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The Future Is Now: A Review of the Literature on the Use of Computers in Early Childhood Education (1994–2004)

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This article considers the research literature of the past decade pertaining to the use of computers in early childhood education. It notes that there have been considerable changes in all aspects of our lives over this time period and considers studies in which information and communication technologies (ICT) and in particular, computers, have been studied in early childhood contexts.

It has been noted (e.g., Siraj-Blatchford & Siraj-Blatchford, 2004) that there has been a tendency of late for governments, policy makers, and those who oppose the use of computers in schools (e.g., Alliance for Childhood, 2000; Armstrong & Casement, 2000) to question the money spent on computers for educational settings. Often such calls are justified in terms of contending that educational outcomes have not improved commensurately with the amount spent on technological hardware. This would appear to be spurious since the measures of such outcomes do not require the use computers or technological skills, and often rely on the memorization of facts that are characteristic of learning in bygone days. Comparisons of computers versus non computer contexts for learning have become less frequent since the research of the 1980s, yet it is still apparent that there are those who want a "back to the basics" approach to education in the 21st century as exemplified in the *No Child Left Behind* policy that is the flagship of the Bush administration in the USA.

This review of the research literature pertaining to empirical studies related to the use of computers by children in the early childhood years (i.e., birth to 8 years of age) covers a significant time period and one in which major and fundamental changes have occurred in the very fabric of our society. New technologies have revolutionized how we complete even the most basic tasks in life and computers have become a ubiquitous aspect of everyday activity. However, although this is evident in all aspects of society, from the local to the global, within the educational context the use of new technologies is still superficial since they are still not fully integrated into curriculum (Yelland, 1997). This is despite the proliferation of policy and hardware into our schools, and the fact that computers and other technologies have been shown to be significant in the lives of young children (CEO Forum, 1999; Kaiser Family Foundation, 1999).

On the cusp of the time frame under review, (1994 to 2004) Clements, Nastasi, and Swaminathan (1993) considered the then current literature pertaining to young children and computers and created an interesting metaphor to describe the use of computers in early childhood education. They said that we stood at a crossroads and that we needed to decide what path to take in terms of the ways in which computers would be used by young children. Would we use them to *reinforce* existing practice or to *catalyze* educational innovation? In the article Clements et al. (1993), considered a number of research results that basically demonstrated that computers could be used in *innovative* ways with young children in early childhood contexts. This discussion can now be extended and continued in the present article by interrogating issues such as, how computers have been incorporated into early childhood education during the decade and by considering the ways in which their use may be fundamental to the rethinking of early childhood curriculum. In particular, this review of research addresses the use of computers in the curricular areas of literacy and numeracy and considers the ways in which they have afforded opportunities for young children to use higher order thinking skills, engage in creative and critical thinking, and also how the use of new technologies may support young children's social development and knowledge building processes. The article will also consider some examples of pockets of innovation that have been created by early childhood educators who have shared their practices with others in practical ways, prior to summarizing the major issues that have been researched over the past decade and highlighting where we might move to during the next decade.

TECHNOLOGY IN EARLY CHILDHOOD EDUCATION

In the 1980s there was vigorous debate about the role of technology, and computers in particular, in early childhood curriculum (Barnes & Hill, 1983; Cuffaro, 1984). Some early childhood educators were of the opinion that young children should not use computers because they:

- were too abstract and only let children experience ideas/ concepts in two dimensions;
- minimized the role of teachers;
- did not assist children to work collaboratively; and
- were used with programs that were considered to be developmentally inappropriate.

As previously stated, the debates continue today and the media frequently seize upon the ideas of individuals and groups that call for a suspension of funds to support the purchase of computer hardware and software in early childhood classes. (Alliance for Childhood, 2000, Armstrong & Casement, 2000) Their evidence is often unsubstantiated and not supported with empirical data (Clements & Sarama, 2003). However, when decisions have to be made about funding, the education dollar has many demands on it, and such arguments seem to be able to capture the feelings of those who want to see a return to traditional methods of education in which the computer has no significant role to play.

Additionally, there appears to be major concerns in some quarters regarding the amount of time that children spend using computers, grounded in the fear that once children start to use them they will not want to experience traditional play materials, and will only want to play computer games. In fact, the data shows that this is unwarranted. For example, Shields and Behrman (2000) cited the results of National survey data which revealed that children from 2 to 17 years of age spend approximately "...34 minutes per day, on average, using computers at home, with use increasing with age. (Preschoolers ages 2 to 5 averaged 27 minutes per day...)...exposure in the early primary grades, at least, is relatively modest" (p. 6). They also found that use of computers in the home context was associated with "slightly better" (p. 9) academic use. Other studies of children's achievement in an after school program called the 5th Dimension (Blanton, Moorman, Hayes, & Warner, 2000), have indicated that the children in these groups not only scored higher in traditional achievement tests in reading and mathematics but they were also reported as having a higher level of knowledge and understanding for reading, the use of grammar, mathematics, and of course computer knowledge, as well as being able to follow directions more effectively when compared to another group that did not participate in the program.

