Influence of Computer-Generated Visuals on Word-Problem Solving

Philip Wong

Abstract

This study investigated the effects of different visual strategies in the solving of word problems in computer-based lessons. There were three visual treatments, namely, visual-supplied, self-generated, and no-visual. Together with this, students were given two option-control treatments of programme-control where subjects solved ten problems, and learner-control where subjects solved six problems and were then allowed to choose up to ten additional problems.

Primary four students (n = 138) from two schools were randomly assigned to treatments in a (3 x 2) factorial design. To complete the experimental task, subjects worked individually at the computer for three sessions, each lasting approximately forty-five minutes. During the lessons, subjects were shown examples and prototype solutions, and solved word problems. A delayed post-test was administered a week later. Using on-task scores as the dependent variable, no visual treatment effect was detected. The self-generated group’s post-test mean scores were significantly higher than those of the other two visual groups. Subjects in the learner-control group attempted five more problems than subjects in the programme-control group but the post-test scores were lower in the learner-control group. Results from this study suggest that requiring students to generate their own visuals is an effective strategy for solving word problems. Although students in the learner-control group attempted additional problems, their additional exposure did not result in higher post-test scores.

Descriptors: Word problems, computer-assisted instruction, visualisation, elementary school students, Mathematics instruction, problem solving.

The ability to solve word problems is one of the most important objectives in the study of mathematics. Yet teaching word problem solving is recognised to be difficult. One of the reasons for this difficulty is that finding appropriate solutions to word problems is a complex task and indications of this complexity can be gleaned by reviewing studies which report that students score lower on word-problem solving than on computation (NAEP, 1979). To counteract the difficulty of solving word problems, many mathematicians and teachers have proposed untested methods to help students. Of the many hints, strategies and methods, the use of visuals is one that is widely endorsed. However, very few empirical studies have shown positive results on the effectiveness of self-generated visuals for solving word problems in elementary schools.

With the availability of microcomputers in schools and in classrooms, the emphasis on the use of computers for word-problem solving has shifted from process research to classroom application. One distinct advantage of computers over other traditional instruction is the ability to of accommodating and adapting instruction to student needs. For example, in student-centred instruction (CBI), students are given to students in selecting the activities in which they are interested. There is evidence to suggest that student-centred instruction and the feelings of self-confidence, self-esteem, and responsibility lead to better learning outcomes. In this study, we looked into one means of combining student-centred and teacher-controlled instruction: the use of visual strategies in teaching word problems.

Visual Representation

Understanding a mathematical problem involves representation. Representing a mathematical problem is an important initial step in solving it. Various physical or symbolic representations in this initial step can lead students to ask questions, reformulate the problem, and provide an opportunity for using various techniques, strategies and methods. For example, rewording the problem, drawing pictures (diagrams), and deriving a context, diagrams, pictures (diagrams) and solving the problem.

A number of ideas have been proposed in the literature regarding the role of drawing visuals. Lesh and Akin (1993) believe that drawing visuals can be an external representation in many cases, that drawing visuals can help students see a more refined and more meaningful solution. Kaufman (1993) believes that students may use external representation to help them think about abstract notations of the solution. Kaufman (1993) suggests that students may use visual tools to support their thinking or problem-solving activities.
over other traditional instructional modes is their ability to offer individualised instruction by adapting instructional materials to suit individual needs. For example, in computer-based instruction (CBI), some levels of control can be given to students to allow them to make choices in the selection of additional instruction. There is evidence that increased control promotes feelings of self-efficacy and self-determination and assists students to become independent and responsible learners (Gay, 1986). Many learner-control studies have investigated the influence of one or more individual characteristics such as cognitive styles, learning styles and ability levels on learner-control strategies in CBI. But extraneous factors such as social and cultural climate, may also determine how well these strategies work. No studies, however, have looked into other characteristics not under the control of the individual that could influence learner-control strategies.

Visual Representation in Word Problems

Understanding and creating internal representation of a problem situation forms an important initial step toward successfully solving word problems. Building students’ competence in this initial step can help them be better problem solvers and courses in problem-solving have emphasised this aspect and have taught various techniques of representing problem situations such as rephrasing problem situations, rewording the problem situation into another context, deriving equations, and drawing visuals (pictures and diagrams).

