ABSTRACT

This study investigated the comparative efficiency of computer-assisted instruction (CAI) and traditional teaching methods on tenth-graders’ learning of earth science in Taiwan. A total of 151 students enrolled in four earth science classes participated in this pretest/post-test control-group experiment. Experimental-group students learned earth science concepts through the CAI, whereas comparison group students were taught by a traditional approach. Results include: (1) Students in the experimental group had significantly higher achievement scores than did students in the comparison group ($F = 4.90$, $p<.05$); (2) There were also statistically significant differences in favor of CAI on students’ test performance, especially on the knowledge ($F = 8.00$, $p<.005$) and comprehension ($F = 5.80$, $p<.05$) test items, but not on the application ($F = 0.12$, $p>.05$) test items. These findings suggest that incorporating CAI into secondary schools has promise in helping students’ grasp of earth science concepts.

Keywords: Education – computer-assisted; education – geoscience; education – secondary; education – outside United States.

Introduction

Computers play an important role in contemporary teaching and learning of science concepts. Recent science education standards in the US state that “Instructional technology, which provides students and teachers with exciting tools – such as computers – to conduct inquiry and to understand science...” (National Research Council, [NRC], p. 24). The American Association for the Advancement of Science (1993) recently developed the Benchmarks for Science Literacy to employ computers in science classrooms. They stated that, “Computers have become invaluable in science because they speed up and extend people’s ability to collect, store, compile, and analyze data, prepare research reports, and share data and ideas with investigators all over the world.” (p. 18). Several Taiwanese national curriculum guidelines also stress the use of computers in secondary-school science classrooms.

Many teachers or researchers in the area of geoscience education have attempted to develop computer programs or to employ computer-assisted instruction (CAI) at the college level. For example, Nichols (1987) implemented a computer-assisted oil exploration and production game for college students to use in a short course on petroleum geology. Yurkovich and others (1989) employed a computer telecommunications network, MicroNet, to deliver coursework and to provide students with a variety of enrichment activities. Burger (1989) reported a simulation program designed to teach the geology of oil exploration in a game format. Diemer and others (1989) presented a computer program that merged an expert system and the imaging technology into a tool to assist in students’ learning of mineral identification. Shea (1991) developed a computer-based program for a subduction-zone earthquake exercise. Bohrer and Bohrer (1994) used interactive computer-assisted lab exercises, which combined text, graphics, and simple animation, to test students’ level of comprehension, identify their misconceptions, and help students seek explanatory information. Smith and Abley (1996) incorporated a multi-media computer-assisted instruction into a mineralogy course. Murray and Yavine (1998) used a computer-assisted mineral identification program in an introductory physical-geology class. Renshaw and others (1998) examined the impacts of a hydrogeological computer-assisted instruction on students’ problem solving skills. They found that the CAI is effective in developing problem-solving skills, particularly for students with greater prior exposure to science and engineering. Hall-Wallace (1999) also described the process of integrating computer technology across the curriculum and reported the impacts of technology on teaching.

Most of the aforementioned research studies in the area of earth science education have emphasized the innovative development of computer programs or the introduction of computers or computer software into geoscience classrooms at the college level. However, empirical research conducted on the comparative efficiency of CAI and traditional instruction, particularly at the secondary-school level, is limited. In the 1999 March issue editorial of the Journal of Geoscience Education, Shea (1999) called for more “rigorous educational research all across the board” (p. 110) in the area of geoscience education. This study is intended to meet the call.

Purpose

The purpose of this study was to make a comparison of Taiwan tenth-grade students’ learning of earth science concepts with CAI versus traditional teaching methods.
Methodology

Participants: Participants included 151 tenth-grade senior-high-school students attending four earth science classes and one earth science teacher, who taught the above classes, at a modern public senior-high school located in Taipei City, Taiwan. These students were typical of tenth graders, with a mean age of 16. The participating teacher in the current study held a master’s degree in earth science and had three years of experience teaching the subject.

Test: To measure student learning of earth science concepts, a high-school teacher and the author constructed and developed the Earth Science Achievement Test. A panel of specialists, including three high-school teachers and three professors, verified the content validity of the test. Thirty test items were used as both pretest and post-test measures of students’ learning of earth science concepts. The Kuder-Richardson Formula 21 (KR-21) was used to determine the reliability coefficient of the achievement test. The estimated reliability coefficient of 0.77 was noted.

Individual items in the instrument were also grouped into three levels of cognitive domain (knowledge, comprehension, and application) based on Bloom’s (1956) taxonomy. Knowledge items involve recalls or recognition of ideas or concepts, comprehension items emphasize student understanding of ideas or concepts, and application items require students to apply acquired knowledge to an apropos or new situation. A panel of judges, who were knowledgeable about the criteria of these categories, individually grouped these items into three levels with a high degree of agreement. (Pearson-product-moment coefficients ranged from .846 ~ .905). After completing the grouping procedure, the experts resolved any remaining disagreements. Consequently, the achievement test included five items at the knowledge level, eighteen items at the comprehension level, and seven items at the application level. The classification of test items was aimed at investigating students’ levels of understanding of earth science concepts. Some examples of sub-level items used in the achievement test are shown in Appendix A.

