Teaching and Learning Using Computer-Assisted Instruction (CAI) in the Science Class

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Introduction

In many countries across the world today, the productive use of information technology is one of the most significant indices of national and economic development. Information technology is that knowledge created, collected, put together, discussed, regained and protected (Jennings-Wary & Wellington, 1985). Even countries that are in the process of transition from nationalist society to global, are part of this new wave of change. The key instrument to this globalization is the ubiquitous computer. The improvements in technology, especially in computer technology, bring changes and make things easier for every part of daily life. While all these changes occur, education cannot be thought to be apart.

This paper reflects on the use of Computer Assisted Instruction (CAI) in enhancing the teaching and learning science subjects, particularly at the secondary school level. My paper draws heavily on evidence from research conducted in United States, United Kingdom, Canada and Europe on the effectiveness of CAI in science teaching. The reason for focusing on such educational systems is obvious: first these countries have reached a high stage of technological development – a study of the evolutionary pathways they have followed to implement CAI and its attendant problems and solutions from those who have been there before would provide an effective template for such implementation in developing countries. Secondly, due to porous software and hardware acquisition policies, countries like Nigeria are fast beginning to become aware of Information and Communication Technology, ICT, issues so rapidly that government has started to issue out various policies to cover the use of ICT in real-life. It is therefore a matter of time before our learned template would be useful to us in implement ICT policies at the mass-acceptance level. Computer Assisted Instruction is one step in the long journey of ICT implementation in the country.

Nature of Science Pedagogy

In Nigerian classrooms, traditional patterns of science education have remained largely unchanged for most of the last century. In fact, the organization of the curricula for high schools has remained essentially constant since 1988 when the Federal Government introduced a new science curriculum. Hailed by its developers as a radical departure from the traditional chalk-and-talk method of teaching to a more interactive spirally structured methodology, the new science curriculum soon degenerated back into the traditional mould of rote learning of dry scientific facts (Adamu 1992).

Further, very often, science instruction in primary and junior secondary schools has lacked a clear focus and has been provided by teachers ill-prepared to deal with science content. The natural curiosity of children, eager to understand their surroundings, is often diminished by instruction that discourages inquiry and discovery because of a combination of traditional forces and lack of expertise in science teaching. In the senior secondary schools, science

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instruction becomes increasingly textbook-centered. Even though laboratory experiences (or demonstrations) usually are included, students are rarely encouraged to use scientific methods to solve problems relevant to their perception of the world.

The typical pedagogical pattern reflects an authoritarian, didactic approach to classroom management. The reason may be that many teachers have never encountered a learning experience in which they constructed meaning from the experience. Similarly, the professional preparation of most administrators has not provided experience with this type of learning. It is little wonder, therefore, that many science classrooms present an environment in which students learn by rote and repetition from teachers who exercise authoritarian control over the learning process. Many educators who would like to change this approach lack the support of colleagues, administrators, policy planners, and parents, who only remember a more traditional approach and are only interested in the students getting better examination results. (diploma disease here)

Surprisingly, this is not a peculiar problem to Nigeria. For instance, the comparative performance of America's children on science achievement tests clearly demonstrates the failures of the current delivery system. So much that it was warned that, in American schools,

> "…without significant transformation of the curricula, strategies, and methods used in our classrooms, science learning will not improve. Moreover, the reform of science education must address the needs of *all* children, but it will do so only with the support of teachers, administrators, policymakers, business and community leaders, and the general public."[2]

Yet it is acknowledged that computer use by any teacher is a function of his or her computer experience and expertise, availability of hardware and software, and perceived need. An excellent science course may be taught without the use of a computer. However, the careful incorporation of computers into a science course can and does add an important level of enhancement. Although not as conclusive as one might hope, studies do indicate that computer use in science education can improve learning and positively influence students' attitudes and self-esteem.