A number of theoretical propositions have been proposed to account for the importance of drawing visuals during word problem solving. Lesh and Akerstrom (1982) believe that forming an external representation by drawing visuals helps young problem solvers refine their mental representations. The iteration process of forming internal (mental) and external representations may lead to the generation and selection of more refined representations and thus, to the solution. Kaufmann (1985) cites research studies to support his theory that problem solvers process a problem visually when the problem task is new and novel, but, if they are familiar with the task, will switch to verbal processing.

Although theoretical propositions indicate that drawing visuals is helpful, this procedure is not frequently practised by many people. However, there is evidence to show that expert problem solvers draw visuals to represent problem situations more often than novices do. Heller and Greeno (1979), after reviewing a number of studies that investigated word-problem solving in arithmetic, physics, and thermodynamics, note that experts construct diagrams whenever they are useful while novices rely mainly on verbal statements. On the other hand, children do not draw visuals or diagrams to help them solve word problems. Ekenstam and Greger (1983) conducted a large scale survey of sixth-grade children’s strategy in solving word problems. In one of the subtasks, students were asked to assess the correctness of a worked answer to a word problem. Most students concentrated on determining the accuracy of the calculation and very few bothered to check on the set-up of the problem. Hardly any students drew visuals to help in the solution.

Effects of Visuals on Word-problem Solving

It is well known that visuals lend to better performance than words in paired-associate learning because of the dual channels for encoding information (Paivio, 1971). Visuals have also been incorporated in textual materials to help in comprehension and to aid in recall. However, in word-problem solving, the functions of supplied visuals are not clear. It has been hypothesised that visuals help students: (a) to conceptualise the problem, (b) symbolise the problem situation through familiar images, and (c) to understand the problem better (Campbell, 1964).

The literature on the effectiveness of visuals in solving word problems has produced contradictory results. Threadgill-Sowder and Sowder (1982) in their review of literature
reported several studies which showed that young students performed better when word problems were accompanied by visuals. Most of the studies reviewed involved subjects solving word problems in a testing situation without any extra instruction or practice in using the visuals to solve the problems. While visuals are effective in group testing situation, they are not when students are tested individually or when time constraint is imposed. Further studies by Sowder and associates (Moyer, Sowder, Threadgill-Sowder and Moyer, 1984; Threadgill-Sowder & Sowder, 1982; Threadgill-Sowder, Sowder, Moyer, & Moyer, 1985) have consistently shown that students obtained higher scores when word problems are presented in a visual format than in the verbal format. Moyer et al. (1984) suggested that word problems presented visually help to reduce reading-related working memory overload, recall similar past experience and link visuals to appropriate schema, provide another channel to enable students to understand the problem situation, and organise the problem information to facilitate the selection of appropriate schema and the recall of data for computation.

While word problems accompanied with visuals help to enhance word-problem solving performance, the effects of pupils' self-generating visuals are not so clear. Three studies showed that some form of training in the use of visuals in word-problem solving heightened performance (Gamer, 1979; Nelson, 1974; Yancey, 1981). One study showed no difference in performance when visuals were generated by students (Wersan, 1981), and another showed that it was difficult for students to generate pictorial representations of the problem statement without training (Walter, 1984).

These contradictory results from different studies can perhaps be explained by the variability of the design. Length of treatment, age of subjects, type of problems, and the type of covariates, are some factors that will affect the results of the studies. The ability to generate visuals and to use them depends not only on the age and ability of students, but also on the type of word problems and the type of visual tasks involved. Word problems involving complex concepts (eg proportion and commutativity) as used in Wersan's and Walter's studies, can influence the effectiveness of the method of self-generation of visuals.

**Learner Control**

One exciting feature of computer-based instruction is its ability to offer various types of options for learners. Options such as selecting the amount and type of materials, specifying the type of instructional strategies, and choosing the amount of instructional support are commonly incorporated into CBI materials; the instructional effectiveness of these options have been investigated (Kinzie, 1990).