By 1996 the National Association for the Education of Young Children (NAEYC, 1996) released a position statement regarding the use of computers in the early childhood years. They did this as a response to the recognition that "Technology plays a significant role in all aspects of American life today, and this role will only increase in the future" (p. 1). The policy statement highlighted seven issues that related to the use of computers. These were:

- the role of the teacher was essential in choosing developmentally appropriate software and they should join with parents to advocate for good software for young children;

- the recognition that some applications of software could enhance cognitive and social skills (Clements, 1994; Haughland & Shade, 1990; Rhee & Charvangri, 1991);

- the use of computers needed to occur within the context of continued use of traditional early childhood materials;

- there was a need for the promotion of policies of equity and social justice in the allocation of computers in schools;

- attention should be paid to any negative aspects related to stereotyping of individuals or groups be avoided; and

- support was needed to assist the profession to become confident and competent with computer technology.

Immediately, following the statement, in the same issue of *Young Children*, Elkind (1996) reported his misgivings about the presence and use of computers in early childhood settings. His concern related to the fact that he felt discussions were not critical enough about the use of the machines in educational contexts and further that no consideration of child development was included. He continued that observations about children's high levels of cognitive competence in computer contexts were premature and not in fact stable, for example, in terms of being related to Piaget's stage of concrete operational thought. The problem with this line of argument is that maps new learning onto old contexts and considerations, that were created before new technologies and their potential for learning were conceived. Further, the theories that Elkind references were conceptualized in a very different age, and their relevance to learning in the 21st century has not been challenged or indeed supported with any empirical studies to indicate that their main premises are sustainable.

The essence of the debate about the use of computers by young children frequently focuses on the alleged poor quality of educational software, deploring the violent content of video games, and being fearful of the possibility that children will be severely damaged if they accidentally access pornography on the Internet when unsupervised. They are framed around questions like "Why should children be exposed to computer technology from an early age? Are computers and computer software essential to children's education? What can we expect them to gain?" (Armstrong & Casement, 2000). It would be interesting to note the answers if the same questions were posed in relation to other more traditional technologies (e.g., blocks, jigsaw puzzles, and of course books) that are found in early childhood centers and classes. While such critics ask questions about computers there seems to be no questions asked about expenditure on text books for young children, which often illustrate the same qualities of rote learning and abstract tasks, that such critics find so offensive in commercial software.

RETHINKING CURRICULA

Dede (2000) has challenged us to think about the fact that

> we have the technical and economic capacity to develop technologically rich learning environments for children to prepare them for life as adults in a world very different from the one we have known.

> Whether we have the political and cultural will to accomplish innovative uses of media for learning and empowerment across all segments of society remains to be seen. (p. 180)

One of the main problems when considering the use of technology in education, is that computer activities are often still an "add-on" to regular school work or based around structured software in an attempt to enhance and extend curriculum topics. Instead of being a catalyst for change, new technologies have been in the main, mapped on to old curriculum that were conceptualized in different times. It has been noted (Tinker, 1999; Yelland, 1999, 2002c) that we have a great deal of information about the ways in which new technologies are able to transform learning, yet curricula in schools remains much as they were last century. Resnick (1998, 2000) suggested that we should view computers in the same way that we view finger paints, blocks, beads, and other materials for making things. He also suggested that compared with "traditional materials" computers can expand the range of things that children can create and in doing so enable them to encounter ideas that were not previously accessible to them. This requires a bold new approach to curriculum, which encapsulates a notion of design and opportunities for children to explore and investigate in ways that were not possible without the new technologies

Additionally, as Rochelle, Pea, Hoadley, Gordin and Means (2000) stated "Studies overwhelmingly suggest that computer-based technology is only *one element* in what must be a coordinated approach to improving curriculum, pedagogy, assessment and teacher development, and other aspects of school structure" (p 78).

Further, there is an increasing recognition that curriculum decision-making needs to take note of children's out-of-school experiences and build upon them. Dede (2000), for example, has called on educators to "…reshape children's learning experiences in and out of school to prepare them for a future quite different from the immediate past. Meeting this challenge involves teaching new skills, not simply teaching old skills better" (p 178).

In Australia this has been achieved through the conceptualization of a new basics curriculum in Queensland, and the essential learnings framework of both Tasmania (Department of Education, Tasmania, 2003) and South Australia (Department of Education and Community Services, 2003). Furthermore, the Australian Council of Deans of Education in the charter for reform (ACDE, 2001) suggested that we should focus on *new learning*, one aspect of which involved the integration of new technologies in all aspects of learning. In fact, in all of these examples the use of information and communication technologies (ICT) is an integral part of learning and incorporated into conceptualizations of what constitutes realistic and authentic curriculum in the 21st century. There is the realization, for example, that " Information technologies offer new possibilities for innovation and enterprise…" (Department of Education, Tasmania, 2003, p. 22) They are accompanied by statements that promote a vision of citizens in the information age being able to, for example, "think flexibly and creatively and to manage their learning throughout life…" as well as the realization that "…the ability to apply knowledge to new situations and make informed choices and decisions will be of paramount importance" (Department. of Education, Tasmania, p. 13).

