,6,7,8,9, and 10. The answer is 55. The sum is like this.



$$1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 9 + 10 = 55$$



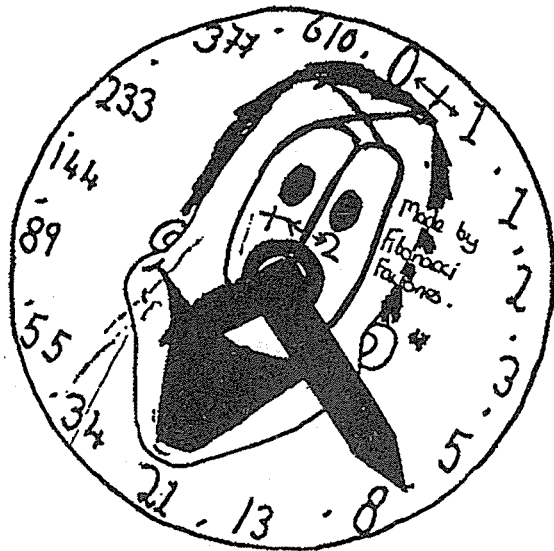
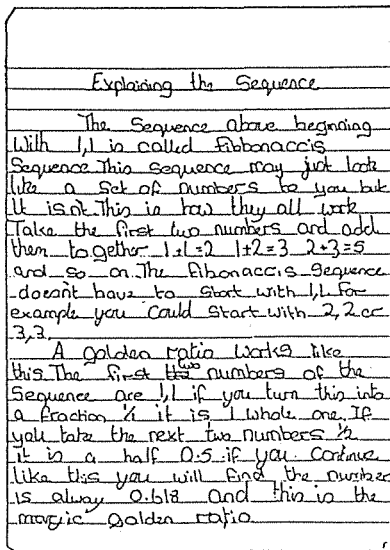
(NCET, 1989, p. 6)

5. Utilising mathematical operations

Applications software, like spreadsheets, can also be used to assist in the development of content knowledge. This software is often known as content free. An example may be provided with some mathematical content already present, but the package largely allows for the teacher or the user to input their own content. According to Quinn (1986) spreadsheets can be used by primary school children as a very efficient and speedy number cruncher to investigate number patterns and relationships. For example, a grid could be created to investigate what happens to a given set of numbers when each is multiplied by 2, then 3 and so on. A simple formula would have to be created for each column or row to produce an accurate answer. Some spreadsheet packages also have the facility to create simple graphs from the results produced. Simplified tailor made spreadsheet programs, such as *Forte*, would be more appropriate for primary school use than commercial packages such as *Excel* (Microsoft Corporation, 1992).

Using a spreadsheet package an investigation of Fibonacci numbers was conducted over a period of time by groups of eleven year old children of varying abilities. Figure 4 shows two examples of how children reported their findings.

Figure 4. Children's explanations of the Fibonacci sequence



(MESU, 1989, p. 41)

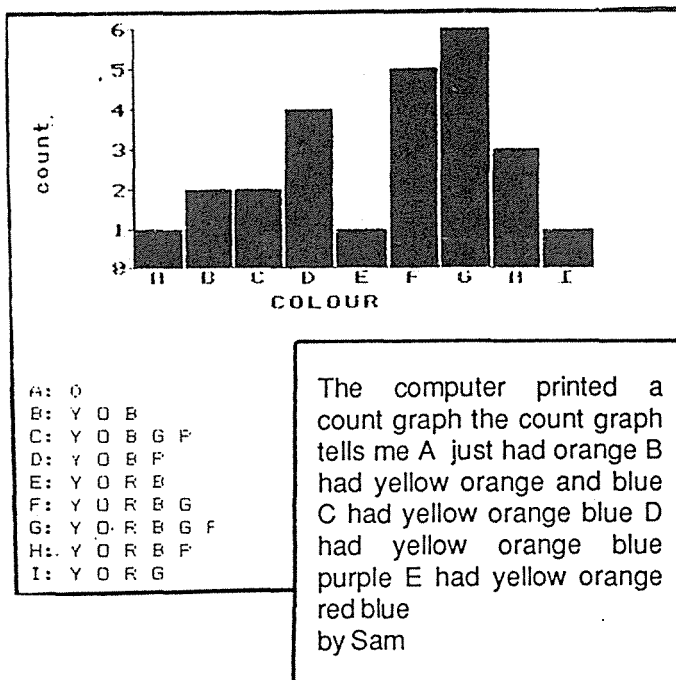
Mathematical processes

It would be difficult to disagree with anyone who suggested that children were not engaged in using at least some mathematical processes in well designed mathematical activities. Good software packages are no different. Processes like organising, estimating and predicting are frequently used by children engaged in completing tasks found in many types of software. The SMILE suite of programs, for example, "offer children opportunities for strategic thought and seeing relationships within mathematics as well as for consolidation and practice of skills" (Morgan, 1990, p. 14). *Jumping* (Council for Education Technology for the United Kingdom, 1984) is a strategy game where children play against the computer to investigate and find winning strategies. From instructions to the computer numbers are presented in an ellipse on the screen. A target number is