It is generally believed that it is advantageous to allow students to exercise control in the learning process. By allowing students to make decisions during the learning process it will improve achievement by increasing motivation, reducing anxiety, and improving attitude toward learning. Most research studies in CBI have not provided support for this notion and have in fact found negative correlation between control and achievement (Kinzie, 1990). But under certain conditions, for example, when provided with advice about their learning progress, students are able to judge their own learning ability (Tennyson & Buttry, 1980).

Students can be given the choice of selecting the types or amount of materials they deem most suitable for their needs. But most students are not good judges; this is especially true for young students. While it is important for less able students to obtain more instructional support, they did not seek it when allowed to control lessons (eg Carrier, Davidson, & Williams, 1985). Fisher, Blackwell, Garcia, and Greene (1975) investigated the effects and the pattern of selection of problems by fourth and fifth graders during an arithmetic CBI lesson. Some students consistently chose the easiest problems; others chose the more difficult problems. Tennyson & Buttry (1980) found that twelve graders, when given complete control of lessons, tended to choose an amount of material insufficient to master concepts and to terminate lessons too early. This resulted in poor achievement scores. Some students who received the advice concerning their performance level did not seek additional support even though they needed it. When they were allowed to select the amount of instruction, they tended to select the amount of material insufficient to master concepts and to terminate lessons too early. This resulted in poor achievement scores. This finding supports the notion that students are not good judges of their learning needs and abilities.

Besides age and ability characteristics such as cultural and social environment can influence the use of additional instructional options. Numerous cross-cultural studies have shown that Asian students are more positive and, under certain conditions, will spend more hours on homework than European students. Social factors, such as social and cultural environment, are cited as the major cause of this phenomenon. Mathematics achievement is related to these factors and the additional instructional support students receive can influence their motivation and on their learning outcomes.

**The Current Study**

One purpose of this study was to investigate the effects of giving students control over selection of instructional materials while using visuals to solve word problems. Another purpose was to investigate the effectiveness of using visuals to solve word problems. One of the main arguments of using visuals is that it is a powerful tool for self-generated learning and understanding word problems. Hence, the current study was designed to investigate the effects of using visuals to solve word problems.
achievement scores. On the other hand, students who received feedback about their progress toward the mastery of concepts, stayed on-task long enough to master the concepts. College students are better judges of the amount of practice and were able to judge and select an appropriate quantity of practice items required to master mathematical concepts (Judd, Bunderson & Bessent, 1970). But they over-practised and, consequently, took more time to complete a module. The ability to be good judges, thus, will depend on the age and ability level of the students. Hannafin (1984) suggests that older and more academically capable students may have more refined cognitive strategies and are able to apply them to instruction. But younger children and less able students do not have the refined cognitive strategies or the self-evaluation skills needed to monitor their own progress during instruction.

Besides age, ability, and personal characteristics (eg level of motivation), factors such as cultural, social, and educational environment can influence students opting for additional instructions during the lesson. Numerous cross-cultural studies have indicated that Asian students (eg Japanese and Taiwanese) are more positive toward school learning and spend more hours on homework and on after-school instruction (Walberg, Harnisch, & Tsai, 1986). Social factors such as parental support and cultural emphasis on education have been cited as the main contributors to the higher mathematics achievement of Asians. Perhaps, these factors and the extra instruction students receive can influence students’ task perseverance and on their selection of the amount of instruction.

The Current Study

One purpose of the current study was to investigate the effectiveness of the strategy of using visuals to represent problem situation for solving word problems. It compares two different methods of using visuals: supplied visuals versus self-generated visuals. Reading ability, computation ability and spatial visualisation are some individual difference factors that have been found to be correlated with students’ word-problem solving performance and these factors will be used as covariates.

Another purpose was to extend the range of variables of how learners operate when given options to select additional instruction. Do Singaporean students select additional instruction when given the choice? If they do, do the students benefit from extra instruction?

Method

Subjects

The sample was 138 Primary Four students from two primary schools in Singapore. These students follow a six-year primary curriculum consisting of studies in the first language (English), a second language (Chinese, Tamil or Malay), science, mathematics, social studies, and aesthetics. At the end of their sixth year, students sit for a national examination, the Primary School Leaving Examination, and if successful, proceed to secondary education. Few students have had any regular exposure to computer work.

