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INNOVATIVE COMPUTER-ASSISTED STRATEGIES IN THE LEARNING OF MATHEMATICAL CONCEPTS AND SKILLS

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INTRODUCTION

The rapid development of hardware and software in the last four decades has made the computer one of the greatest technologies ever created in the history of mankind. By the many research studies carried out successfully throughout the years and the numerous development systems and educational projects using the computer technology, it can be seen that the computer has become a useful partner in education. In particular, computer-assisted strategies are one viable area for curriculum research and practice which is the theme of this year's conference of the Educational Research Association, Singapore.

In the thirty years or so of research into computer-assisted strategies in teaching and learning, mathematics stands out as one subject area in the curricula of primary, secondary and tertiary education which has surpassed others in terms of the number of studies initiated and completed and the variety of content and pedagogical aspects studied.

Many people may ask, *Why use computers?* and equally many, *Why not?* To us, there are more than enough reasons to justify the introduction of computers into the educational scene. Firstly, media equipment and technology have always been applied for use in educational endeavours and innovations from the very simple chalkboard to overhead projectors to audiotape and videotape recorders to film projectors. There is no reason why such an advanced technology as the computer could not be beneficially applied in education.

Secondly, the power and high-speed of the computer give rise to many possibilities in using it as a technology in improving teaching and learning. For example, the computer is used as a central controlling device for the coordination and integration of a multi-media instructional system. It is used in large and small computer-assisted instructional systems in the learning of many subject areas. Research has shown that innovative teaching involving the computer technology can accomplish in certain ways what conventional teaching is supposed to achieve, especially in the teaching and learning of mathematics. Many mathematical concepts and skills can be taught by adopting computer-assisted strategies which enable pupils to achieve equally well or in many cases even better in certain mathematical skills.

Thirdly, since the advent of the microcomputers in 1975, the 80's have seen a rapid growth of different makes of hardware and peripheral equipment not only in numbers but also in capability and efficiency. The decreasing cost of microcomputer has made it affordable to schools and even middle-income families as evidenced by the many systems being purchased by them and the constant upgrading of their old systems. Consequently, microcomputer laboratories are becoming a common facility considered desirable for schools and colleges not only for use by teachers in teaching various subjects but also by students in learning skills in computer literacy and applications.

COMPUTER-ASSISTED STRATEGIES

There are three categories of computer-assisted strategies which we consider important and which have achieved a reasonable degree of success in enabling students to learn mathematical concepts and skills. They are:

(1) Computer-assisted instruction (which in our usage includes computer-assisted learning, computer-based learning and computer-managed instruction) whereby the computer is an expert in the subject to be learnt and tutors the students by executing the instructional programmes.
(2) Adjunct computer-assisted instruction where the computer is used as a tool, assisting the learner in investigating mathematical concepts and properties.
(3) Learning through the computer whereby students interact with it in the language it understands and thereby learning concepts and procedures by manipulating facts and understanding them.

(1) Computer-assisted instruction

Chong (1983) defines computer-assisted instruction (CAI) as a "teaching method in which the computer is used as a medium whereby prepared and programmed instructional material is given to the learner in sequence" (p.56). Interventional, motivational and evaluative techniques are built into the programmed material to make CAI effective not only to improve student performance in the learning tasks but also to make it possible by sound pedagogical principles.

Many CAI systems have been developed for various subject areas, including Mathematics. PLATO, an acronym for Programmed Logic for Automatic Teaching Operation, is a CAI system that was conceptualised in 1960 at the University of Illinois for many college subjects. It began as a large system using mainframes and has gradually evolved into a powerful computer-based education system with approximately 1100 terminals at about 200 dispersed locations. Since 1982, PLATO courses have been taught by Micro-PLATO which is a stand-alone microcomputer network system with courseware that has been converted for use on microcomputers. PLATO has been adopted in universities and in many countries.

Another large computer-based instructional system is TICCIT which is an acronym for Time-shared, Interactive, Computer-Controlled, Information Television. The courseware which includes English and Mathematics was developed at Brigham Young University. TICCIT's main characteristics include the incorporation of instructional tactics, strategies designed to teach primarily concept-classification and rule-using objectives rather than memory drill, and the provision of learner control of subject content to be learnt.