designated and turns are taken to jump over numbers to arrive at the target. The size of each jump can be altered from one to a maximum of four. With each new game a different target and the maximum size of a jump can be set.

Databases can be useful tools in the classroom for the development and application of mathematical processes. Where there is pre-existing data and children are engaged in exploring the data, processes such as questioning, comparing and hypothesising may be used. Where there is no pre-existing data and a database has to be constructed, additional processes are used, such as observing, grouping and classifying e.g. collecting data from a survey on the kinds of music which different age groups like and dislike, organising that data, interrogating the database to find answers to questions posed and drawing conclusions about the results. A database software package which has a variety of graphing facilities to display the responses to these questions is particularly useful in the interpretation of the data (see Figure 5).

Figure 5. Number of flame colours of different kinds of paper



(NCET, Book 2, p. 9)

In this series of activities junior primary children were recording the colours of the flames made when different kinds of paper were burnt. For example, the graph shows that paper A produced only one colour and that was orange.

Integrating content and processes

Many software packages provide opportunities for the integration of mathematical content and processes. Thematic software often has this potential. Particularly in the junior primary years this may mean that a software package theme incorporates many subject areas or it may be used as a mathematics theme e.g. *Teddy Bear's Picnic* (Norgate, 1988) integrates language and mathematics topics on odd and even numbers, directionality and pathways, and many counting ideas, in a variety of problem solving contexts. This package is suitable for four to seven year olds and can be used with a concept keyboard.

Specially designed microworlds also enable processes and content to be integrated. A microworld can be seen as a particular context characterised by its own language patterns and functions which the user can draw upon to create and direct particular kinds of screen displays such as graphical images.

Logo could be considered as a special type of microworld where children can explore complex geometric ideas by creating shapes and controlling their own learning by making sense of their ideas in a problem solving context (Papert, 1980). Number ideas can be used as children investigate pathways and directions to make shapes. Compatibility of mathematical objectives can be found between the use of Logo and recommendations made in syllabus documents (Ross, 1993).

For example in Band A of the Space strand in *A national statement on Mathematics for Australian schools (1990)*, the following recommendations are made:

Experiences in shape and structure should be provided which enable children to:

A1 build structures and make and investigate geometric models ...

Experiences in location and arrangement should be provided which enable children to:

A5 give and follow directions for moving and locating objects ...

(pp. 85, 85)

For young children it is suggested that their drawing with the computer be replicated by their physical movements and so help understanding of some measurement concepts (Campbell & Stewart, 1993). This approach was utilised in a study where children created pathways for themselves to follow on the ground and used concrete objects such as pattern blocks to investigate different unit lengths of measurement. It was found that this group of children were more accurate in estimating distances, given a unit length, than those who had not used Logo in a series of lessons on measurement (Campbell, Fein & Schwartz, 1991). Concrete materials can also be used by integrating Logo with Lego to help children write procedures which will direct their newly made Lego models i.e. developing and trialing a set of sequenced instructions (Sneddon, 1993).

Noss (1987) has suggested that Logo can be viewed in two quite different ways - one view is that children are learning mathematical *content*, and the other view is that knowledge of mathematical *processes* is gained when

problems need solving in the Logo microworld. These views are explained as follows:

View 1: By writing simple programs to investigate geometrical ideas, children are learning mathematical *content* e.g. attributes of two dimensional shapes.

View 2: Children problem solve using mathematical *processes* irrespective of the content e.g. the processes of trial and error are used to draw a two dimensional shape.