BECOMING LITERATE AND NUMERATE IN THE INFORMATION AGE

The emphasis on being literate and numerate in the information age has been stated as being a policy imperative across the world (e.g., Australian Council for Educational Research, 1990; Department of Education Training and Youth Affairs [DETYA], 1999, 2000; Her Majesty's Inspectorate, 1998; National Council of Teachers of Mathematics [NCTM], 1998). Those who do not support the use of computers in school suggest that standards in these "basics" have dropped and that children are no longer able to read, write, spell, and/or add, even though there is no empirical data or government statistics to support these contentions. Still, curricula and school timetables in early childhood classrooms across the globe are being organized around literacy and numeracy "hours" in order to promote the basic skills from an early age (Department of Further Education and Employment, 1998) and children are vigorously tested to document these "basic skills" of a bygone era. Thus, the use of computers has been marginalized and are rarely found to be an integral part of learning scenarios which encompass, what is regarded as, literacy and numeracy. If we think back to the metaphor created by Clements et al., (1993) it is evident that there are wonderful opportunities not only to reconceptualize literacy and numeracy in the technological age (e.g., ACDE, 2001; Cope & Kalantzis, 2000; Education Queensland, 1999; New London Group, 1996) but to also choose the path of innovation for literacy and numeracy, with ICT. However, most examples of the use of computers in literacy and numeracy have tended to be with computer assisted learning (CAI) software and the drill and practice genre which reinforce "old learning" and emphasize the acquisition of skills in a vacuum with no attempt to relate them to authentic activity.

New Literacies

Lankshear and Knobel (2003) mapped recent empirical research work related to early childhood literacy and discovered that there was a dearth of studies available for review. In the process they also found that *mainstream* literacy journals, which deal with the topics of reading, writing, and literacy, marginalized the reporting of studies that incorporated the use of new technologies. They referred to the work of Kamil and his colleagues who reviewed the literature (Kamil & Intrator, 1998; Kamil, Intrator, & Kim, 2000) and reported that in the period from 1990 to 1995 when 437 articles were published in four pre-eminent literacy journals only 12 were research articles pertaining to the use of technology for reading and writing. Of these, only three studied reading and technology and two of them actually incorporated audio and television in the design, not computers.

The review of the literature that Kamil et al. (2000) conducted covered the whole range of school education, and from this only a small number of projects were concerned specifically with the early childhood years, but they did include studies which incorporated the early years with later years of schooling. They were able to make some preliminary, but very general comments about the use of computers and other technologies in literacy education. These included studies that showed:

- children who used word processors were judged to have better quality compositions than those who used pen and paper (Bangert-Drowns, 1993);
- the dynamic nature of multimedia seemed to help children to create mental models more effectively and improved comprehension (Kamil et al., 2000);
- the use of computer software seems to benefit the learning of special populations, such as children with learning disabilities, English as a second language and the young child (Kamil et al., 2000);

- the use of computers in reading and writing seemed to motivate children more effectively (Kamil et al., 2000); and

- computer based learning activities in language activities seemed to induce greater levels of collaboration and discussions (Dickenson, 1986).

Lankshear and Knobel (2003) conducted a further review by searching literacy journals as well as specific early childhood journals and technology journals. From 554 articles in nine journals, only 18 were in the broad area of using the new technologies and 5 were specific empirical studies related to technology and literacy. They cited Fleming and Raptis (2000) who had observed in their work that only 25% of the literature of all educational technology literature (in English) could be described as empirically based research. Forty four per cent (44%) of the literature described implementations of multi media and other technologies but relied on anecdotal evidence of their use in classrooms.

Lankshear and Knobel (2003) generated a list of studies that were almost all based in North America and included doctoral dissertations and clearinghouse documents. They found a group of 17, which they clustered around three topics, and five studies that examined the effect of using a specific literacy program called Wiggleworks with Kindergarten and Year 1 children (Ross, Hogaboam-Gray, & Hannay, 2001), the effects of software (CAI and hypermedia authoring) on measured outcomes in reading achievement levels and motivation (Mott & Klomes, 2001), the impact of networked computers (Casey, 1999) and their own investigation (Lankshear & Knobel, 2002) into the literacy education resources available for young children on the National Grid for Learning in the UK. These clusters identified were:

- uses of CDROMS on early literacy (Doty, Popplewell, & Byers, 2001; Higgens & Cox, 1998; Higgins & Hess, 1998; Humble, 2000; Labbo & Kuhn, 2000; Matthews, 1997; Smith, 2001, 2002);

- teaching techniques associated with using new technologies (Turbill, 2001; Wepner & Tao, 2002); and

- the use of new technologies by learners from diverse groups (Boone, Higgins, Notari, & Stump, 1996; Brett, 1997; Clements, 1998; Godt, Hutinger, Robinson, & Schneider, 1998; Howell, 2000; Hutinger & Clark, 2000; Parette & Murdick, 1998).

The studies were basically structured to compare particular aspects of literacy (e.g., reading, comprehension, teaching techniques) comparing computer-based examples with the noncomputer contexts. The results tended to be equivocal, with some studies demonstrating superior performance with the technology while others did not. For example, with regard to comprehension and the recognition of unfamiliar words, computer contexts were found to be more effective. In contrast, on the other dimensions there were no differences evidenced or minimal effects noted. In relation to the second cluster, the focus of the research was related to issues around why teachers find it so difficult to incorporate new technologies into their programs. Turbill (2001) identified three factors:

- lack of time and expertise to explore and understand the software;
- limited conceptualizations of literacy held by teachers; and
- lack of understanding about the capabilities of new technologies and the confidence to use them in their teaching.