Using a random set of numbers, students names were drawn from the school register and were assigned to six cells of a 3 x 2 design (three levels of visuals by two levels of learner-control). Due to various reasons, 12 subjects were eliminated leaving 21 subjects per cell.

Instrumentation

The Comprehensive Tests for Basic Skills, Form U, Level F (CTB/McGraw-Hill, 1981) was used for testing students’ reading comprehension skills and the Form U, Level G for the computation skills. The Punched Holes Test (Wilson, Cahen, & Begle, 1968) for elementary school students was used for assessing students’ spatial visualisation ability. This test, an adaptation from the adult ETS Paper Folding Test (French, Ekstrom & Price, 1963), was modified for children by the National Longitudinal Studies of Mathematical Abilities (NLSMA) Group in 1967.
The word problems were drawn from previous research projects (Sowder, Threadgill-Sowder, Moyer & Moyer, 1984; Yancey, 1981). These word problems were similar to those found in school textbooks. Basically, each problem consisted of two parts. In the first part, information with numerical values describing the problem situation was presented and in the second part, a question was posed. Two criteria were used for the selection of word problems: (a) the problems must be appropriate for third to fifth graders and (b) the problems must involve double-step arithmetic operations (e.g., multiplication and then addition). The reliability coefficient (KR 20) of word problems used during lessons was 0.79, and for the ten word-problem post-test was 0.78.

Treatment

There were three visual treatments: visual-supplied, self-generated, and no-visual; and two option-control treatments: learner-control and programme-control.

Visual-supplied treatment

The visuals appeared for all the problems and examples in the three lessons. Simple iconic visuals with labels representing each problem were drawn. For example, to show five thousand three hundred trees, a group of trees were drawn with the label “5300 Trees.” There were no attempts to represent the actual number of items in the visuals. Some problems required only two visuals to represent the problem while some required three. Figure 1 illustrates a sample visual screen for the word problem.

Self-generated treatment

For this treatment, subjects had to draw their own visuals on sheets of paper provided. To help subjects in drawing visuals, examples in the lessons were accompanied with visuals (same visuals as those in the visual-supplied treatment). Specific instructions on how to draw visuals were provided. Subjects were told to draw a group of articles and attached a label to them. Instead of visuals appearing, a prompt “Draw pictures to help you” was presented. Also to encourage them to draw visuals, subjects were told that they would be awarded an extra point for visuals drawn in each problem.

No-visual treatment

This was the control treatment. The treatment procedure was the same as the visual-supplied group except that visuals were not presented. To maintain consistency, the keyboard was locked for fifteen seconds before subjects were allowed to key-in their answers to the word problem.

Learner-control treatment

For Lessons 2 and 3, subjects were allowed to choose the number of problems they would see. In order to prevent students from not solving any problems, they had to work out three word problems before being given the option to select more problems. On completion of the three problems, subjects were asked whether they would like to try another problem. If positive, another problem was presented. If negative, the lesson terminated and the total scores were shown. This choice was presented until the total number of problems reached eight.

Problem Two

A Christmas tree farmer has 5460 trees. He cuts down 1230 trees. Next day, he cuts down 500 more. How many trees are standing now?

5460 trees cuts 1230 cuts 500 more = Type in your answer and press <RETURN>.

Figure 1: Screen Display - Visual-supplied Treatment
At that point, the lessons terminated and subjects were informed of their scores. The maximum number of problems chosen for Lessons 2 and 3 was eight (three mandatory and five optional) and the minimum number was three (three mandatory and no optional problems).

Programme-control treatment

Under this mode, subjects did not have a choice in selecting the number of problems to solve. Instead, each subject would have to solve four problems in Lesson 1 and five problems each in Lessons 2 and 3.

Procedure

Before the collection of data, subjects were given the reading, computation, and spatial visualisation tests. Subjects attended three CBI lessons, each lasting from thirty to forty-five minutes. The first lesson was an orientation one and scores were not collected. The lessons were delivered on Apple Ile computers in the schools’ computer laboratories. Each computer station was numbered so that subjects could be randomly assigned to the stations and thus, to different treatments. Within each session, all of the six treatments were present.