Conceptual Frameworks in CAI

It will be helpful, before discussing specific strategies of CAI and science education, to offer some definitions of CAI and other kinds of learning activities involving computers. As Kulik, Kulik, and Bangert-Drowns point out in their 1985 research summary, "the terminology in the area is open to dispute" (p. 59). Those seeking to make sense of the array of terms used by educators and researchers — computer-assisted instruction, computer-based education, computer-based instruction, computer-enriched instruction, computermanaged instruction — can easily become confused. The following definitions are a synthesis of those offered by Bangert-Drowns, et al. (1985), Batey (1987) and Grimes (1977), and represent commonly accepted (though certainly not the only) definitions of these terms:

- Computer-based education (CBE) and computer-based instruction (CBI) are the broadest terms and can refer to virtually any kind of computer use in educational settings, including drill and practice, tutorials, simulations, instructional management,

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[2] Critical Issue: Providing Hands-On, Minds-On, and Authentic Learning Experiences in Science, at http://www.ncrel.org/sdrs/areas/sc0cont.htm

supplementary exercises, programming, database development, writing using word processors, and other applications. These terms may refer either to stand-alone computer learning activities or to computer activities which reinforce material introduced and taught by teachers.

- Computer-assisted instruction (CAI) is a narrower term and most often refers to drill-and-practice, tutorial, or simulation activities offered either by themselves or as supplements to traditional, teacher-directed instruction.
- Computer-managed instruction (CMI) can refer either to the use of computers by school staff to organize student data and make instructional decisions or to activities in which the computer evaluates students' test performance, guides them to appropriate instructional resources, and keeps records of their progress.
- Computer-enriched instruction (CEI) is defined as learning activities in which computers (1) generate data at the students' request to illustrate relationships in models of social or physical reality, (2) execute programs developed by the students, or (3) provide general enrichment in relatively unstructured exercises designed to stimulate and motivate students.

The single best-supported finding in the research literature is that the use of CAI as a supplement to traditional, teacher-directed instruction produces achievement effects superior to those obtained with traditional instruction alone. Generally speaking, this finding holds true for students of different ages and abilities and for learning in different curricular areas. As summarized in Stennett's 1985 review of reviews, “well-designed and implemented D&P (drill-and-practice) or tutorial CAI, used as a supplement to traditional instruction, produces an educationally significant improvement in students' final examination achievement” (p. 7).

Further, according to Batey 1986, Capper and Copple 1985, Kulik and Kulik 1987, Rupe 1986, Stennett 1985, as well as enabling students to achieve at higher levels, researchers have also found that CAI enhances learning rate. Student learning rate is faster with CAI than with conventional instruction. In some research studies, the students learned the same amount of material in less time than the traditionally instructed students did; in others; they learned more material in the same time.

This enhanced learning rate is accompanied by high retention of learning. Capper and Copple 1985, Kulik 1985; Kulik and Bangert-Drowns 1985; Rupe 1986, Stennett 1985. Further claims were that if students receiving CAI learn better and faster than students receiving conventional instruction alone, do they also retain their learning better? The answer, according to researchers who have conducted comparative studies of learning retention, is yes. In this research, student scores on delayed tests indicate that the retention of content learned using CAI is superior to retention following traditional instruction alone.

The following studies found positive effects associated with microcomputer use in science education applications:

- Higher achievement and more positive attitudes were observed in a high school biology course that was “computer-loaded” (Hounshell & Hill, 1989). Also scientific reasoning skills were found to be enhanced using a microcomputer-based curriculum.
- Specialized computer programs were found to help develop inquiry skills while also increasing scientific knowledge even when strong “misconceptions” were present at the start (Shute & Bonar, 1986).

More than one study found that computer use by students enhanced their self-esteem (Robertson, Ladewig, Strickland, & Boschung, 1987). This may also account, in part or in whole, for the increased interest in science by lower achieving students who have computers incorporated into their curriculum. Whatever the reason, the effect is positive and adds another reason to use computers in the classroom.