The studies with *diverse groups* of children all pointed to positive outcomes in learning contexts with computers while the remaining studies were simply descriptive examples of effective uses of technology in a variety of contexts, related to reading comprehension and word recognition for example.

A review by Clements and Sarama (2003) revealed success in the use of computer environments for special needs children (e.g., Cognition Technology Group at Vanderbilt [CTGV], 1998; Hutinger et al., 1998; Schery & O'Connor, 1997; Walker, Elliot & Lacey, 1994). While Oken-Wright (1999) also noted that the use of technology was considered as one of the 100 Languages of the Reggio Emilia approach, which facilitated the representation of ideas and images that were not possible without the technology. Clements and Sarama (2003) cited empirical studies that provided evidence that "computer based writing can encourage a fluid idea of the written word and free young children from mechanical concerns" (p. 13). They referred to studies by Jones and Pellegrini (1996) and Yost (1998) to demonstrate the greater level of sophistication of writing in computer contexts, including the ability to be metacognitive, that is monitor their own progress, and to respond to feedback, for example, than in pencil and paper contexts for writing. Further, Moxley, Warash, Coffman, Brinton and Concannon (1997) demonstrated that young children revealed improvements in both story writing and spelling over a two year period.

Lankshear and Knobel (2003) highlighted the need for contemporary research to focus on "…the types of literacy education experiences required for higher level participation in the kind of knowledge-information society described by leading theorists" (p. 78). This view concurs with that postulated here, that is, a positive way forward is to consider the ways in which new technologies may assist us to reconceptualize literacy and to rethink the nature of the activities inherent to becoming literate in the 21st century. Certainly, the advent of ICT have changed not only the ways in which we are able to communicate but have also facilitated the ease by which we are able to compose new texts and access sources of information, which would have been impossible even five years ago. There are probably a myriad of reasons why educators, politicians, and the general community need to compare the use of computers to traditional educational materials. However, it is apparent that being literate in the information age requires *new* skills (e.g., New London Group, 1996; Cope & Kalantzis, 2003) and the use of new technologies in everyday life means that becoming literate remains a fundamental aspect of life in the 21st century, within this new framework.

Numeracy

Forman and Steen (1999) have characterized the information age as a "data drenched society." They suggested that we are surrounded by numbers and the need to process, interpret, and use them in a large variety of ways. In this way the need to become quantitatively literate or numerate has become an important imperative in our society (Mathematical Sciences Education Board, 1995). Similarly, the acquisition of what we now refer to as higher order thinking skills (i.e., being able to think creatively and in divergent ways, analysing contexts, and making plans to solve problems, posing problems, collaborating effectively in teams, monitoring progress, responding to feedback, synthesizing ideas, and re-evaluating to new plans where necessary), which can be considered as the "new" basics of the 21st century.

As previously noted the importance of developing a numerate populace who can function effectively with the practical mathematical demands of everyday life in the 21st century has been recognized worldwide (Australian Council for Educational Research, 1990; DETYA, 1999, 2000; Her Majesty's Inspectorate, 1998; NCTM, 1998, 2000). New demands in the high performance workplace (Maughan & Prince Ball, 1999) means that a traditional view of mathematics, which focused on memorization, rote learning, and knowing facts devoid of context and application has been replaced with one in which mathematics has some purpose and application, and where becoming numerate is conceptualised in a broad way (DETYA, 2000). Such a vision considers mathematics and becoming numerate in the context of societal and individual expectations. This vision has been accompanied with a shift in pedagogy which now emphasises the use of both whole class and small group teaching, active exploration, inquiry, and problem solving, engagement with mathematical ideas through collaborations and creative explorations, mathematical representations incorporating a variety of media, which include the use of ICT, and the communication of findings with peers and authentic audiences (Kilderry, Yelland, Lazaridis, & Dragicevic, 2003).

As part of this process, the consideration of modes of representation has been very important to the teaching of mathematics in the early childhood years. As a major part of the legacy of Piaget (1972) there has been a belief that young children need to use and play with concrete (3 dimensional) materials to understand mathematical concepts before they consider them in abstract terms, that is, in the written form with symbols and operations. This has led to the design of carefully sequenced mathematics lessons, which move from real world examples, through the use of three dimensional materials to creating contexts for using the abstract language of mathematics. However, with the advent of computers, the very notion of what constitutes "concrete" is not clearly understood, and the ramifications for such sequences of learning are now seriously called into question. For example, Clements (2000) considered the nature of concrete materials and manipulatives and noted that computer manipulatives have distinct advantages for the teaching of early childhood mathematics. Using the Shapes software as an exemplar, but also considering other types of computer manipulatives (e.g., base 10 blocks), Clements (2000) used empirical work to demonstrate that there are a number of pedagogical and mathematical benefits in using the computer based manipulatives. For example, under pedagogical benefits he considered that the Shapes software provided:

- another medium for storing, recording, replaying and retrieving configurations and ideas that was beneficial for the continuity of projects and reflections for concept building. This was also noted by Ishigaki, Chiba, and Matsuda (1996). This was particularly evident in creations that explored the concept of symmetry as shown in Figure 1;

- manageable and "clean" flexible manipulatives that would do exactly what the children wanted and were easy to work on because they could be fixed and not disrupted by others. Manipulatives also afforded more inbuilt opportunities to link the "concrete" and the symbolic with feedback;

- an extensible manipulative in which a variety of shapes are more easily constructed. For example with Shapes children were observed creating a large range and variety of triangles with just the basic equilateral triangle by virtue of the fact that they could be overlapped and arranged more easily in the computer context. This in turn could be a source of useful discussion as a pedagogical technique about the nature and structure of triangles, and

- a means of recording and extending work by virtue of the fact that work could be printed and shared in other contexts such as homes without computers.

