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The effectiveness of knowledge-based tools in the classrooms

George P. L. Teh

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THE EFFECTIVENESS OF KNOWLEDGE-BASED TOOLS IN THE CLASSROOMS

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ABSTRACT

Various programmes have been implemented to promote the use of computers in education in Singapore. But there has not been any systematic research into the effectiveness of the use of computers in education in this city state. This paper reports the results of a funded project aimed at investigating the effectiveness of using PROLOG created knowledge-based tools in 24 randomly selected secondary classrooms in Singapore. More specifically, this research focused on the comparative effectiveness of providing the experimental classes with computer-based learning modules vis-a-vis the control classes which were taught using the expository mode, the attitudes of subjects towards knowledge-based learning environments and expository learning environments, and the different effects on the boys and girls in this sample of computer-based learning classes in terms of selected criterion measures.

INTRODUCTION

Numerous studies have been conducted to determine the effectiveness of providing students with computer-aided learning vis-a-vis the traditional expository method in terms of student achievement and student attitudes (Hasselbring, 1984; Bangert-Drowns, 1985; Clark, 1985; Kulik, Kulik and Shwalb, 1986; Nelson, 1988). Results have been conflicting due to the many different conditions under which studies have been undertaken. However, recent meta-analyses carried out by Kulik and Kulik (1987) on the effectiveness of computer-aided learning suggest a meaningful treatment impact.
It has been difficult to assess the impact of computer-based learning materials on achievement. Could this be, in part, because few if any studies have used specific courseware tailored to the needs of the school curriculum?

Although some initial studies have been carried out to assess the effectiveness of PROLOG-based knowledge-based tools (e.g. Dean, 1986), a large study involving more experimental subjects and schools would perhaps verify the extent of effectiveness of using knowledge-based tools in schools.

The questions that formed the focus of this study were:

1. Will lower ability students studying in Secondary Two Normal who have been provided with knowledge-based learning modules perform better than students who use the traditional materials prescribed by the Singapore Ministry of Education on measures of:
   (a) achievement of the experimental topics,
   (b) attitudes towards learning.

2. Will the knowledge-based learning modules be differentially effective for boys and girls in this sample in terms of these two criterion measures?

**METHODOLOGY**

**Sample**

A total of 671 lower ability students (345 boys, 326 girls) of Secondary Two Normal classes from 12 randomly selected secondary schools in Singapore served as the subjects for the study. These schools are all located in the four education zones and a stratified sampling technique was used to randomly select three schools from each zone.

In each school, two classes of Secondary Two Normal were selected by random sampling techniques and assigned as experimental and control groups, respectively. For each of the experimental and control groups, the number of subjects was 348 and 323, respectively. All schools are co-educational in order to allow an unconfounded test of whether the use of knowledge-based tools in learning geography is differentially effective for boys and girls.
Instrumentation

The data was collected using the Geography Achievement Test (GAT). This instrument was designed to measure students' cognitive achievement in geography and was developed by the investigators. The GAT was a paper and pencil multiple-choice test consisting of 30 items with four alternatives each. Respondents were asked to mark the correct answer by circling the appropriate alternative. The reliability (coefficient alpha) for the 30 item GAT for the whole group was 0.95. A 20-item semantic differential instrument (SDI) was also developed by the investigators and was designed to measure attitudes towards learning geography using knowledge-based tools. A seven-point scale was placed between each adjective pair, and respondents were asked to circle the number on the scale which reflected their feelings about the lessons in learning geography. The alpha (reliability coefficient) for the 20 items of the semantic differential instrument for the whole group of the study was also 0.95.

Design and Procedure

The experimental design used for this study was the pretest-posttest control group design (Campbell and Stanley, 1963). Random assignment with subjects in experimental and control groups from each school, was used to examine the treatment effect due to exposure to the knowledge-based learning mode. The experiment was carried out with 12 schools comprising an experimental and a control class in each school. One experimental and one control class in each school was taught by the same teacher, who also was involved in administering the pretests and posttests.

The treatment materials for this study consisted of a set of computer-aided learning modules on the concept of decision-making in geography used for sixteen 35-minute lessons, over a period of two months. This is the most difficult concept to teach and is one of the five concepts that students have to cover in their Secondary Two Geography syllabus for Singapore. The teaching method for the experimental groups was the computer-aided learning (CAL) mode of instruction. The teaching method for the control groups was the traditional expository approach.

To maintain group equivalence, both the experimental and control groups were:
(i) subjects who used a computer before. Prior experience of the experimental group with a computer would control any Hawthorne effect which might arise;

(ii) taught by means of the cooperative approach. Lessons were generally student-centred. Students also worked on a small group basis.