Bialo and Sivin 1990, Braun 1990, Mokros and Tinker 1987, Robertson, et al. 1987, Rupe 1986, have researched that, the following is a list of reasons given by students for liking CAI activities and/or favoring them over traditional learning. These student preferences also contribute to our understanding of why CAI enhances achievement. Based on these research findings, students say they like working with computers because computers:

- Are infinitely patient
- Give immediate feedback
- Are more objective than teachers
- Free teachers for more meaningful contact with students
- Are impartial to race or ethnicity
- Are great motivators
- Give a sense of control over learning
- Are excellent for drill and practice
- Call for using sight, hearing, and touch
- Work rapidly--closer to the rate of human thought.

It is clear, therefore that CAI is an extremely effective way of teaching, no matter the subject. However, I will now focus on Science Education.

CAI in Science Education – Research Evidences

International research on CAI use in science indicated that computers tend to be used in physics rather than biology in secondary schools (Pelgrum & Plomp, 1993). Furthermore, subject disciplines appear to have acquired penchants for particular CAI: databases for social sciences, spreadsheets for mathematics, word processing for English and computer based laboratories for science. Although in fairness, in recent years this appropriation has been eroded, probably as familiarity with CAI software, expectations of society, and demands of various National or State Curricula have changed. As a result, in recent years research has begun to empirically evaluate the impact of CAI on teaching and learning, rather than simply document potential use of a variety of CAI applications in science classrooms.

A software publishers association's report (Bialo & Sivin-Kachla, 1995) on the effectiveness of Technology in schools suggested that positive effects of technology were dependent on the teachers' role, characteristics of student populations, subject disciplines, classroom organisations, software design and access to technology. It could be argued that the majority of classroom interventions would record a positive effect if all the above criteria were addressed.

Indeed these changes have been suggested before CAI was advocated and used in schools. For example, teachers who employ child centered approaches such as the Interactive approach (Biddulph & Osborne, 1984) have described the need for changes in classroom organization and teachers' and students' roles. Apple Classrooms of Tomorrow, commonly referred to as ACOT classrooms (Dwyer, Ringstaff, Haymore, Sandholtz, Apple Computer

Inc, 1990a) appear to be technology enriched classrooms in which technology became the instrument of change and facilitated the adoption of constructivist practices.

Apart from word processing reports, worksheets etc, information technology tools particular to science lessons include data loggers, spreadsheets, databases and simulations (Rogers, 1990). To this list the United Kingdom National Council for Educational Technology (NCET) (NCET, nd a) add modeling. In addition, the list could now include the internet, and multimedia in terms of CD -ROM and in terms of authoring.

Datalogging

Datalogging links a computer with sensors or probes which allow for measurement, presentation and analysis of data. These types of activities are often known as Computer Based Laboratories (CBL). There is a vast array of datalogging software, for example, the range of sensors by Education electronics and Phillip Harris (UK companies); Softlab, an icon driven windows based application that can be used with a range of dataloggers (available from NCET, UK); a range of sensors from Pasco Scientific (Australian based, American software); a range of Tain Electronics dataloggers and sensors (Australian based company); and LogIT, a palm-sized datalogger which allows three sensors to collect data simultaneously and can store the results of up to four separate experiments.

The benefit of this tool is that it allows for the 'too fast or too slow' measurements, such as the fermentation of yeast, monitoring habitats of minibeasts, or weather conditions (NCET, nd b). It also gives comparable, prompt presentations and allows for direct measurement of quantities that might normally warrant calculations (Rogers, 1990). The datalogger can collect information faster than people, has a larger memory store for this data, can be used over long periods of time, allows for speedy computation, provides real time presentations and has credibility because it is high tech (Scaife, 1992).

Research evidence supports the use of data logging in secondary science classrooms and findings from selected studies are described in the following paragraphs. Nakhleh and Krajcik (1994) investigated how different levels of information presented by various technologies affected fifteen senior high school students' understanding of acids, bases and related concepts. The student sample did not involve very high or very low achieving students. The students were divided into three groups and each group used different technologies for the same set of titrations, some used indicators, others pH meters and others sensors and computers. Students using microcomputer based labs demonstrated a greater integration of their knowledge of acids and bases and the students using the pH meter demonstrated the least integration. The students using sensors and probes created more acceptable and unacceptable relationships and crosslinks than students in the other two groups.