Instructional Method: The CAI developed and employed in this study emphasized the following stages and characteristics:

1) Problem identification: Students were first shown a video clip of a debris-flow hazard (Figure 1) that occurred in Nan-Tou Province in 1996. Then, they were asked to identify facts associated with this specific problem on a natural hazard and were required to find out possible factors that might cause this hazard, through guided inquiry provided by the computer program. This stage was intended to help students identify potential problems and scientific fact and to analyze problem situations.

2) Information collection: Students were then assigned a private research office (Figure 2) that was equipped with a variety of materials and information such as shelves of books for references, geologic maps, animated weather-satellite images for analysis, and detailed documents of virtual field trips for geological investigations. Students need to go through all the aforementioned materials and tools to collect necessary information in association with the debris-flow hazard. The purpose of this stage was to help students pay attention to the distinction between facts, to encourage students to prepare and implement their plans by analyzing and investigating the research questions, and to eventually facilitate their learning.

3) Results presentation: At the final stage, students prepared the final results of their individual work and submitted their research reports to the teacher. The most important characteristics of CAI are that it is interactive and self-paced.

The traditional instructional method used in this study stressed a teacher’s direct lectures and explanations of the debris-flow hazard and its relationship...
to typhoons, other natural events, and the impacts of human activities. The key feature of this “teacher-centered” instruction was to provide students with clear and detailed instructions and explanations. The teacher assumed the role of the “provider” of information and undertook the task of transferring science knowledge to students.

Procedure and Data Analysis: A pretest/post-test control-group design as described by Campbell and Stanley (1966) was chosen for this study. The 151 participants in both groups were tested before and after the two-week intervention. During the two-week period, the experimental group (n = 79) and the comparison group (n = 72) received an equal amount of instructional time and were taught the same instructional content. Topics covered during this period included “Typhoon Herb and Debris-Flow Hazards.”

A number of factors such as tenth-grade earth science students, the school administration, the participating teacher, the group sizes within each of the types of instruction, the same instructional content, and teaching duration were held constant. The independent variable was the method of instruction and the dependent variable was student concept-learning achievement. An analysis of covariance (ANCOVA) was conducted on the post-test scores with the pretest scores as the covariate to detect any significant differences between the experimental and control group. The level of confidence was set at 0.05.

Results and Discussion

Table 1 delineates the descriptive statistics of students’ pre- and post-test scores on the total test items and on its three sub-level items of cognitive domain, that is, knowledge, comprehension, and application levels, whereas the ANCOVA analysis on students’ post-test scores with three levels of understanding is summarized in Table 2. Based on the adjusted post-test mean scores shown in Table 1, we found that students in the CAI group scored generally higher than did students in the traditional group on total items and on the knowledge and comprehension level items. The results also indicated that, after a two-week intervention of the CAI, there were significant differences in students’ learning of earth science concepts between subjects in the experimental group and the comparison group [F (1, 148) = 4.90, p < .05] as shown in total items of Table 2. Most notably, the CAI significantly improved student achievement to a greater degree than did the traditional teaching method at the knowledge [F (1, 148) = 8.00, p < .005] and comprehension levels [F (1, 148) = 5.80, p < .05] (see Table 2, knowledge and comprehension levels). However, CAI appears to fall short of traditional methods in enhancing students’ learning outcomes at the application level of cognitive domain (see adjusted post-test mean scores at the application level in Table 1), in spite of the fact that the differences were statistically insignificant, F (1, 148) = 0.12, p > .05, as shown at the adjusted level of Table 2.

It was found that the CAI was not only at least as effective as the traditional teaching method given the same coverage of topics but also produced more positive outcomes on concept learning than the traditional instruction. The results of this investigation support previous work (Geban and others, 1992; Levine, 1994; Whiting, 1985; Yalcinalp and others, 1995) in which these studies demonstrated positive effects of CAI on students’ science achievement. Maybe it is because pupils exposed to the CAI were provided the opportunity to understand the problem, identify facts associated with the problem, collect necessary data and information, elaborate their solutions, and finally to solve the problem on their own. Or, maybe the CAI was more fun for students to learn with on the debris-hazard subject than was the traditional method.

The results of the study are also in line with several meta-analyses of CAI efficiency in a wide variety of classroom settings, grade levels, and subject areas (for example, Kulik, 1983; Kulik and Kulik, 1986, 1987, 1991; Kulik, Kulik, & Schwab, 1986). These studies all reported that CAI usually produces positive effects on the achievement of students, on student attitudes toward instruction and computers, and on student attitudes toward subject matter at different educational levels.