(2) Adjunct computer-assisted instruction

In this category, the computer does not present information to the learner but assists the learner in his investigation or acquisition of mathematical concepts and properties. The main objective here is that the computer relieves the learner of tedious and time-consuming tasks whose results rather than their actual performance are necessary to the learning of the concepts, thus enabling him to concentrate on the essentials of the concept. In the case where the learners are required to observe certain patterns from various cases, by performing the tasks quickly, the computer enables the learner to examine more cases than he is able to if he has to perform the tasks manually. The use of this type of computer-assisted strategy often involves the use of investigative worksheets as well as discussion between students themselves and discussion between students and teacher.

Since one of the most powerful features of a computer is its graphics, a common example in this strategy of using computers in learning is the use of graph plotting software to investigate properties of equations or properties of families of curves. In fact, not only does the computer save the learner time involved in curve plotting, the student may be unable to sketch curves of a more complex nature without the assistance of the computer. Specially written software could also be used to carry out certain processes such as transformations, leaving the learner to examine the properties

of the processes. This graphic power of the computer is especially useful in teaching geometry where students often have difficulty in visualising the curves or figures concerned.

Also in this category is the use of the computer as a high powered calculator to perform mathematical procedures such as algebraic manipulations, differentiation or integration. Again the emphasis here would not be the actual tasks of differentiation or integration but perhaps in the modelling process which may lead to algebraic or differential equations.

(3) Learning Mathematics through the computer

The third category of innovative computer-assisted strategies involves the creation of an intellectual environment within which the students can discover mathematical principles and learn mathematical concepts. Such "microworld" software is open ended and the student has the initiative while the computer executes the actions requested by the student, regardless of whether they are correct or appropriate.

The obvious example here is the LOGO microworld where in learning to programme the computer, students are encouraged to examine mathematical properties of geometry concepts, concepts of proportion and of variables.

In using any programming language to solve mathematical problems, students are able to see the execution of algorithms which they have programmed. For example, they could use a simple iterative procedure which involves the systematic and exhaustive search for solutions to a problem.

Yet other microworlds like the "Geometric Supposer" allow students to explore geometric properties by entering their own parameters for construction. Here, students are able to make sense of the various properties through interacting with the microworld environment.

This form of computer-assisted learning is particularly appropriate in the light of the 1992 mathematics curriculum where the central theme is problem-solving. This is because, in the process of programming, algorithmic thinking and problem-solving heuristics are strongly encouraged. Heuristics such as "guess and check", "look for a pattern", "being systematic", "considering all possibilities" and overall strategies such as planning in a logical way and algorithmic thinking are particularly important. By allowing the students to work on the computer independently, to explore algorithms and to make discoveries for themselves, they develop their reasoning ability, their creativity and their problem-solving skills. On the affective domain, the spirit of enquiry and the desire to investigate are nurtured in a friendly, non-critical microworld environment.

RESEARCH ON EFFECTIVENESS OF COMPUTER-ASSISTED STRATEGIES

Although the results of research on the effectiveness of CAI have been somewhat inconsistent and inconclusive, there is still great potential for CAI to be successfully implemented in the classroom. The inconclusiveness is mainly due to the inability to meta-analyse a large number of research findings because of vast differences in research methodologies and contexts and the large number of different subjects researched upon. Nevertheless, the results seem to indicate that CAI is as effective as a more traditional instructional mode at least at the drill and practice level. Meta-analysis of independent studies of CAI in mathematics have shown that normal instruction supplemented by CAI usually led to higher achievement and better attitude towards the subject. CAI has also been found to be more effective among low-achieving students in both the primary and secondary schools especially in mathematics and remedial mathematics.

Table 1 shows a summary of major studies of the effects of CAI carried out by different researchers or groups of researchers in the 70's and 80's.

Table 1 A summary of major studies of effects of CAI

	Population Sampling	Treatment	Dependent Variables	Key Findings
Vinsonhaler & Bass(1972)	primary	supplemental drill	achievement	+ve
Jamison, Suppes & Wells (1974)	primary college	drill tutorial simulation problem-solving	achievement attitudes	+ve only at primary
Edwards et al. (1975)	primary secondary college	drill tutorial simulation	achievement retention	+ve in achieve-ment only
Robitaile (1977)	grade 9		achievement attitudes	+ve +ve in short term, not long term
Hartley (1977)	primary secondary	drill tutorial	achievement	more +ve primary than sec.
Burns & Bozeman (1981)	primary secondary	drill tutorial	achievement	more +ve primary than sec.
Kulik, Bangert & Williams (1983)	grades 6-12	computer-based instruction	achievement attitudes time reduction	+ve
Kulik & Kulik (1985)	college	CAI CMI CEI	achievement attitudes course com-pletion time reduction retention	+ve
Bangert-Drowns, Kulik & Kulik(1985)	secondary	CAI CMI CEI	achievement attitudes attendance retention	+ve
Kulik, Kulik & Bangert-Drowns(1985)	primary	drill tutorial CMI	achievement retention attitudes	+ve
Ferrel(1987)			attitudes	not sig.