The computer functioned as a memory accessory because the information provided by the microcomputer labs were displayed as graphs on a screen, enabling students to focus on reflecting on the titration (Nakhleh & Krajcik, 1994). Appropriate teacher mediated instruction would be effective in promoting the formation of more suitable concepts and relationships and reduce the inappropriate concept developments. Thus the dataloggers allowed students to address issues that were not mundane. But the appropriateness of the scientific ideas developed needed teacher mediation if the students were to strive for the ideas purported by the scientific community.

In physics, datalogging has been used in movement experiments. Teachers were accustomed to their students experiencing difficulty in understanding data that was presented by ticker tape to such an extent that the exercise became one of deciphering code rather than a study of motion (Scaife, 1992). The use of datalogging software diminished this hurdle by providing data in a form that was acceptable and easy to interpret. Hence the skills developed were more akin to evaluation rather than comprehension of ticker tape encoded data. Thus sensor use facilitated higher order processes of analysis, rather than restricting access to such processes by drowning the data in complicated code.

Linn and Songer (1991) indicated the potential of computers in performing graphing functions which assisted students' understanding of science concepts while addressing issues of repetition in graph drawing. Work by Summers, Solomon, Bevan, Frost, Reynolds and Zimmerman (1991) also supported the use of sensors in promoting knowledge of science concepts and processes. In general the value of using sensors lies in the removal of constraining factors which may have confined students to the realms of lower order thinking processes. Sensors and probes address and deal with issues of repetition and decoding, leaving students free to analyse data that is clearly presented. This does not mean that students should not for example be taught graphing skills, but it does mean that students will not be restrained from showing other skills they possess, because they lack one particular lower order skill. Some students may be poor at physically constructing graphs but may be sound at interpreting the data. If these students are only presented with opportunities to draw graphs they will always be impeded from demonstrating other skills they possess.

Spreadsheets

Spreadsheets allow data to be stored and are particularly useful for data that involves discrete measurement (for example, mass, angles). Spreadsheets eliminate the drudgery of repeated testing or calculation while affording opportunity to contemplate ‘what if’ questions (Dreyfus, Feinstein & Mazouz, 1993). The value of using a spreadsheet in science lessons lies in its ability to readily process results, provide accessible and meaningful presentations of those results, and provide a processing medium that is sufficiently accessible for the majority of students (Goodfellow, 1990; Osborn, 1987) . In essence they offer similar strengths to dataloggers.

Excel and Lotus are spreadsheets commonly used in secondary education in the United States. For example, Blickensderfer (1990) used spreadsheets in chemistry to resolve simple chemical kinetics problems, Webb (1993a) described the use of Excel on PCs to study the Planets, by entering data on orbits, surface temperatures etc, and then reviewing questions such as; why the second planet from the Sun was hotter than the planet Mercury?

Dreyfus, et al (1993) described the use of the Lotus 123 spreadsheet aimed at developing students' skills of quantitative aspects of biology. A cluster of 24 activities were designed to enhance the skills of secondary biology and agriculture students who had demonstrated difficulties, either when working with graphs, or in their understanding of relations between variables. When memory was assisted by meaningful learning, the technical aspects of the spreadsheets were not a limitation.

The ability to retrieve, explore and manage large quantities of data is an important skill, having much use in fields such as criminal investigations or discovering and relating climatic and environmental effects on people and places (Harris 1994). Spreadsheets reduce mundane skills, although this needs to be balanced against the chore of inputting data onto a spreadsheet.

Despite the research evidence for its effects in science teaching, there are some discords with regards to the use of spreadsheets in science teaching. For instance, some studies, find CAI to be of limited value in science applications, especially when the control group is given equivalent non-computer support. For example, a study by Wainwright (1989) showed that a control group using worksheets scored significantly higher than did an experimental group using CAI. Wainwright suggests that paper and pencil worksheets allowed the students to more easily experiment with trial and error in balancing chemical equations.

A major problem in evaluating the results of studies designed to measure the value of CAI is the elusive factor of the quality of the software used in the study. Not only should the software be well designed, but there also must be a match between the objectives of the software (or courseware), the understanding of the teacher as to how to apply it, and the needs or interests of the students.