At the end of the treatment period, both the experimental and control subjects were administered the GAT and semantic differential instruments as posttests in the same way that these two instruments had been administered as pretests before the lesson. The administration of the pretests and posttests was done within a two-lesson period of 35 minutes each.

Analysis of Data

For the achievement tests, statistical procedures were based on two phases: descriptive and inferential. In the first phase, histograms were made for each dependent variable, for each group, and presented in a manner which enabled inter-group comparisons to be made. Three quantitative indices of between-group differences were computed: the effect size estimator from meta-analysis; "eta-squared", the correlation ratio (formed by dividing the between-group sum of squares by the total sum of squares); and "omega-squared", the estimate of the value of the correlation ratio of the population.

Since the results of the descriptive phases signal the presence of a meaningful treatment impact, such as a minimum value of 0.3 for the meta-analysis estimator, analysis of covariance was computed to test the hypothesis that observed between-group differences could be attributed solely to sampling error. The value of 0.3 was suggested as a usable cutoff point as it was the average effect found in Kulik and Kulik’s 1987 meta-analysis of computer-based learning effectiveness.

For the affective tests, profiles of group means on the 20 semantic pairs were generated to show the relative effect on subjects' attitudes towards knowledge-based learning environments and expository learning environments.
FINDINGS

The histogram of the posttest scores on the GAT for the whole group shows wide inter-group differences in terms of treatment effects (Figure 1). The histogram of the posttest scores of the experimental group (Figure 2) further confirmed the disparity when compared to that of the control group (Figure 3). The mean score of the experimental group was 26.12, with a S.D. of 2.56 and a high score of 30 and a low of 14. The corresponding figures for the control group was mean = 9.91, S.D. = 4.68 with a high of 27 and a low of 1.

Figure 1
Histogram of posttest scores of GAT by treatment
Figure 2
Histogram of posttest scores of experimental group

Figure 3
Histogram of posttest scores of control group
Three quantitative indices of between-group differences were also computed: the effect size estimator from meta-analysis; eta-squared and omega-squared. Table I reports the results of these between-group differences.

Table I
Quantitative Indices of Between-Group Differences on the GAT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect-size Estimator</td>
<td>3.46</td>
</tr>
<tr>
<td>Eta-squared</td>
<td>0.83</td>
</tr>
<tr>
<td>Omega-squared</td>
<td>0.83</td>
</tr>
</tbody>
</table>

These indices signal the presence of a very meaningful treatment impact. The value of the effect-size estimator was 3.46, far in excess of the 0.3 which was the average effect found in Kulik and Kulik's 1987 meta-analysis of computer-based learning effectiveness.

The ANCOVA procedure, with subjects' T-scores (a public examination promotion score used to assign students to different schools) and their semestral assessment scores as covariates, was computed to test the hypothesis that observed between-group differences could be attributed solely to sampling error. Table II reports the results of the ANCOVA computation.

Table II
ANCOVA Results for Group (Experimental/Control) in Posttest Scores on the GAT

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares</th>
<th>DF</th>
<th>Mean square</th>
<th>F</th>
<th>Sig. of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariates</td>
<td>1802.60</td>
<td>2</td>
<td>901.30</td>
<td>66.22</td>
<td>.000*</td>
</tr>
<tr>
<td>Main effects</td>
<td>42473.82</td>
<td>1</td>
<td>42473.82</td>
<td>3120.84</td>
<td>.000*</td>
</tr>
<tr>
<td>Explained</td>
<td>44276.42</td>
<td>3</td>
<td>14758.81</td>
<td>1084.43</td>
<td>.000*</td>
</tr>
<tr>
<td>Residual</td>
<td>9077.69</td>
<td>667</td>
<td>13.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>53354.11</td>
<td>670</td>
<td>79.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant at p < .01
The ANCOVA results confirm the presence of a reliable treatment effect. With the covariates partialled out of the total variance, the squared multiple correlation coefficient (equivalent to eta-squared) remained high, having a value of 0.82. Within the sample, more than four-fifths of the variance in posttest GAT scores, with covariates partialled out, can be attributed to the treatment.