Children's development and application of content and process knowledge was the focus for a study by Harel (1990). Fourth grade children used the programming language Logo and Logo Writer to develop an instructional package on fractions for others to use - a procedure called Instructional Software Design (ISD). Children in the project made their own decisions about how best to represent fraction ideas, developed a deep understanding of these ideas, and importantly necessitated the doing of mathematics. In this "doing" children

viewed themselves as capable of using their growing mathematical power, made sense of new problem situations in the world around them, and were able to communicate their mathematical ideas and build arguments to support their ideas (Harel, 1990, p. 33)

Mathematics in use

Programs like *Cars-Maths in Motion* simulate real life problems encountered in rally car driving. In this example, children must make decisions about the speed of the car, angles on bends, distances to be covered, time allocations and other problems associated with

endeavouring to finish the race. Children work in pairs or small groups to plan their strategies before and after their interactions with the software. As one teacher commented about a child who was using this program:

My biggest thrill came when listening to a child, by no means the most able in the class, think for a while and then say,

"92% of 270 km/hr. 10% is 27, so take that off. 1% is nearly three, call it (the 2%) six and add that back again...249!"

Why did it take you so long? I asked jokingly.

"I couldn't believe you were asking something so easy," he replied, "I thought there might be a catch in it!"

(NCET, 1989, p. 6)

The information given in these types of games is usually both pictorial and written: sometimes found on the screen and often in the guide book which is part of the complete software package. Children encounter and discuss problems using language specific to the situation. Thus mathematical language is used purposefully in a meaningful context (Downes, 1987).

According to Lovitt and Lowe (1993) computer simulations can be used for:

Demonstration	The computer slowly emulates the children's actions preferably using graphics.
One trial	All steps are visible and the results displayed as a table.
Many trials	The computer's speed is used to carry out many trials in a very short space of time, then displays the results in table and graph form.

Computer simulations have not only the advantage of introducing children to situations which they would otherwise not encounter but do so in a safe, non-threatening climate.

Computer simulations and the relevance of context to mathematical investigations were evident in a project involving the facilities of electronic mail and suitable software packages (Kershaw, 1987). Primary schools located in different geographic locations conducted some investigations of the earth's circumference using Eratosthenes' ideas. Each location organised their results, exchanged this information with other centres via electronic mail and reached a consensus about their conclusions.

In another experience using electronic mail, a graphics package, and word processing facilities, two schools exchanged information on the layouts of their classrooms. Gradually these were refined to include three dimensional figures and each school constructed a scale model of the other classroom. Exchange visits enabled the accuracy of their models to be checked.

Classroom organisation

Earlier we reviewed recommendations of curriculum developers (see Chapter 4). Some of these referred to how computers might be used in classrooms. For example, the *Learning Mathematics Handbook* (Curriculum Programmes Branch, 1989) suggested that computers could be used by children individually, in pairs, small groups or by the teacher with a whole class. We also listed software and hardware concerns of a generic nature when discussing characteristics of good software and placement of computers (see Chapter 3).

When consideration has been given to these concerns, planning and organisation for mathematical activities should involve:

✓	Determining the purpose of computer use in relation to mathematical objectives e.g. developing content knowledge, using problem solving strategies, practising a skill.
✓	Choosing a suitable piece of software.
✓	Deciding upon the number of children who will use the computer at any one time.
✓	Determining the composition and roles of the group, and establishing procedures e.g. will the group be of mixed ability? who will be the keyboard operator? does consensus need to be reached on a decision before an input is made?
✓	Identifying those children who will benefit by using the chosen piece of software i.e. not all children in the class will need to interact
✓	Organising mathematical activities for those children who are not engaged in computer use. These tasks away from the computer can also be designed to meet the lesson's objectives but with the use of other resources.
✓	Providing any resource material which is to be used in conjunction with the time spent using the computer.
✓	Timetabling individuals or groups for computer use and setting time limits, particularly if computer hardware is limited e.g. children may be rostered for their computer time throughout the day or week and during other timetabled subject periods in order to undertake a specified computer task.
✓	Allocating time for discussion and reflection of mathematical ideas. Having children communicate their strategies or findings in a written or pictorial form after they have completed a task with the computer is particularly useful.

All of the above steps imply that the computer is being used purposefully as an important part of the mathematics teaching/ learning program. Its use is not seen as peripheral to mathematical activity, as a fill-in, a reward, or where children or teachers choose software unrelated to the purpose of the lesson.

Some organisational examples

1. In schools

A local primary school opted for a computer room and appointed a computing coordinator. A school policy was developed which stated that all children in the school should become familiar with computers and that they should be used to enhance the delivery of the classroom curriculum. The mathematics curriculum incorporated computer use and identified particular software packages which were relevant to learning objectives. Each class was allocated time to use the lab at least once a week, with the computing coordinator planning and managing activities. Later the policy was revised as teachers felt it was necessary to associate computer use more closely with the learning activities of the classroom. Each classroom was then provided with at least one stand alone computer for this purpose. The room continued to be used as before, but with a greater emphasis on integration with classroom activities.