Simulations

Simulations emulate physical systems and processes and are generally designed for specific processes (Scanlon, O'Shea, Smith, Taylor & O'Malley, 1993). There are five main ways of using computer simulations for learning science:

- for hypothetical experiments, such as experiments that would normally be impossible due to safety, access, magnitude or time constraints, (Steed 1992), for example nuclear power stations;
- for breaking the laws of nature (Scanlon, et al, 1993), such as exploring kinematic collisions which violate conservation of momentum;
- for tidy experiments (Scanlon, et al, 1993), where students will not be overwhelmed by the messy practicality of science and may see the patterns and trends;
- for instrumental data capture (Scanlon, et al, 1993), and display, where the simulation allows sensors and probes to provide the real time data which can then be plotted and explored;
- for mathematical modeling, where the students alter laws or provide the data, (Scanlon, et al, 1993) the latter is similar to modeling.

An additional benefit in science classrooms is that simulations can be re-run and hence ideas re-explored.

Modeling

Unlike a simulation, which remains restricted to a particular phenomena, modeling allows students to use modeling languages to solve problems. Computer based modeling concentrates on developing and evaluating a model (Schecker, 1993). It accomplishes this by identifying the problem, defining the purpose of the model, deciding on the main factors, defining relationships within the model, evaluating and re-testing the model (Webb, 1993b). Therefore theory modeling has similar potential to simulations, if not more.

Modeling in physics education has been advocated for at least a decade, but data from empirical classroom trials is scarce. Indeed much research on icon oriented modeling systems in physics involves case studies. However, Schecker (1993) describes empirical studies in progress. Students aged 16 -17 used 'STELLA' to analyse kinematics, dynamics, work and momentum. In one school, the teaching environment employed open student directed questions and students took turns to operate the modeling software. It was imperative that students deduced the model structures themselves, either in groups or in class discussion. They also needed time to test and revise their models.

Multimedia (CD ROM, databases and authoring packages

The term multimedia simply implies more than one medium and in the context of this review includes hypermedia (non linear access and hence different pathways through a variety of media), as well as databases such as CD ROM, and authoring packages. Maor (1994) investigated use of a computerized database in a constructivist learning environment with the intention of providing students with opportunities to develop inquiry skills in their science lessons. It was noted that students were able to design different investigations to address the same questions and were able to discuss different interpretations of the graphs constructed. The students also developed analysis skills and progressed onto formulating hypothesis in later stages of the study. Maor observed that a constructivist environment using a database enabled students to develop higher level thinking skills, such as generating creative questions and conducting complex investigations. Students developed the ability to reflect on different levels of hypothesizing and this reflection increased their higher level thinking skills. However, to experience this success, the software must avoid technical problems, the environment should be constructive, and the teacher's role is crucial.

Research has indicated that editing assignments and hypermedia/multimedia environments should promote learning of the content, because it encouraged students to become reflective, to judge and evaluate information in terms of its appropriateness and its relevance. In such an approach the students are, as Perkins (1986) suggested, designers of knowledge. Multimedia and hypermedia authoring allow students to express their creativity and, dependent on the way they are used, support lateral thinking (Rodrigues, 1996b).

Generally recent research literature on applications of multimedia authoring relates to teachers creating presentations for students' use (e.g. Bowers & Tsai, 1990; Jonassen, 1986; Landow, 1989). These teacher-led representations provide access to data but the students are still bound by the teachers' content and design decisions. However some research literature documents students creating Hypercard stacks. Hypercard is software that provides the user with a series of 'cards' which represent screens.

Barba and Merchant (1990) investigated the effects of embedding generative cognitive strategies such as note taking, paraphrasing capacity, on disc glossary, simple line drawings, highlighting and a review capacity, into a Hypercard stack. These strategies benefited low verbal learners rather than high verbal learners. Howe and Vasu (1990) indicated that learners were better able to recall information if responding in pictorial rather than verbal form.