A typical task during the lesson consisted of the following sequence. A word-problem situation was presented on the screen for students to read. They were advised to read the problem carefully. After a lapse of five seconds, instructions were provided for subjects to press the return key for the presentation of visuals. The visuals appeared followed by a time delay of ten seconds during which the keyboard was locked. After the pause, the problem question appeared. This procedure was adopted to prevent impulsive actions and also to encourage subjects view the visuals. Subjects then typed in their answers which were judged and if wrong, were shown the correct answer. For each correct answer one point was added to the On-Task Answer score. On pressing the return key, five options for the selection of process operations were presented (Figure 2).

Subjects selected one process operation that was perceived would yield the correct numerical answer. If successful, one point was added to the On-Task Process score, and they would proceed to the next problem. If unsuccessful, the prototype solution, which explained how the answer was obtained, was presented. They would then proceed to the next problem. The first lesson lasted for approximately thirty to forty-five minutes. For Lessons 2 and 3, subjects were required to sit at their assigned microcomputer stations which were loaded with the programmes they were working on previously. Subjects who completed their lessons ahead of others were sent back to their class. A delayed post-test consisting of 10 word problems were administered a week after the treatment.

Problem Two

A Christmas tree farmer has 5460 trees. He cuts down 1230 trees. Next day, he cuts down 500 more. How many trees are standing now? Choose only 1 method.

Type a, b, c, d or e and <RETURN>

a) 5460 - 1230 then subtract 500
b) 5460 - 1230 then add 500
c) 5460 + 1230 then subtract 500
d) 5460 - 1230 then multiply 500
e) 5460 + 1230 then add 500

Figure 2: Screen Display - Selection of Process Operations
In summary, the following sets of data were recorded:
(a) Individual-difference variable scores of computation, reading, and spatial visualisation
(b) On-Task Answer score for correct answer during the computer lessons
(c) On-Task Process score for correct selection of process operation during the computer lessons
(d) Post-test Answer score for correct answer in the post-test
(e) Post-test Process score for correct process operation in the post-test
(f) Number of problems attempted by subjects in the learner control group.

Results
There were two different option-control groups. Subjects in the learner-control group solved six word problems before they were allowed to choose up to ten additional problems (total maximum number of problems was 16). Subjects in the programme-control group solved a fixed number of problems (10). The number of problems attempted by the subjects in the learner-control group was 14·1 for the no-visual group, 15·3 for visual-supplied group, and 14·9 for self-generated group. Tables 1 shows the means and standard deviations of the On-Task Answer and On-Task Process scores. To compensate for unequal number of problems attempted, the number of problems attempted was used as a covariate to adjust the means of the on-task scores.

Table 1 shows the means and standard deviations of the On-Task Answer and On-Task Process scores. To compensate for unequal number of problems attempted, the number of problems attempted was used as a covariate to adjust the means of the on-task scores.

Table 2 shows the post-test scores. Subjects in the learner-control group while attempted an average of five more problems than subjects in the program-control group their On-task performance for the two groups was not significant. Univariate analysis of the Post-test Answer showed that the program-control group means were significantly higher than those of the learner-control group \( F = 4·47, p < .05 \). Post-test Process scores were also higher for the program-control group than the learner-control group \( F = 5·26, p < .05 \).
Reading, computation and visualisation scores were used as independent variables in four multiple regression equations with On-Task Answer, On-Task Process, Post-test Answer, and Post-test Process as dependent variables. The purpose of this set of analyses was to determine the amount of variance these independent variables contributed to the problem-solving scores. Using the forward regression procedure, each variable was added to the regression equation without removing the other variables already present. Table 3 shows the values of $R^2$ when all independent variables entered into the equations. Nearly one-third of the variance of the post-test scores were accounted by the independent variables. To select the independent variables for covariates, a stepwise regression was used. Spatial visualisation and computation were two variables (Table 3) that accounted for most of the variance in the on-task and post-test scores. When these variables were in the regression, reading scores did not contribute to any significant change in the variance and thus was not used as a covariate.

Multivariate analysis of covariance (MANCOVA) was used to analyse the data with On-Task Answer and On-Task Process as combined dependent variables. Computation was used as a covariate variable while spatial visualisation was included as a factor to assess aptitude-treatment interaction (ATI) effects. The main effect for visual treatment was found to be not significant $F(4, 230) = 1.35, p = .25$. After adjusting the means for total number of problems attempted, there was no significant difference between learner-control and programme-control. There was no ATI effect between spatial visualisation and visual treatments.