In another primary school children had access not only to a computer laboratory but to their own portable computer. Teachers were able to more readily integrate computer use into their mathematics lessons as children were either directed to the use of particular programs or

they could access a computer facility if they wished during their mathematical activity. In addition they were able to take their computer home. Parents became familiar with the way computers were being used in the classroom as the children worked on mathematics projects (Smith, 1993).

2. In a classroom

A Year 2 teacher was working on transport as her theme for the term and decided to use cars and surveys in her mathematics program for her mixed ability class of twenty one. She had one BBC computer, disk drive and printer in her classroom. The following steps indicate the way in which she organised a series of mathematical activities.

- ✓ Children measured cars with hand spans and drew pictures to represent their results.
- ✓ Children collected numbers from number plates and used calculators to add the numbers from any three number plates.
- ✓ Headings for fields in a database were discussed and agreed upon e.g. cars (number of cars seen in 20 minutes), time and day (when data collected).
- ✓ A worksheet was drawn up by the teacher for children to record their data.
- ✓ Data was collected by children in groups of three or four.
- ✓ After the data was entered on the database children were rostered in pairs at the computer, having already decided upon the questions they wanted to ask. Some of these requested that graphs be drawn.
- ✓ Away from the computer children drew their own graphs, used cards and hoops to display information in concrete form, and used pencil and paper to record their results symbolically.

(Carter, 1989)

Some innovative projects

1. The Sunrise project

The Sunrise project was initiated at the Australian Council for Educational Research and by 1990 involved two primary schools in Victoria and one in Queensland. Laptop computers were made available for each child who then remained in the program for three years beginning with Year 5 or 6 and continuing into the first years of secondary school. Children had access to other resources such as Lego materials, word processors, graphics packages and Logowriter.

The aim of the project was focused on the kinds of learning and learning environments which could occur in schools, when children, teachers (including curriculum developers) and parents were seen as a learning community. Teachers designed projects based on children's interests. The nature of the setting supported independent learning, and dialogue among all the players in the community was a natural ingredient of the project dimensions, which also generated the "doing" of real mathematics. Thus children posed the questions, engaged in creative and critical thinking, and made use of inquiry processes such as pattern finding and validating to solve problems (Nevile, 1990; Belward, Mitchell & Ryan, 1991). In this project then, the mathematics culture of the learning environment was epitomised by beliefs about:

- the social nature of learning mathematics;
- choices children should have in their use of other resources;
- children engaging in real mathematics tasks; and
- children constructing their own mathematical knowledge in their own unique ways.

The computing culture of the project relied primarily on the culture of a Logo microworld and its attendant assumptions about this computer medium enabling children to think and express themselves. Also implied was a belief that benefits to children's thinking and learning skills would only be felt if they had constant computer use over a long period of time.

2. Multimedia at the Shell Centre

A multimedia curriculum package titled *The World of Number* has been developed at the Shell Centre for Mathematical Education in the U.K. It contains interactive video disks which integrate sound, graphics, movement, film and video clips to create mathematical environments for exploration. Many different types of modules incorporate various computer facilities such as databases, simulations and drawing packages. Problem starters, specific tasks and project ideas are included for teachers, but children are encouraged to pose their own problems for investigation. Although the package was targeted for 11- 16 year olds, children outside this age range have successfully used the package.

The importance of communication and describing individual perspectives are emphasised by the developers as critical influences on construction of personal mathematical knowledge. As they use mathematics to explore the problems (which use contexts and characters of their real world), to explain and understand their world, children build mathematical language from their own sense-making language (Burkhardt, 1992; Caddy, 1993).

Like the mathematics culture of the Sunrise project, this curriculum package also supports ideas about an individual's unique construction of mathematical knowledge. However its perspectives on using

mathematical knowledge are different. It values real world mathematical situations but prescribes the settings and particular mathematical topics which in turn direct the development of appropriate mathematical language.

Learner control was seen as a central feature of this computing culture. The culture of the computing environment was also characterised by the accessibility of the different resources made possible by the power of the computer.

Doing mathematics with computers

In an earlier chapter we outlined a framework for mathematics learning which now needs to be considered again in light of the suggestions and recommendations made by curriculum developers. You will remember that we outlined some common goals of mathematics education and described some recent views on how children learn mathematics as well as some significant factors influencing their learning.