A study in which multimedia editing was used to promote science learning showed students worked cooperatively, were motivated and found science content material from a variety of sources in order to create a package for their audience (Beichner, 1994). A group of nine, seventh and eight graders, each worked for several hours per week on a project over the course of a school year. The students used a hybrid of Hypercard and Supercard and began to write for an audience. The students became concerned with the accuracy of information as much as the need to make the information interesting.

Internet and Electronic Mail Internet and Electronic Mail

Telecommunication technologies have pedagogical potential in that they offer teachers and students opportunities to present, manipulate and access information in new ways (Bruntlett, 1995). In an attempt to avoid duplicating information, the research involving Internet will not be discussed in detail in this review as a companion review has been written with specific regard to the Internet.

Robinson (1994) described several uses of email; for example classrooms used email to send information to other schools in the US; a program called 'Global Laboratory' allowed schools to engage in collaborative projects that fostered international cooperation in investigating global climate changes and local environmental issues; in areas that are short of teachers of particular disciplines such as physics, email is used to teach and work with students wishing to pursue these subjects; Computer Pals Across the World was a project which involved over 10 schools in Europe, USA and Canada who regularly shared information for science projects that ranged from water content of snow to climactic conditions in which environmental awareness and global citizenship was a fundamental concept.

In the United States the government has supported networks to enable students to have access to information without charge, the rationale being that it makes education more equitable for rural schools and addresses the issue of dwindling numbers of students in science and science related areas (Monk & Haller, 1993). In the United Kingdom the National Council for Educational technology, the Ministry for Education, and the British library boards were investigating the potential and requirements of on-line information such as Internet and Reuters Business briefing service for a variety of subject domains (Rodrigues, 1996). The rationale for the investigation being the potential of these services to address issues of inequity of access to information and methods of accessing available information.

Using CAI in Science Assessment

Reams of science questions can be collated in the form of card files with keywords to help identify suitable questions for the purpose of constructing examination papers (Wheatley, 1983). However, beyond item banking, technology offers open ended approaches to science assessment while addressing issues of cost, validity and quality (Singley & Taft, 1995).

Computers could have direct questions in a tutorial structure which provided immediate feedback and become a diagnostic tool, ascertaining student's initial levels of knowledge and understanding (Altschuld, 1995). These computers could maintain continuous records of student's achievement and difficulties. Computer interfaces could record complex responses to questions and in that record provide access to students' thinking rather than simply their ability to provide the right response (Singley & Taft, 1995). In a different context, the computer could allow students to progress and test alternatives that might other wise have not been possible and in so doing facilitate student reflection on science concepts and alternative concepts (Altschuld, 1995).

Collins and Earle (1990) examined the effects of computer administered testing in a biology class, they found that high and middle ability students benefited from using the computer in addition to attending regular classes, but low ability students did not. Baxter (1995) provided a comparison of two methods of assessing students' learning, the first involved concrete materials the second involved manipulation of icons to solve electrical circuit problems. Students completed both assessments, but there was an interim period of three weeks between assessments. The mean performances for the group were alike, but individual student performances deviated greatly.

Teachers and Equipment

Many teachers believed that they were ill prepared, either in pre-service or in-service, to effectively integrate CAI into classroom use (Sherwood, 1993). This endorses global findings. For example, despite the fact that more than 8,000 schools of the 10,900 schools (primary schools) in the United States had a computer, the actual classroom use of computer technology was not uniform (Swift & Zielinski, 1995). A UK questionnaire type study (NCET, 1993) evaluated the use of CAI in science in 171 schools. Schools' reasons for using CAI in science ranged from educational benefits, work experience or the National Curriculum (the majority), to management led or pupil pressure (the minority). The most widely used application at lower secondary school was datalogging, simulations then followed by database, graphing and word-processing (NCET, 1993). In upper secondary school the most widely used applications were simulations, dataloggers, databases, graphing, and energy analysis.

At post 16 the trend was datalogging, simulation, graphing, databases and word processing (NCET, 1993). However, Rogers and Wild (1994) reported that the NCET study also showed that only 11% of schools used CAI for more that three hours a year, 54% made some use and 35% made no use of CAI at all.