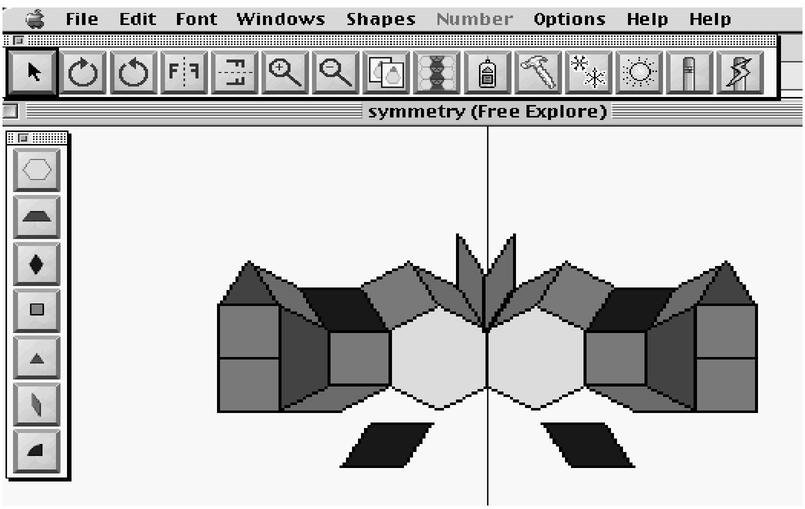

Figure 1. Exploring symmetry with Shapes software

In terms of the mathematical benefits, Clements (2000) contended that the Shapes software enabled children to build and internalize mathematical concepts meaningfully. He suggested that it facilitated:

- Bringing mathematical ideas and processes to a conscious awareness, for example, the "tools" incorporated as part of the program enabled children to explore with flipping and turning shapes so that they could be viewed from different perspectives. This included a line of symmetry as shown in Figure 1.

- Understanding the nature of manipulatives and how they could facilitate understandings by virtue of the media.

- The decomposition of processes, in which children can move to and fro between construction and deconstruction of shapes and in doing so develop understandings about component parts.

- The creation and use of different levels of "units." For example, single shapes could be considered as ungrouped objects or grouped as a bigger unit and can be manipulated (e.g., turned) at different times and ways; and

- the connection of spatial and geometric concepts with number. For example, with on screen base 10 blocks in which the process of "trading" became more relevant since the on screen blocks could be broken up into their composite "ones" and used more effectively. Additionally, in the computer context the number symbols were associated with the blocks in a dynamic way and in doing so facilitate the process of building mental actions.

In another context, Wright, (1994) investigated children's exploration of Shapes in a computer graphics environment. Wright found that children demonstrated sophisticated understandings of concepts about shapes and symmetry in this context and that the computer manipulatives afforded them the opportunity to play with ideas and transform objects on the screen.

During the last decade research has continued with young children and Turtle geometry (e.g., Clements, 1994, 1999, in press; Clements & Battista, 2002; Yelland, 1995, 1998a, 1998b, 1999, 2002a; Yelland & Masters, 1997). It has revealed the ways in which young children are able to experience spatial and numeric concepts in new and dynamic ways in computer contexts. Geo-Logo (and Shapes) is computer software that is embedded in a mathematics curriculum called *Investigations in Number, Data and Space*. Explorations by young children in these environments have been shown to provide contexts in which children can engage with and demonstrate sophisticated understandings that are well beyond age expectations (e.g., Yelland, 1997, 1998a, 2001, 2002c; Yelland & Masters, 1997).

In the main, the research of the past decade has focused on the application of higher order thinking skills rather than discussing the specific ways in which learning with technology differs from traditional methods by way of textbooks or with pencils and worksheets. Specifically, Clements and his colleagues (Clements, 1994; Clements & Battista, 2002; Clements & Burns, 2000; Clements, Sarama, & DiBiase, in press; Clements, Battista, Sarama, Swaminathan, & McMillen, 1997) have demonstrated that young children working in computer contexts reveal greater depths of understanding and higher levels of performance than those who did not, in a range of mathematical concepts, and also that they remain engaged with tasks for extended periods of time. This has included empirical work, which shows, for example, a greater explicit awareness of the properties of shapes and the meaning of measurements when working with turtles. They also learn about measuring length (Clements, Sarama, Swaminathan, & McMillen, 1997) and the nature of angles (Clements & Burns, 2000; Clements, Battista, Sarama & Swaminathan, 1996). In several studies, Yelland (e.g. 2000b 2000c) has demonstrated that young children are able to make connections about number patterns and the relationships between numbers in a Logo based game and has also (Yelland, 1998) provided examples of children working with mathematical concepts that are not included in mathematics syllabus documents until well beyond their year level. In one study (Yelland, 1998a) children aged 8 years of age worked on activities, which included the use of negative numbers to 250, quadrants and the creation of computer procedures for action, which included the very abstract notion of variables. They were then able to incorporate all these elements into a task that required them to create a project of their choice, which often took extended periods of time but were characterized by high levels of engagement and persistence. Yelland (1998a) did not contend that these eight year olds have the same ways of understanding and using such concepts as older children but rather that their experiences with them at this age and in a computer context means that the curriculum that follows should recognize this experience and build on it rather than remain the same since it become superfluous to their prior knowledge and experiences.