Learning mathematics is about *doing mathematics*. Learning environments then are those where children are using their mathematical knowledge. They are actively involved with materials and experiences which embody mathematical concepts. Experiences are of a social nature where social interactions occur between children, and between children and teacher. Children construct their own knowledge and understanding. Language is used to refine meanings as children endeavour to make sense of their mathematical knowledge. As mathematical knowledge grows, segments are linked together in a sense-making way to form each child's unique network or map of connected ideas. The mathematics classroom

context reflects the beliefs the teacher has about mathematics learning.

The examples selected to describe some classroom practices in the previous section illustrate how enterprising, creative teachers and curriculum developers are combining to explore ways in which mathematics learning can be enhanced by the nature of children's interactions within a computing technology context. Researchers and curriculum developers have questioned their perspectives of mathematics and the current curriculum in the light of the power computing technology can give the learner (Nevile, 1990; Olive, 1992; Caddy, 1993). They are looking to move beyond the present boundaries and expectations which have been set for children's achievements in mathematics. They are exploring different environments where the nature of children learning to do mathematics and teacher's roles are transformed.

6

Mathematics education reform and computers

We referred earlier to the differing cultures which could be found in mathematics classrooms (see Chapter 2). Examples were given of how prescriptive resources, teacher controlled knowledge, and views on how children learned mathematics have determined the nature of current mathematics cultures. Two innovative uses of computers pointed the way to some different mathematics cultures, where features of computing cultures, such as learner choices and the stimulation of thinking processes, were recognised.

Computing cultures can allow children to control their own learning and knowledge. The computer can be used "as an *object-to-think* with" (Papert, 1980, p. 23). Engaging in activities with a computer can challenge the mind and evoke thought (Turkle, 1984). The power of mathematics in explaining our physical and social world can be more widely accessed with computer resources (Noss, 1992). Learning can take place in cooperative and collaborative ways (Finger & Grimmett, 1993). Children need not be locked into prescribed ways of learning mathematics to obtain right or wrong answers.

If, as Bigum and Green (1993) suggest, classroom environments, curriculum, teachers and students will

need to respond to the implications of electronic technology, then what happens in schools, and in particular, mathematics classrooms and mathematics cultures will need to be different. Software packages will do the calculating, draw the graphs, manipulate data, introduce children to new mathematical ideas at an earlier age and make obsolete many elements of current curriculum. Children will become proficient in using investigative and exploratory skills, become critical thinkers (Swadener & Blubaugh, 1990). Teachers will become learners as they too experiment, make mistakes and discover new ideas (McDonald, 1993).

But change is slow and although many questions still remain unanswered their focus has become clearer. Olive (1992) has identified current research in this area by classifying a number of these questions.

Questioning	implementation	how teachers' attitudes impact upon computer use, what skills are needed in their teaching.
	content and mathematics teaching	identifying strategies and understandings which are useful in a computer-dependent society.
	children's thinking and learning	how teachers' and children's beliefs about mathematics might change ways in which technology might influence children's understanding and use of mathematics.

When they emerge, findings of these and other research studies about the use of computers in primary mathematics will be of immense interest. But awaiting results should not prevent responsive classroom teachers from questioning their own beliefs and practices about children learning mathematics in a computer supported environment, and challenging the expectations of current curricula.

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Research and investigation ideas for teachers

Investigate how:

- computers might be used as a focus for school mathematics policy development and planning
- computers can be used in a range of equity issues e.g. physical disability, gender, culture, and other special needs, with particular emphasis on learning mathematics
- school and classroom computer resources can be organised for optimum student learning in mathematics
- tools software (Logo, databases, spreadsheets, graphics, word processors) can be integrated into primary school mathematics programs to optimise student learning
- computers can be used to develop mathematical problem solving skills utilising as wide a range of strategies as possible
- to evaluate effectively mathematics software, integrate it into the school / class program, and apprise staff of its teaching and learning potential
- the computer can be used as a diagnostic and remedial tool in mathematics education
- parent information/awareness programs might be structured and implemented
- computers might influence/direct changes in mathematics curricula.

NOTES

1. $\frac{1}{x^2} = x^{-2}$

2. $\frac{d}{dx} x^{-2} = -2x^{-3}$

3. $= -\frac{2}{x^3}$

4. $= -\frac{2}{x^3}$

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Lorraine Kershaw was the Project Officer for this CAUT project. She was previously a lecturer for seven years in mathematics and computer education at the Edith Cowan University. Lorraine has taught across all primary grades for many years as a classroom teacher and specialist support teacher. Her research interests include influences on adult learning, the thinking and learning strategies of young children, and the use of computers in primary mathematics education.

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