The following data reflects a variety of subject domains. However data particular to Australian science classrooms have not yet been disseminated in an easily accessible form, and therefore it seemed pertinent to consider the data available, thus providing some insight into current practice in secondary schools. The most common application was word processing (96%). A significant number of teachers also used drill and practice software (89%), simulations and problem solving software (82%) and tutorial programs (78%). It was noted that programming had decreased substantially in secondary schools (Sherwood, 1993).

For many teachers, the unreliability of computers was an issue and reduced their confidence. As computers became more and more unreliable they required some degree of technical expertise to fix things (Birch, 1995). This unreliability may be due to the age of the computers found in schools.

The Environment Created by CAI, the Teachers and the Students

The technology itself will not be a vehicle for the acquisition of knowledge and skills. Instead CAI needs to be embedded in powerful teaching environments (De Corte, 1990). This probably accounts for the perceived success of the ACOT schools. Positive features of technology when introduced into the classroom can result in changes in the classroom environment, both in terms of teachers' roles and in terms of the nature of the activities undertaken by students (Scaife, 1993). In practice the procedure and outcomes of any computer based activity emerge through talk and joint activity between the teachers and students (Mercer & Fisher, 1992) .

Therefore the defining influence on structure and outcomes of a computer based activity, other than that of the software, is the teacher. Talk was an important facet of computer based activity, because students need to be taught strategies which help them justify their reasoning and defend their view point (Mercer, 1994). This can be achieved by using non-computer activities to teach these strategies while raising students' levels of communication.

At least four computer specific variables can influence the students' working and type of discussion; the physical design of the hardware, the layout of the equipment, the software used and the teacher's role. Technology had yet to have an impact on school environments and the skills of teachers continues to be limited, because hardware, software, teacher training and support organisations were critical factors that were yet to be given high priority in facilitating CAI use in schools (Sims, 1993). The variety of hardware installed in schools including BBC, Acorn, Apple and IBM has led to confusion as compatibility between home and school CAI environments has posed problems.

In addition, teacher CAI skill and familiarity levels are more a result of personal familiarization programs, undertaken voluntarily, rather than formal in-service and pre-service training courses. Furthermore, teacher education programs do not contain a significant amount of CAI experiences which promote the use of CAI as an environment for enhancing student-teacher interaction (Sims, 1993).

These constraints have led to a subdued integration of CAI in schools. Simply having computers in schools would not improve learning, and planning for learning should precede any hardware purchases. The focus needs to shift to the needs of the student, rather than the purchase of hardware (Bork, 1995). This shift would take into account the physical environment as well as the pedagogy employed. In terms of the physical environment, the following need to be considered when promoting technology use:

- access (easy use for multiple activity).
- territory and collaboration (group work possible).
- comfort, social conditions and acoustics (rooms to take into account sound reduction).
- flexibility (diverse learning settings).
- classroom organization (Stuebing, Celsi, Knox Cousineau, nd).

Furthermore, the software needs to provide the best learning environment and has to be user friendly rather than workable only for skilled teachers or students (Bork, 1995). Bork also notes that the interactive nature of the technology has to be truly, rather than superficially, interactive. The interaction needs to facilitate customizing the learning environment and providing active motivated learning. Computers situated in the classroom are more prone to regular use throughout the year in comparison with classes where use has to be scheduled (Bork, 1995). However, having sufficient numbers of computers is as critical as the convenience of their location (Becker, 1991).

Another issue that needs to be considered stems from the fact that Australia is a multicultural society and international research, pre-1989, in other multicultural societies suggested disparities in CAI access amongst children of different backgrounds existed in schools (see for example Martinez & Mead, 1988). These are important facets, if computer use is to become culturally and gender sensitive. It would be naive to pretend that past research has not indicated differences in computer use being dependent on teacher perceptions of students based on their race. While more recent research has yet to be disseminated, some early studies indicated that minority and poor students spent more time on drill and practice programs (Anderson, Welch & Harris, 1984) and language programs focused more on quantity rather than the relationship between the learner and the software (DeVillar & Faltis, 1991).