Thus, the Geo-Logo and Shapes experiences provide examples of the ways in which new ways of teaching and learning with computers challenge the content of current curricula for young children and impact on their later experiences in schools. Empirical research that has been conducted with the software (Clements et al., 1997; Yelland & Masters, 1997; Yelland, 1998b, 2000b, 2001) has not only shown high level of cognitive activity and the use of higher order thinking skills but has also provided case studies of young children engaged in learning mathematical concepts in a collaborative way, demonstrating the varied ways in which they appropriate the concepts and use them for their own purposes.

The research has indicated that when used in an open ended exploratory way Logo can support the creation and maintenance of a good understanding of mathematical ideas. The importance of teacher scaffolding to support effective learning has also been demonstrated (Masters & Yelland, 2002; Yelland, 2000c; Yelland & Masters, in press). As Clements and Sarama (2003) stipulated "… research indicates that working with Logo can help students to construct elaborate knowledge networks (rather than mechanical chains of rules and terms) for geometric topics" (p. 20).

PROMOTING AND ENCOURAGING CREATIVE AND CRITICAL THINKING

In considering the role of creativity and new technologies in education, Loveless (2002) noted that there has been much discussion and disillusionment about the ways in which teachers can offer opportunities for children to be creative in their thinking in recent times. She suggested that the research literature had indicated that certain characteristics of teaching and learning contexts that promoted creativity were needed and that these comprised of:

- an awareness of the ways in which creativity is related to knowledge across the curriculum;
- opportunities for exploration and play with materials, information, and ideas;
- opportunities to take risks and make mistakes in a nonthreatening atmosphere;
- opportunities for reflection, resourcefulness, and resilience;
- flexibility in time and space for the different stages of creative activity;
- sensitivity to the values of education which underpin individual and

local interest, commitment, potential, and quality of life; and

- teaching strategies which acknowledge "teaching for creativity" as well as "teaching creativity" (p. 4).

Loveless (2002) also indicated that digital technologies have an increasingly important role to play in classroom activities to support creativity in the classroom. These include:

- developing ideas
- making connections
- creating and making
- collaboration
- communication and evaluation

The interesting thing about this literature is that it reveals that the researchers are concerned with curriculum implementation and *incorporating* the use of ICT in their thinking about the fundamental issues that confront education. This is a very important shift and represents a difference from the literature of the previous decade in which computers were more of a novelty and only considered separately to mainstream educational issues. It contrasts to the review of literature for literacy research in early childhood noted by Lankshear and Knobel (2003) and provides hope to those early childhood educators who view computers and other new technologies as being integrated into young children's teaching and learning experiences.

Rochelle et al., (2000) reminded us that some of the pioneers of research in the cognitive sciences who have attempted to understand the processes of thinking, perceiving, and remembering have also been at the forefront of helping us to understand how technologies can improve learning (see Bransford, Brown, & Cocking, 1999). Rochelle et al., (2000) have suggested that such research has indicated that learning is most effective when characterized by:

- active engagement;

- participation in groups;
- frequent interaction and feedback is provided; and
- connections to real world contexts are made.

Rochelle et al. (2000), have noted that traditional school experiences are actually quite poor at providing such contexts and in fact, the characteristics of innovative uses of computers are conducive to learning that is all of those listed.

The studies by Clements and his colleagues (Clements, 1994, 1999; Clements & Battista, 2002; Clements & Sarama, 1998) and Yelland (Yelland, 1998a, 1999, 2001, 2002a, 2002b) have not only provided empirical evidence around the ways in which young children are able to comprehend mathematical concepts in more dynamic ways and apply them in authentic contexts but also have demonstrated the ways in which young children are provided with opportunities to deploy strategic and metastrategic (Davidson & Sternberg, 1985) strategies in problem-solving and problem-posing situations.

A variety of computer-based activities can be regarded as conducive to the development of problem-solving skills. For example, Clements (1994) and Yelland and Masters (1997) have shown that the role of the teacher in scaffolding children's learning is crucial to the development of such skills not only while children are engaged in the task but also in the creation of a problem-solving environment that encourages young children to play actively and/or explore the objects and ideas they encounter. This has been the case with software ranging from Logo to interactive fiction on CD-ROMS, graphics, presentation packages, and more recently the creation and development of online communities of learners. Papert (1996) has explored the creation of new ways of knowing through providing opportunities for students working in microworlds to create problems and then present solutions. Students are provided with authentic learning opportunities that require the use of higher order thinking skills. Yelland (2002b) and Yelland and Masters (1997) have shown that the exploration of microworlds enables the creation of new and more powerful ways of knowing and understanding mathematical ideas. Removing the focus on content approaches provides opportunities for children to work with real world ICT in life like situations, which many learners find empowering. Effective teaching and in particular scaffolding is a critical part of this. In one study Yelland (2002c) found that when working in a Geo-Logo context with tasks related to the use of number for measurement young children were working in a metastrategic way but were not using the requisite mathematical connections to aid their thinking until the teacher provided scaffolding to support this type of strategy. This was important since superficially the environment seemed to be rich in learning opportunities and the children were certainly highly motivated by the tasks. However, the task was a catalyst for using relationships between numbers to predict the distances between objects. This was not evident until the teacher introduced a matrix that the children could use to record their actions and accompany this with specific questions about the relationships between the numbers. When the children made the connections it was almost contagious that they wanted to share them with the group and explain how they were derived. Sharing strategies enabled the children to become more aware of the pattern of the relationships inherent to the tasks and they then wanted to engage with them again so that they were able to test out their ideas.