Table 3: Regression on Dependent measures

<table>
<thead>
<tr>
<th>Dependent Measures</th>
<th>Spatial</th>
<th>Computation</th>
<th>Reading</th>
<th>Visualisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-Task Answer</td>
<td>Beta</td>
<td>t</td>
<td>Beta</td>
<td>t</td>
</tr>
<tr>
<td>-22</td>
<td>2.45*</td>
<td>-21</td>
<td>2.36*</td>
<td>-</td>
</tr>
<tr>
<td>On-Task Process</td>
<td>-38</td>
<td>4.61*</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Post-test Answer</td>
<td>-32</td>
<td>4.17**</td>
<td>-39</td>
<td>5.07**</td>
</tr>
<tr>
<td>Post-test Process</td>
<td>-26</td>
<td>3.29**</td>
<td>-28</td>
<td>3.24**</td>
</tr>
</tbody>
</table>

* $p < .05$  ** $p < .005$

Table 4: MANCOVA for Post-test Answer and Post-test Process

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillais-Bartlett</th>
<th>F</th>
<th>$(df_1, df_2)$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>.13</td>
<td>4.26</td>
<td>(4, 232)</td>
<td>.002</td>
</tr>
<tr>
<td>Option-control</td>
<td>.043</td>
<td>2.60</td>
<td>(2, 117)</td>
<td>.078</td>
</tr>
<tr>
<td>Visual x Option</td>
<td>.16</td>
<td>1.65</td>
<td>(4, 232)</td>
<td>.160</td>
</tr>
<tr>
<td>Covariates</td>
<td>.40</td>
<td>14.96</td>
<td>(4, 236)</td>
<td>.001</td>
</tr>
</tbody>
</table>
In post-test scores, computation and spatial visualisation scores were used as covariates with the Post-test Answer and Post-test Process as combined dependent variables. The main effect for visual treatments was significant (Table 4). Both Post-test Answer and Post-test Process scores showed highly significant visual treatment effects. Simple contrast showed that the means of the self-generated group were significantly higher than both the visual-supplied (p < .005) and no-visual groups (p < .005) but not between the supplied-visual group and the no-visual group.

Discussion

It was interesting to note that subjects in the visual-supplied group, when provided with visuals during the lesson, had the highest proportion of correct on-task answers and process operations. In the written post-test, where no visuals were provided, they had the lowest scores. Perhaps the presence of visuals during the lesson and the absence of visuals in the post-test could have caused this pattern of results. A number of explanations could account for this.

First, there was no direct instruction during the lessons for subjects in the supplied-visual group to “learn” the strategy of using visuals. Subjects were unable to internalise the strategy of representing the word problems visually, and thus not able to transfer the strategy when visuals were not provided. One kind of evidence that led to support this proposition was the small number of subjects (only two subjects) in the visual-supplied group who attempted to draw visuals during the post-test. To provide better evidence for this proposition, other research methods, such as interviews or subject protocols, should be employed. Unfortunately, the design of this study did not include these methods and one can only postulate about this proposition.

Second, visuals supplied during the lessons might provide another source for processing the information as hypothesised by Paivio’s (1971) dual coding model. For example, subjects who had difficulty in processing the textual statements verbally could do so visually. The presence of visuals “might call into play additional internal resources that the solver does not use spontaneously” when only verbal problems are presented (Threadgill-Sowder et al., 1985, p. 56). The visuals, for example, could have helped subjects to link the verbal statements with the visuals and make the problem more meaningful. The absence of visuals during the post-test could deprive subjects of this extra source.

Third, the presence of visuals could help subjects in understanding the problem by activating relevant past experiences and schemata. The activation of various linked knowledge structures could help in the construction of an appropriate semantic internal representation of the problem (Moyer et al., 1984).