At predominantly white schools students used computers for programming and this suggested that teachers believed basics needed to be mastered before higher order thinking could be sought (Office of Technology Assessment, 1987). However poor and minority students did not have the basics (Doyle, 1991; Laboratory of Comparative Human Cognition, 1989). In preparing teachers to use CAI in school science in Australia, care needs to be taken to ensure that these assumptions and teacher beliefs are reviewed and addressed.

Conclusions

The potential of computer based technology in science classrooms is immense and science education should reflect the range of computer use as a tool for learning and as a tool employed by scientists. However, all of these uses will only be effective and of benefit if teachers design appropriate tasks and if the CAI has fitness for purpose. The use of CAI in school science needs to provide students with both the skills of using the available CAI and provide another medium by which they might make sense of the science information with which they are presented.

However, the potential will not be realised until strategies are demonstrated as effective, resources are accessible and reliable and teachers are provided with supportive scaffolding and are confident CAI users themselves. The role and beliefs of the teacher are fundamental to the integration of CAI into classroom use. Fundamental aspects of successful integration are teacher involvement in the change process and the perceived immediate value of the processes or materials to teachers (Brown, 1994).

Teachers have lagged behind industry in the use of educational technology for teaching (Robinson, 1994), and the reasons for this centre on the lack of familiarity with the technology, a lack of understanding and appreciation of the potential use, and a lack of time and opportunity to become familiar with the CAI prior to using it for classroom teaching (Sherwood, 1993). In Australia 68 per cent of a sample of student teachers felt inadequate when using computers (Wilson, 1990), a view shared by many teachers because those starting their careers have limited or no CAI experience (see for example, Summers, 1990a, 1990b; Kay, 1990; Sherwood, 1993). Issues of teacher confidence, teacher ownership of the change process and teacher experiences in terms of CAI and pedagogical practice need to be addressed.

Professional development must provide numerous approaches for educating science teachers with regard to CAI use. These could include courses/implementation programs:

- which promoted use of CAI in learning science (the why, what and how to use CAI to enhance science learning)
- which promoted use of CAI in teaching science teaching, (the when, why, what and how to use CAI to enhance science teaching)
- which updated new technology experiences, keeping abreast of CAI developments
- deployed in school environments to provide support for the change at the place and point of change
- that provided insight into available curriculum materials which would support the use of CAI in science teaching and learning.

Perhaps, initially rewards and incentives should be made available for teachers making the change, either through more resources, options to courses, or opportunities to share their learning and teaching in other environments. Professional development could include on site visits to schools with exemplary practices. In this way, a practicum of sorts would provide teachers with opportunities to share ideas, see and experience good practice and become aware of what is really possible in classroom environments.

Sherwood (1993) stated that most teachers were now at a stage at which they wanted in-service to help them in classroom practice, rather than provide simple information about the technology. They wanted to know how to put it into practice and wanted to see classroom strategies that demonstrated effective use.

Empowering teachers and students through ownership of the change and decision making process has been shown to be a powerful medium for change. Adopting a student centered approach, for both professional development in terms of teachers acquiring CAI expertise and in terms of students using CAI in their learning environment should be a fundamental concern of all professional development programs. This would allow for teachers to experience the value of student centered learning and for them to experience ways in which this could be put into practice in their own classrooms.

Telling teachers about the value of CAI and the benefits in terms of learning is unlikely to result in them changing their teaching practices or adopting CAI use. Involving them in experiences, either case study practicum or hands on with a variety of CAI applications, is more likely to demonstrate the potential of CAI and the circumstances that would be necessary if change is to result in positive learning outcomes. As Papert (1990) stated, 'better will not come from finding better ways for the teacher to instruct but from giving the learner better opportunities to construct' (p.3). In similar speak, better professional development will come from providing teachers with better opportunities to construct, because in the case of using CAI in teaching and learning science, the teachers are the learners.

Science education of the future will certainly incorporate computer use--including word-processing, many forms of CAI, laboratory instrumentation, interactive video courseware, and scientific database searching--and the educational process will be better because of it.

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