How are computers best used in education? Some would argue that computers are best used as cognitive tools that help amplify human ability by assuming a significant part of the cognitive burden of information processing. Those arguing that way would emphasise the use of computer-based cognitive tools such as word processing, data management, graphics and communications programs across the school curriculum. In contrast, others would argue just as strongly that the computer is best used as a tutor for the systematic presentation and mastery of subject matter knowledge. Computer-based tutorials and drill and practice programs, they argue, will greatly enhance student learning in specific school subjects. In this paper I will argue that the computer is a versatile teaching and learning tool that has an important role to play in all subject fields as both a tutor and cognitive tool. I will also report on a three-year longitudinal study of the Writing to Read program in which the computer is systematically used as both tutor and cognitive tool.

The Computer as a Cognitive Tool

Salomon, Perkins and Globerson (1991, p. 4) call the new electronic information technologies ‘cognitive tools’ or ‘technologies of the mind.’ Such tools, they argue, offer an intellectual partnership that may ‘allow a learner to function at a level that transcends the limitations of his or her cognitive system.’ Human intelligence is more than just the application of the human mind; it involves a partnership between the capabilities of the mind and the cognitive tools provided by the society. Earlier cognitive tools that helped amplify human intelligence consisted of a written language, books, pen and paper, film and so on. More recently developed tools include video, computers, and electronic communications technologies (such as satellites) which enable video images and text and data files to be rapidly transmitted to and from remote locations. Computers, often in conjunction with other cognitive technologies such as video, provide an interactive environment for learning and information processing that far surpasses the capabilities of the earlier cognitive technologies.

Pea (1985) suggests that the partnership of person and computer enables human ability to become distributed with the computer assuming a significant part of the intellectual burden of information processing. For instance, the use of a database or spreadsheet program may not only overcome limitations in human memory, but may enable data to be efficiently retrieved and, in particular, reorganised and displayed in ways that greatly assist question answering, decision making, and problem solving. Low-level, and often tedious, memorising and manipulation of data are performed by the computer freeing the user to concentrate on the higher level interpretation of relationships, hypothesis testing, and exploration of implications.

In education, such a use of technology may augment the information processing capabilities of students and, more importantly, through such partnership and interaction may enable students to discover new knowledge for themselves and develop a range of effective information processing skills (Sinclair 1987). What Salomon et al. (1991) call the effects of learning with computers may result in enduring ‘cognitive residues’ as the learning of new knowledge and cognitive processing skills take place. Database programs, for instance, may be used in almost any subject in the school curriculum. Teachers or students may create databases about the planets in science, neighbouring countries in
social studies, instruments of the orchestra in music, schools of painters in art, Shakespearean sonnets in literature, vitamins in health and so on. The database, if multimedia technology is used, may include slide shows, video sequences, or audio segments such as animal sounds or speeches of historical figures. Students working alone or in small groups may use the processing power of the computer to reorganise the data into carefully specified tables to assist them in finding answers to questions and in testing hypotheses against the data.

In a similar way, the user-friendly composing and editing capabilities of the word processing program provide a supportive environment in which explorations of creative written expression may be conducted (Bangert-Drowns 1993; Bolter 1991). Because it ‘encourages a fluid conceptualisation of text and frees the writer from mechanical concerns’ (Bangert-Drowns 1993, p. 69), the word processing program enables the writer to concentrate on higher level matters of self-expression and communication with others.

A number of researchers and writers agree that the use of such computer-based cognitive tools greatly enhances student exploratory learning (Breuer & Hajovy 1987; Dudley-Marling & Owston 1988; Elder & White 1989; Sinclair 1987; Watson & Strudler 1988). There is also general agreement from among them that the concomitant development of information-processing skills needs careful nurturing and teacher direction. The processes used in the purposeful interrogation of a database or in the creation of a piece of written expression need to be made explicit and students need to be encouraged to reflect critically on the processes they have used.

The particular merits of using a word-processing program have been recently discussed by Bangert-Drowns (1993) and Bolton (1991). Bangert-Drowns (1993) conducted a meta-analysis of 32 studies that compared the quality and quantity of writing outcomes of students using word-processing programs and students writing by hand. He found that word-processing students were significantly superior in terms of both length and quality of writing.

THE COMPUTER AS A TUTOR

The tutorial was one of the earliest educational uses of computers and was modelled on theory and research concerning programmed instruction. In programmed learning, the instructional process most often involves presenting information, asking questions, monitoring responses, providing feedback, summarising key points and keeping records of performance. Instructional principles involved in programmed learning include prompting desired responses (to ensure that learning is as error free as possible), repeated practice of responses, and immediate reinforcement of responses.