Fourth, the visuals might have inadvertently provided additional help to subjects by organising and interpreting the information of the problem and indirectly provided hints to the selection of arithmetic operations (Threadgill-Sowder et al., 1985). For example, when a second visual contained less number of items than the first visual, it could imply subtraction or division. When visuals were no longer provided in the post-test, these extra functions of visuals were removed and could have affected subjects’ performance in solving word problems.

Post-test scores showed significant visual effect with the self-generated visual group having performed better than the other two groups. Consistent with other observations (e.g., Lester, 1985), young children can be taught to use heuristic strategies in solving word problems. In the current study, subjects in the self-generated group were able to draw and use visuals for solving the word problems and in so doing, improved their performance. The process of generating their own visuals was a more effective strategy than being supplied with visuals as shown by the higher post-test scores of the self-generated group. The active process of generating visuals took a longer time, but once the strategy was learned, it was applicable even after a delay of one week.

While past studies on learner control in CBI indicated that young students tend to terminate instruction too early (Buttrey, 1980), in solving six word problems stopped but instead asked for additional work of possible fact of the result. First, much experience with the computer, might have believed it was similar to real life practice. Third, this might influence the subject.

Numerous cross-cultural studies have shown that Asian students are more persistent to spend more hours in school instruction. Several factors such as emphasis on education, may contribute to the achievement of these factors causing more problems, but would improve.

The number of subjects did not correlate. In fact, the Post-test control group vs. learner-control and in the Post-test also observed improvement. It can be observed even in the control group a program-control problems during the additional post-test performance, which use were same for comparison. The schema learning was a problem with it.
instruction too early if allowed (Tennyson & Buttrey, 1980), that was not the case here. After solving six word problems, subjects could have stopped but instead, they continued and opted for additional word problems. There are a number of possible factors that could account for this result. First, most of the subjects had limited experience with CBI and the novelty of working with the computer might have prompted them to ask for additional problems. Second, subjects might have believed that problem solving exercise was similar to rote learning and opted for more practice. Third, cultural and social factors could influence the subjects to attempt more problems. Numerous cross-cultural studies have indicated that Asian students (e.g., Japanese and Taiwanese) are more positive towards school learning and spend more hours on homework and on after-school instruction (Walberg et al., 1986). Social factors such as parental support and cultural emphasis on education have been cited as the main contributors to the higher mathematics achievement of Asians (Miura, 1987). Perhaps, these factors could influence subjects to attempt more problems believing that attempting more would improve their performance.

The number of problems attempted by students did not correlate with post-test scores ($r = -14$). In fact, the Post-test Answer for the program-control group were significantly higher than the learner-control group (means = 4·60 and 3·75) and in the Post-test Process, a similar trend was also observed (means = 6·63 and 5·56). This was observed even though subjects in the learner-control group attempted more problems than the program-control group. Exposure to more word problems during the lessons did not help students in the post-test. There was no positive transfer of the additional experience from the lessons to post-test performance. Instructional strategies which use worked examples for analogies and for comparison with other problems may facilitate schema learning. A worked example is a sample problem with its solution worked out to illustrate how the solution process is carried out. In this study, worked examples were provided at the beginning of each lesson. Prototype solutions provided at the end of each unsuccessful attempt at answering the word problem were also worked examples. For students in the learner-control group, they were shown more prototype solutions. However, they were unable to use their added exposure of prototype solutions and transfer the experience to the post-test. This may be due to the lack of specific instructions to “learn” from the prototype solutions. The fourth grade students in this study were not able to learn by themselves without this extra instructional procedure. While it is important for students to develop metacognitive skills in problem solving (e.g., Lester, 1985), subjects in this study were unable to do so on their own, as reflected by the lower mean scores of the learner-control group. Subjects in the learner-control group attempted more problems and had more exposure to instructions. However, during the lessons, subjects were not told to “learn” from the prototype solutions. It was assumed that subjects would learn and benefit from the extra instruction when they saw the prototype solutions. The assumption was wrong. Other findings have also shown that young students when left on their own, were unable to generate their own learning strategies (e.g., Biehler and Snowman, 1986).

**Conclusion**

Although Asian students may show different learner control patterns in computer-based instruction, students need more guidance to benefit from any extra exposure of instructional materials. The results of this study suggest that requiring students to generate their own visuals could be an effective strategy for solving word problems.
REFERENCES