(Adapted from Woo-Tan (1989) pp 37-39.)

We would like to focus on three research studies done locally which investigated the effects of using computer-assisted methods in this way to learn mathematical concepts and properties. These studies were carried out by past students of the Master of Education programme at the former Institute of Education.

Research Study by Tan Puay Khim (1987)

Tan (1987) investigated into the effects of computer-assisted instruction (CAI) on a group of secondary 3 pupils who were taught the concepts of linear equations.

The aim of the study was to determine whether, when compared with those pupils taught in the traditional expository approach, these pupils would gain more in achievement scores, retain information longer, and improve in their attitudes towards mathematics. The experiment was carried out over a period of two weeks involving a total of 12 lessons each lasting 35 to 40 minutes. The instruments used were a 50-item objective test on Linear Equations and a retention test to measure achievement and the 32-item Mathematics Attitudes Inventory to measure pupils' attitudes towards mathematics.

The statistical technique used was the independent t-test to determine whether there was any significant difference between the mean scores of the two groups.

The results showed that pupils learning from the CAI mode obtained significantly higher mean test scores on the objective test as well as the retention test than those learning from the traditional expository mode of instruction. However, there was no significant difference in attitudes towards mathematics for the two groups of pupils after treatment.

Research Study by Woo-Tan Lay Beng (1989)

The effects on achievement and attitudes towards mathematics of a total of 70 boys of average ability from two intact classes in a secondary school were investigated by means of CAI in comparison with the traditional directed approach (TDA). The period of instruction was three weeks with a total of 15 lessons each lasting 35 minutes.

The CAI approach consisted of a specially designed courseware on transformation geometry supplemented by worksheets. The traditional directed approach consisted of expository teaching by teacher who initiated, directed and controlled the learning with exercises to reinforce the learning of concepts.

Achievement was measured by means of the Transformation Geometry Achievement Test and attitudes were measured by two instruments, namely, the Attitudes Towards Mathematics Questionnaire and Attitudes Toward Transformation Geometry Questionnaire. The independent t-test was used to analyse the data.

It was found that the CAI group out-performed the TDA group in terms of achievement. In particular, they did better in translation, stretching, shearing and combinations of transformations. In reflection, rotation and enlargement, both groups seemed to be comparable. As for cognitive levels, the CAI group out-performed the TDA group in comprehension and application items but not knowledge items.

The researcher found that in both attitudes towards mathematics and attitudes towards transformation geometry, CAI group improved significantly than the TDA group.

Research Study by Lee-Leck Mui Kiah (1985)

At the tertiary level, the achievement and attitudes towards mathematics of two groups of a total of 63 pre-service primary school teachers were compared after they have undergone an 8-lesson instruction over a period of four weeks on graphical representations and interpretations of linear and

quadratic equations. One group was taught by means of the CAI method and the other by the Normal Lecture method.

The statistical techniques used were the univariate t-test and the multivariate analysis of variance.

A self-constructed Algebra Achievement Test was used and three attitudinal scales, namely, Suydam-Trueblood Attitude Towards Mathematics Scale, the Modified Mathematics Attitudes Inventory and the Algebra Attitude Scale, were used.

As in the study by Tan (1987), the CAI group had significantly higher achievement and attitudinal scores towards the topic than the normal lecture group but not attitudes towards mathematics.

CONCLUSION

In Singapore, there has been a concerted effort in exploring the use of computer-assisted strategies in the teaching and learning of various subjects, especially Mathematics, in both the primary and secondary schools as well as in tertiary institutions. We must confess that although much has been accomplished so far, there is still much more to be done. Research studies here and there by interested persons have been reported in international and local conferences but not sufficiently large in numbers to really make an impact to effect curriculum change and practice.

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