The computer made it possible for these principles of programmed instruction to be applied in a systematic way. Early applications, such as the extensive library of Plato programs, involved the use of mainframe computers. More recently, tutorial and drill and practice programs have been developed for use with microcomputers and make considerable use of the sound, colour and animation capabilities of such computers. Drill-and-practice programs also often incorporate a game-like context. While the form of the computer tutorial still has much in common with programmed instruction, many such programs may now include simulations (e.g. in teaching science principles such as Charles’ Law or Ohm’s Law) and, in multi-media application, video segments.

School teachers have commonly been unimpressed with tutorial programs. Early tutorial programs for school education often had quite glaring weaknesses in instructional design, were not completely relevant to the class curriculum, and tended ‘to be little more than expensive page turners’ (Merrill et al. 1986). The behaviourist philosophy of the computer tutorial has also been contrary to the cognitive and constructivist philosophies that have dominated teaching now for several decades. Despite these weaknesses and problems, reviews in the 1980s (Kulik, Kulik & Cohen 1980; Kulik, Bangert & Williams 1983) and later (Niemic, Sikorski & Walberg 1989) concluded that learning from computer-assisted instruction was superior to learning from traditional teaching methods (with CAI taught secondary school students performing at the 63rd percentile on examinations compared with control students who performed at the 50th percentile [Kulik, Bangert & Williams 1983]). Another consistent finding was that CAI led to significant time savings in instruction (Kulik, Kulik & Cohen 1980). The design of tutorial packages has improved dramatically over recent years and they appear to be finding greater favour with teachers today.

USING THE COMPUTER AS BOTH A TUTOR AND COGNITIVE TOOL: WRITING TO READ

Often in education fairly narrow positions are taken about how to teach. As already discussed, some reject computer tutorials or drill and practice and advocate the use of simulations and problem solving programs. Others argue for the opposite. In language learning, some advocate whole language experiential approaches and totally reject phonic skill instruction. Such a taking of one position to the exclusion of another often ignores the point that any subject matter area requires some relatively low level learning of associations and concepts which provide a basis for higher level learning of principles and their application in reasoning and problem solving (c.f Gagne 1985). A combination of direct instruction and exploratory learning, each directed towards the achievement of particular learning goals, is often needed to optimise performance.

Writing to Read is a language program published by IBM that uses the computer both as a tutor and cognitive tool to teach writing and reading skills and processes. It assumes that an early introduction to writing with word processors together with a phenom-
ically-based invented spelling program, and a language experience reading emphasis will promote effective learning of literacy amongst school beginners (Martin & Friedberg 1986; Sinclair, Doneley & Collins 1992).

In the Writing to Read program children progress systematically through a series of learning stations, viz., a computer station, typing/writing station, a journal station, a listening library station, a make words station, and an optional activities station (e.g., games and puzzles). The computer is used extensively at two of these learning stations. At the computer station, computers are used in tutorial mode for the direct instruction and practice of phonic skills. At the typing/writing station, computers are used for the word processing of stories which are published for classroom display or for the children to take home to show parents. In addition, audio technology is used at the listening library station where the children listen to stories through headphones while following the text in books.

I have recently completed a study of the use of the Writing to Read program with data gathered from a cohort of 60 students who have been followed longitudinally through their kindergarten year 1 and year 2 classes (Sinclair in press). Use of the Writing to Read program is confined to the kindergarten year 1 classes. The inclusion of observations from year 2 was to enable the effects of the program to be monitored for a year beyond its completion.

The children’s development and achievements in writing and reading were monitored by documenting both the products of learning and the processes by which those products were attained. This was done using specially chosen or prepared tests, the naturalistic observation of reading and writing, and interview and questionnaire to monitor the qualitative reactions of the teachers, the pupils and the parents.

**READING ACHIEVEMENT MEASURES AND THEIR INTERRELATIONSHIPS**

Reading age (RA), as measured by the St Lucia Word Reading Test, was found to increase substantially over the evaluation period. In kindergarten the Writing to Read program was used for a six-month period. At the end of kindergarten, mean RA was 69.85 months, a gain of nine months over the six-month period. Reading to Read was used throughout year 1 and a further average gain of 19 months of RA was recorded over the 12-month period. Use of the Writing to Read program then stopped at the end of year 1. By the end of year 2, however, a further average increase of 16 months of RA was recorded for the 12-month period.

The results reveal, therefore, that reading age grew much faster than chronological age over the period that Writing to Read was used. Over 18 months of use of the program in kindergarten and year 1, the average increase in RA was 28 months. Furthermore, after the Writing to Read program had been completed, reading age continued to grow faster than chronological age but not quite as fast as in the last year of the program.