In this way the Geo-Logo and other computer contexts have provided rich environments in which young children were able to test ideas and embark on creative explorations, which facilitated not only the use of critical and creative problem solving and problem posing but did so in such a way as to promote knowledge building across specific domains of content.

Dede (2000) also recognized that fluency with higher order thinking skills is an essential component of living effectively in the 21st century. He suggested that a particular important skill is the ability to "thrive on fluency," which he defined as the ability to make quick decisions based on incomplete information in new situations. He also indicated that other skills are needed in this new era. These skills include the ability to collaborate with others and the ability to navigate and select information that is relevant to the problem solving process.

COMMUNICATING AND COLLABORATING IN KNOWLEDGE BUILDING COMMUNITIES.

Concerns about the *social* isolation of children as a result of computer use, in the early 1980's literature, appeared to be ill founded when it became evident that children not only loved working with computers but they actually socialized and talked, planned, and collaborated around computer activities more than they did with other traditional play materials. This was evident in other studies which show that children are highly motivated in computer environments (Blanton et al., 2000; CTGV, 1998) and enjoy sharing their experiences and strategies with each other.

Research in child psychology (Griffiths, 1997) reveals that by seven years of age the quality of a child's interactions with those around them plays a significant part of shaping them as a person and their ability or competence in terms of *social* skills. In considering the impact of computers in this context, it is evident that there are widespread concerns about children spending too much time playing computer games as well as the potential dangers of interacting with strangers in an online environments. Once again arguments are based in "either-or" scenarios without a consideration of the benefits of each different context, and the time being spent on computers and online tended to be discussed in negative ways, since it was usually regarded as replacing interactions in the real world. Discussions about the amount of time spent using computers are often framed around concerns about obesity, (sitting too much will restrict physical movement) ergonomics, and visions of individual children being so engrossed with the activity on the computer that they do not interact with others around them. None of these concerns were raised when children sat at uncomfortable desks all day writing with pencils, sitting in rows and rarely collaborating—in fact, in many cases, being reprimanded by the teacher for talking too much to those adjacent to them.

In studying the social context of using computers with young children, Heft and Swaminathan (2002) noted that teachers often paired children at computers due to limited resources (King, Barry, & Zehnder, 1996). Indeed Clements (1994) actually recommended that children should work together, preferably in pairs, since this encourages collaboration and motivates them to work more effectively. Children, also talk more when working at computers in pairs, which can facilitate thinking through problems and the discussion of possible solutions. The resolution of conflict in the problem solving experience has been found to be of particular relevance in these collaborations (Clements). Additionally, other variables such as gender (Yelland, 1998b), the software being used (Haughland & Wright, 1998), and the nature and role of the teacher (Haughland & Wright, 1997) have all been found to be of significance when considering the ways in which children interact when using computers (Heft & Swaminathan, 2002).

Heft and Swaminathan's (2002) study concluded that "…children exhibit a rich versatility of social interactions at the computer" (p. 172). Further, they were not afraid to ask each other or the teacher for assistance when they needed information about how to work with the program that they were using. In this way the computer contexts that they observed "…highlights the rich social environment offered by computer usage" (p. 173).

Working in a multicultural context in inner city London, Brooker (2002) observed that computer software acted as a catalyst for social interactions and language development of children who did not share a common language. She reported that such interactions contributed to learning in a variety of ways and that its presence "…undoubtedly contributed towards the development of the very positive, collaborative, and language enriched multicultural learning environment that we observed" (p. 269). The study also found that peers frequently supported each other in the learning process and that the children benefited from the "mutually supportive collaboration in their problem solving" (p. 269). Even more exciting was the way in which the activities on the computer extended into the children's socio-dramatic play in which they were able to combine and distinguish between the on and off computer components with fluency. Brooker (2002) argued that:

> …the manipulation of symbols and images on the computer screen represents a new form of symbolic play, in which the children treat the screen images as "concretely" as they do the manipulation of any alternative blocks and small-world toys. (p. 269)

Brooker importantly noted that since play is generally considered as a primary mode of learning for young children, when they are able to engage in tasks, which enable them to consciously reflect on the relationship between signs, symbols, and relationships they are engaged in "…a form of semiotic activity that provides a precursor to new learning activities" (Van Oers as cited in Brooker, p. 269)

One particular computer environment for K to 12 students that supports the social construction of knowledge is the Computer Supported Intentional Learning Environment (CSILE) (Scardamalia & Bereiter, 1994). CSILE supports learners by creating knowledge building communities wherein students talk, critique, share, plan, and provide feedback to each other in a variety of modes. This illustrates not only the range of ways in which they communicate but also the extent to which they think differently and collectively. It has been shown that students in CSILE contexts have scored higher on traditional tests across the curriculum than those students from classes without the technology (Scardamalia & Bereiter, 1993).