The findings of this study show that CAI is superior in promoting students’ learning of earth science concepts, especially at knowledge and comprehension levels of Bloom’s cognitive taxonomy. This suggests that CAI could help students acquire knowledge and grasp geoscience concepts. The result is also consis-

<table>
<thead>
<tr>
<th>Levels of Understanding</th>
<th>Pretest Scores</th>
<th>Post-test Scores</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>CAI Group Mean (SD)</td>
<td>Traditional Group Mean (SD)</td>
</tr>
<tr>
<td>Knowledge Level</td>
<td>2.70 (1.20)</td>
<td>2.38 (1.19)</td>
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<tr>
<td>Comprehension Level</td>
<td>12.33 (2.34)</td>
<td>11.54 (2.64)</td>
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<tr>
<td>Application Level</td>
<td>3.35 (1.40)</td>
<td>3.51 (1.39)</td>
</tr>
<tr>
<td>Total Items</td>
<td>18.39 (3.79)</td>
<td>17.43 (4.07)</td>
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</tbody>
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Table 1. Descriptive statistics of students’ pretest and posttest scores.

<table>
<thead>
<tr>
<th>ANCOVA</th>
<th>df</th>
<th>MS</th>
<th>F (1, 148)</th>
<th>F Probability</th>
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<tbody>
<tr>
<td>Knowledge Level</td>
<td>1</td>
<td>8.00</td>
<td>8.00</td>
<td>0.005**</td>
</tr>
<tr>
<td>Comprehension Level</td>
<td>1</td>
<td>21.29</td>
<td>5.80</td>
<td>0.017*</td>
</tr>
<tr>
<td>Application Level</td>
<td>1</td>
<td>0.18</td>
<td>0.12</td>
<td>0.726</td>
</tr>
<tr>
<td>Total Items</td>
<td>1</td>
<td>39.41</td>
<td>4.90</td>
<td>0.028*</td>
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*p < .05, ** p < .005

Table 2. Analysis of covariance on students’ post-test scores with the pretest scores as the covariate.
tent with previous studies that demonstrated CAI ability to teach factual content (for example, Boettcher and others, 1981; Tjaden and Martin, 1995). These findings may be attributed to learning strategies proposed and implemented by CAI, which emphasized students’ understanding of a central issue or problem (debris-flow hazard), gathering and collecting information associated with that issue, and elaborating their own results. These strategies might help develop students’ understanding of earth science concepts and facilitate their learning. However, sublevel achievement investigation showed no significant difference in the higher-level achievement test items of students between the experimental group and the comparison group. It may be that the amount and nature of the application test items on the “debris flow and typhoon” topic were too few and too difficult for both groups of students.

The results of the current study provide empirical data to support the idea that students could learn earth science through the CAI approach at the senior-high-school level. This study also generated evidence to support the notion that CAI is more effective in enhancing the learning of certain earth science concepts than a more traditional teaching method. It is therefore suggested that instruction such as CAI could serve as an alternative in teaching earth science in the secondary classrooms.

References Cited
Appendix A
(Note: correct answers are designated by *)

4) Knowledge-level item:
In which one of the following drainage areas in the Nan-Tou Province did the debris-flow hazard happen in 1996?

5) Comprehension-level item:
Given the following cross sections, which ones might best represent a dip slope that could possibly cause a landslide?

6) Knowledge-level item:

Food for Thought

What is nature? The only answer that can be consistently defended, is, in essence, “Everything!” What, therefore is unnatural? Nothing! The seamless web of nature is one which comprehends humanity and its works, not in the vanished past or the utopian future, but in the here and now – humanity, with its flaws, perversities and frank stupidity. The natural world is simply the world. One cannot conceptually prise away the complex phenomenon of humanity – what our species is and does – from the rest of the phenomenological cosmos, at least not without introducing some form of dualism through the back door. The Interstate Highway System is just as natural as the body’s network of blood vessels. The Grand Canyon of the Colorado is no more, if no less, a part of nature than the canyons of Manhattan. All are products of the unfolding of natural processes operating under uniform laws. Anyone who wishes is entitled to make moral distinctions among these, in whatever direction is most pleasing, but doing so inevitably intrudes a huge dollop of subjectivity into the question. Someone else is free to discern an alternative moral order in the same phenomena; noting factual favors one view over the other. The point is that sub specie aeternitatis human life and all its works cannot be wrested away from “nature” or “biology” without arbitrariness and logical inconsistency.

8) Application-level item:
Which one of the following typhoon tracks (shown in arrows) might have the most detrimental effects on Taipei City?

9) (1) A* (2) B (3) C (4) D