To determine the consistency of the semantic scale responses for the pretests and posttests of experimental and control groups, coefficient alpha was computed. It was found that alpha values for the experimental group were 0.86 and 0.91, respectively; the control group has alphas of 0.88 and 0.93, respectively. Without any exception, subjects in the experimental group positively reassessed their prior opinions about knowledge-based tools in learning geography. The profile of group means on the 20 semantic pairs for the experimental group is shown in Figure 4. Of interest is the fact that subjects found knowledge-based learning environments more interesting, meaningful and colourful. Subjects also positively reassessed their opinions that knowledge-based learning environments were special, uncommon and creative. Subjects in the control group were also asked to rate their feelings about their expository learning environment. The profile of group means indicates that feelings were largely unchanged (Figure 5). There were no significant reassessment of opinion when compared with subjects' initial feelings about their expository learning mode.
<table>
<thead>
<tr>
<th>Understandable</th>
<th>Confusing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bad</td>
<td>Good</td>
</tr>
<tr>
<td>Friendly</td>
<td>Unfriendly</td>
</tr>
<tr>
<td>Harmful</td>
<td>Helpful</td>
</tr>
<tr>
<td>Unsuccessful</td>
<td>Successful</td>
</tr>
<tr>
<td>Meaningless</td>
<td>Meaningful</td>
</tr>
<tr>
<td>Important</td>
<td>Unimportant</td>
</tr>
<tr>
<td>Comfortable</td>
<td>Uncomfortable</td>
</tr>
<tr>
<td>Useless</td>
<td>Useful</td>
</tr>
<tr>
<td>Inactive</td>
<td>Active</td>
</tr>
<tr>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Simple</td>
<td>Complicated</td>
</tr>
<tr>
<td>Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Common</td>
<td>Uncommon</td>
</tr>
<tr>
<td>Colourful</td>
<td>Not colourful</td>
</tr>
<tr>
<td>Interesting</td>
<td>Boring</td>
</tr>
<tr>
<td>Unpleasant</td>
<td>Pleasant</td>
</tr>
<tr>
<td>Valuable</td>
<td>Worthless</td>
</tr>
<tr>
<td>Normal</td>
<td>Special</td>
</tr>
<tr>
<td>Dull</td>
<td>Creative</td>
</tr>
</tbody>
</table>

- o pretest rating
- x posttest rating

Horizontal links between arrows indicate at least two scale difference between mean ratings.

**Figure 4**  
Self-rating of opinions by subjects in the experimental group.
understandable: \( \overset{x}{\circ} \) confusing

bad: \( \overset{x}{\circ} \) good

friendly: \( \overset{\circ}{x} \) unfriendly

harmful: \( \overset{x}{\circ} \) helpful

unsuccessful: \( \overset{\circ}{x} \) successful

meaningless: \( \overset{x}{\circ} \) meaningful

important: \( \overset{\circ}{x} \) unimportant

comfortable: \( \overset{x}{\circ} \) uncomfortable

useless: \( \overset{x}{\circ} \) useful

inactive: \( \overset{\circ}{x} \) active

fast: \( \overset{x}{\circ} \) slow

simple: \( \overset{\circ}{x} \) complicated

difficult: \( \overset{x}{\circ} \) easy

common: \( \overset{\circ}{x} \) uncommon

colourful: \( \overset{\circ}{x} \) not colourful

interesting: \( \overset{\circ}{x} \) boring

unpleasant: \( \overset{x}{\circ} \) pleasant

valuable: \( \overset{\circ}{x} \) worthless

normal: \( \overset{x}{\circ} \) special

dull: \( \overset{\circ}{x} \) creative

° pretest rating
x posttest rating

Figure 5
Self-rating of opinions by subjects in the control group
Table III reports the results of the boys and girls in the experimental group in terms of their achievement and attitudes. The GAT differences were statistically significant at \( p < .01 \), indicating that boys performed as well as girls. The non-significant gender effect on the SDI indicates that there were no statistically significant differences between boys and girls in terms of their attitudes.

### Table III

Gender Differences in Posttest Scores on the GAT and SDI within the Experimental Group

<table>
<thead>
<tr>
<th>Gender</th>
<th>Boys ((N = 175))</th>
<th>Girls ((N = 173))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{x} )</td>
<td>S.D.</td>
</tr>
<tr>
<td>GAT</td>
<td>26.51</td>
<td>2.26</td>
</tr>
<tr>
<td>SDI</td>
<td>117.61</td>
<td>11.37</td>
</tr>
</tbody>
</table>

* Significant at \( p < .01 \)

**DISCUSSION OF RESULTS**

The study investigated the relative effectiveness of an instructional intervention program on achievement and attitudes towards geography learning. It also sought to find out if gender had any effect on achievement and attitude for the experimental group. Experimental evidence obtained in the study indicated that instruction using knowledge-based tools was efficacious in terms of treatment effect. It also engendered positive attitudes towards the study of geography. One interesting aspect of the study was that in the experimental group, gender did not relate to subjects' attitudes towards learning geography.

Three significant implications are discernible from the findings of this study. The first is that knowledge-based tools has a place in computer-aided learning environments. Second, the non-significant gender effect suggests that there were no significant differences between boys and girls in terms of their attitudes. Third, in meritocratic societies like Singapore, boys and girls are well motivated enough to excel in whatever they do, not withstanding the fact that they are slow learners.
REFERENCES