One interesting observation about the research pertaining to the social aspects of using new technologies, is the recognition that both boys and girls are interested in them and want to use them in a variety of learning contexts. In reviewing the literature from this decade it is evident that boys and girls alike are fluent in the use of computers (Yelland, 2002) and access and equity issues related to the use of computers in early childhood classrooms have been considered by early childhood educators so as to ensure *all* children are able to use the new technologies.

CLASSROOMS FOR THE 21ST CENTURY

While the research literature of the last decade has tended to focus on examining ways of operating with technology, particularly computers, within traditional curriculum paradigms, together with a consideration of creativity and thinking skills, which are deemed to be essential to functioning effectively in the 21st century, it is becoming increasingly evident that early childhood teachers have been inspired to rethink their pedagogies and practice in light of what they perceive the new technologies can do for the children in their classes. In this way pockets of innovation related to the use of new technologies by young children have been reported anecdotally in special ICT issues of journals such as *Young Children* (2003) and *Childhood Education* (2003). What is interesting to note is that creative practitioners are leading the way by using a range of new technologies in different contexts. They are creating exciting and innovative learning environments by rethinking their curriculum and pedagogy to incorporate the use of computers, digital and video cameras, mobile phones, and open ended software. In such classrooms children are able to learn in ways that were not possible without the new technologies and additionally they are able to use them to communicate and share their ideas to their peers as well as broader communities. This is evident as children record everyday and special events with digital video cameras to reflect on their inquiries and problem solving, use open ended software and communications technologies to share their ideas with their peers, and create their own digital portfolios to document their learning.

The pockets of innovation are apparent as we prepare teachers to use new technologies (Murphy, De Pasquale, & McNamara, 2003) consider the ways in which we can create context for young children to become media literate (Hesse & Lane, 2003), examine new ways of becoming literate (Robinson, 2003), and numerate (Kilderry et al., 2003). What is especially pleasing is that those who work with children who have special needs (e.g., Mulligan, 2003) are finding that new technologies are providing opportunities for those children to engage in learning environments that are similar to the general school population.

Early childhood teachers and academics can build on this innovative work by documenting it in a systematic research framework that involves teachers as researchers in their classrooms and centers. In this way the next decade will have a corpus of empirical research that clearly demonstrates the ways in which we have created innovative and contemporary learning contexts for young children that optimize their potential for engaging in active learning, inquiry, and problem solving.

CONCLUSIONS

The last decade has been characterized by unprecedented change. The time has actually spanned two centuries in which our lives have been transformed by new technologies but school curricula have remained much the same as they were despite calls for reform and the pockets of innovation that are evident in exciting early childhood education classrooms. Governments have come to realize the importance of the early childhood years for subsequent successful outcomes in the schooling process and the spotlight has been on early childhood educators to lay the foundations of learning for later life.

There is a recognition that computers and other new technologies have a role to play in early childhood education but many remain skeptical about the role of computers in programs for young children. The 1996 statement by the National Association for the Education of Young Children accepted that computers were a part of the lives of young children but did not advocate their use in innovative ways that would facilitate a reconceptualization of early childhood education. Clements et al. (1993) had posed the interesting question of whether we would continue mapping new technologies onto existing curriculum or would we capture the opportunity to think of new educational innovation that would include ICT so that education would be fundamentally changed to engage children with learning and the creation of knowledge building communities. This review of research from the last decade has revealed that innovation is possible when the use of ICT is embedded in new curricula and further empirical evidence has been provided to illustrate that young children can not only experience concepts that were previously well beyond that expected of them but that they could deploy sophisticated strategies and work collaboratively with others in new and dynamic ways in technological environments. This would appear to be the way forward for future research rather than to replicate previous studies, which seem to yearn to compare computer and noncomputer contexts without adding anything to our knowledge about innovative uses of technologies or the ways in which they might stimulate new understandings or facilitate knowledge acquisition.

Research with young children and ICT in literacy and numeracy, in the areas of creative and critical thinking and in the creation of knowledge building communities, which impact on the social lives of young children, have revealed a slow move towards the consideration of the use of ICT as part of a suite of resources that can be used to enhance learning and expression. What is apparent is that the role of the teacher in the learning process is critical. Armstrong and Casement (2000) stated that “Good teachers convey their own interests and excitement in learning.” This should also be the case with their enthusiasm for using new technologies to advance learning. Advocates of the use of computers in educational contexts have always had as their central interest new ways of learning and as we are now living in the 21st century this it is even more essential to incorporate the use of ICT into learning environments.

This view is supported by Rochelle et al. (2000) who concluded that studies have revealed that “…a teacher’s ability to help students depends on a mastery of the structure of the knowledge in the domain taught. Teaching with technology is no different in this regard and numerous literature surveys link student achievement in using technology to teachers’ opportunities to develop their own computer skills” (p. 90).

Papert (1996) has observed “Across the world there is a passionate love affair between children and computers….I see the same gleam in their eyes, the same desire to appropriate this thing.” Early childhood teachers can build on this enthusiasm and provide rich context which incorporate ICT as an integral part of the program so that education remains a relevant part of contemporary society.

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