It was also of interest to determine whether the gains in word reading were accompanied by increases in the understanding of the reading and writing process. Process measures of reading and writing were taken on three occasions in the kindergarten year. It was found that strong and statistically significant development occurred with each measure. The correlations between those process measures and score on the St Lucia word reading test were 0.71, 0.77 and 0.59 for reading process and 0.59, 0.63 and 0.46 for writing process. In years 1 and 2 the California Achievement Test measure of reading comprehension was also used. Scores on that measure increased significantly from year 1 to year 2 and correlations with the word reading test score were 0.65 in year 1 and 0.66 in year 2. It is apparent, therefore, that the program, and particularly its strong emphasis on process writing, is associated with the development of meaning and understanding about the processes underlying reading and writing, as well as with the learning of skills needed to read and write.

**READING AND ITS CORRELATES**

Another finding of the study was the importance for total literacy development of mastery of the alphabetic principle (the relationship between the alphabetic symbols of writing and the sound system of speech). It is the alphabetic principle that is taught by computer tutorial. Understanding of the alphabetic principle increased rapidly over the three-year measurement period. At the beginning of the program there was a zero correlation (0.07) between first-grade achievement and performance on the alphabetic principle test. At the end of the kindergarten year, however, the correlation was high (0.76). Throughout years 1 and 2 the relationship remained high (end of year 1, 0.74; end of year 2, 0.77). The results, therefore, indicate a strong relationship between understanding of the alphabetic principle and reading achievement.

The alphabetic principle was also found to be strongly related to other literacy measures as well. The correlation between performance on the alphabetic principle test and spelling was found to be 0.84 (kindergarten), 0.74 (year 1), and 0.69 (year 2). In kindergarten, the correlation with writing was 0.71. Clearly, knowledge of the alphabetic principle is closely associated with a broad range of measures of literacy.

**ATTITUDES TOWARDS THE PROGRAM**

The learning stations approach used in the program and featuring extensive use of computers and audio technology was considered by the teachers to be a very effective one. It introduced variety for the children, enable self-paced learning to occur, and allowed the teacher to concentrate attention on helping individual children at tasks where that help was most needed. In this way, children were able to work independently and the teacher was able to 'conference' daily with pupils while other children were profitably occupied, an experience that was most difficult to implement in the regular classroom.

In addition to the teachers a sample group of 22 children from the
kindergarten cohort group and another 23 children from two other separate year 1 classes were interviewed. Generally speaking, the pupils were positive about the program because it helped them make progress in learning to read and write which they considered to be important. The great majority of the pupils enjoyed reading and writing and were able to use the skills learned in a range of out-of-school activities. In many cases, also, the program was considered to be a source of fun as they learnt at the work stations. The computer-based word-processing activity, in which they developed considerable expertise, was the most strongly favoured activity. The reality of seeing their own stories created and published was a particular source of satisfaction.

In regard to their children's attitudes, parents indicated that almost all of them liked the program or liked it very much. An overwhelming majority of parents (97%) endorsed the use of computers 'as soon as possible' in the education of their children. Similarly, 96% of parents disagreed that children in kindergarten and year 1 are too young to learn or familiarise themselves with computers. The parents indicated that their children were making use of their new skills in reading and writing in many different ways. They read signs, labels, books and other materials. They wanted to read autonomously and to write words and stories. Parents also mentioned that they wanted to read and be read to, left notes around the house, showed their school work and read what they had written or been given to read at school.

**THE VERSATILE COMPUTER**

In the *Writing to Read* program, technology in the form of computers and audio tape players had a particularly important role to play in creating responsive, self-instructional environments at the learning stations. The computers appear to have been effective when used either for the direct instruction of phonic skills or for the exploratory learning of process understandings. A further advantage of the use of technology in this way was that it released the teacher to concentrate attention on conferencing with small groups of children about their process writing. This enabled the teacher and students to examine and discuss together the processes and structures being used in the writing and encouraged the students to reflect critically on their work. The learning stations approach used in the program of which the computer and audio-tape technologies were important components, was also found to have many effective features by introducing variety for the children and enabling self-paced learning to occur. The study therefore, serves to demonstrate the versatility of the computer as a teaching and learning tool. Computers may be used to create a range of responsive teacher centred and learner-centred environments. That versatility, when effectively used, will enable teachers to match instructional techniques to student learning preferences and to the demand of particular learning tasks. It will also provide a means by which variety of instruction may be introduced into classroom teaching.

One very successful spin-off from the program was the progress made by five and six year old pupils in writing with computers. The quality and quantity of their output, the enthusiasm they show for the writing station and their skill with word processing make writing with computers an attractive feature of *Writing to Read*. It is a major reason that parents are very pleased with the program and wish it to continue. As children are learning literacy, they are also becoming confident and skilled with computers at a very young age.

**REFERENCES**


