行政院國家科學委員會補助專題研究計畫成果報告

問題解決為基礎之電腦輔助教材發展研究 中等學校地球科學 III

本成果報告包括以下應繳交之附件：

- 赴國外出差或研習心得報告一份
- 赴大陸地區出差或研習心得報告一份
- 出席國際學術會議心得報告及發表之論文各一份
- 國際合作研究計畫國外研究報告書一份

執行單位：國立臺灣師範大學地球科學系

中華民國 89年 10月 10日
Abstract

The author compared the relative effectiveness of a Problem-Solving based Computer-Assisted Instruction (PSCAI) and a Lecture-Internet-Discussion Instruction (LIDI) on senior high school students’ science achievement and attitudes toward science in Taiwan. A pretest-posttest control-group experimental design involving eight classes was employed. Experimental group students (n=156) received the PSCAI; comparison group students (n=138) received the LIDI. Instruments included the Earth Science Achievement Test (C. Y. Chang, 2000) and the Attitudes Toward Earth Science Inventory (C. Y. Chang, in press). A multivariate analysis of covariance suggested that (a) students taught using the PSCAI scored nearly significantly higher than did students in the LIDI group and that (b) there were statistically significant differences in favor of the PSCAI on student attitudes toward the subject matter.

Keywords: Computer-Assisted Instruction, Earth Science, Secondary School Education, Problem Solving

Introduction

Computer-Assisted Instruction (CAI) plays an important role in contemporary teaching and learning of science concepts. During the past few decades, many science teachers, educators, and researchers have proposed the use of CAI to enhance science learning in the classrooms. 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). Recent science education standards in the U.S. specifically 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 Taiwanese New Nine-Year Science Curriculum Standards (Ministry of Education, 1999, p. 10) also emphasize using computers as information input and processing tools in the secondary science classrooms to help students deal with their daily-life problems (Chang & Chiu, 2000).

Despite constant advocate of implementing CAI in the secondary schools, confounding research findings on the comparative efficacy of CAI versus traditional instruction are present in the literature. Some studies reported students’ learning outcomes favoring the CAI over those strategies reflected in the lecture-discussion science classrooms (Chang, in press; Davis, Storch, & Strawser, 1987; Ferguson & Chapman, 1993; Gardner, Simmons, & Simpson, 1992; Hughes, 1974; Levine, 1994; Lu, Voss, & Kleinsmith, 1997; Yalcinalp, Geban, & Ozkan, 1995; Whiting, 1985). Conversely,
some studies also found that the CAI approach has no significant effects on the cognitive achievement or learning of science (Morrell, 1992; Olugbemiro, 1991; Summerlin & Gardner, 1973; Wainwright, 1989). Moreover, much of the aforementioned CAI research, which compared computer-assisted instruction versus traditional instruction in science classrooms, might have replicated the errors of media comparison studies (Clark, 1983, 1985, 1994). Therefore, it is worthwhile and more appropriate to explore the relative efficiency between different computer-based teaching formats in terms of their impacts on students’ science learning and student attitudes toward the subject matter in typical secondary classroom settings. The purpose of this study was to investigate such a comparison.

Many researchers including the author in the area of science education have indicated that a problem-solving-based instruction or inquiry-oriented instruction results in greater student achievement and/or attitudes than those strategies reflected in traditional science classrooms (Chang & Barufaldi, 1999; Chang & Mao, 1999; Geban, Askar, & Ozkan, 1992; Hall & McCurdy, 1990; Henkel, 1968; Mulopo & Fowler, 1987; Russell & Chiappetta, 1981). There were relatively few studies, however, which tried to improve pupils' science achievement and increase their attitudes toward science through a problem-solving-based CAI within a regular classroom setting. This study addresses this setting.

Moreover, problem solving has long been a valuable goal in science education; most researchers and educators are not only interested in the problem solving process but also interested in ways to integrate problem solving into instruction. As stated by Pizzini, Shepardson, and Abell (1989): "If a goal of science education is to develop problem solving skills of students, instruction must be devoted to problem solving." (p. 524). Therefore, this study attempted to incorporate problem-solving processes into CAI with the aim at improving science instruction in the secondary classrooms of Taiwan.

Methodology

Participants: Subjects included 294 tenth-grade senior high school students attending 8 earth science classes in Taiwan. These students were typical of tenth-grade students with a mean age of 16; gender was equally distributed among the classes. Two earth science teachers taught these classes at two public senior high schools located in the northern and central region of Taiwan. One teacher hold a master degree in Earth Science and had four years of experience teaching earth science and the other teacher hold an equivalent master degree in Earth Science and had taught the subject for eleven years. These two senior high schools shared similar features, including similar student populations, social-economic background of parents, and school administration.

Instrument: The Earth Science Achievement Test (ESAT, C. Y. Chang, 2000): Assessment of students’ earth-science outcomes was made with a 30-item multiple-choice test to measure students’ science achievement. A panel of experts including three university professors from the Department of Earth Sciences, National Taiwan Normal University, two high school teachers, and the classroom teacher verified the content validity of the instrument. These experts checked the degree of correspondence between the PSCAI and LIDI content and test items, and determined that the nature of the test items did correspond to the important concepts introduced in the PSCAI. The Cronbach’s alpha method was used to determine the reliability coefficient of both the pretest and posttest. The reliability coefficient ranged 0.76~0.78.

Individual items in the ESAT were further classified into the knowledge, comprehension and application levels of Bloom’s taxonomy (1956). Knowledge items put emphasis on remembering of concepts or recalls of ideas, comprehension items require students’ grasp of ideas or concepts, and application items involve students to apply existing knowledge to a different situation. The same panel of
specialists, who were familiar with the criteria of these levels of cognitive domain, independently grouped these items into three levels with high percentage agreement (83% ~ 90%). The experts resolved any remaining disagreements after finishing the categorizing procedure. As a result, the achievement test included 30 items that were divided into three subtests: Knowledge level (5 items), Comprehension level (18 items), and Application level (7 items). The categorization of test items meant to examine students' levels of understanding of earth-science concept.

The Attitudes Toward Earth Science Inventory (ATESI, C. Y. Chang, in press) consists of 30 items designed to survey students' attitudes toward earth science with three subscales measuring attitudes toward the earth science subject, attitudes toward learning of earth science, and attitudes toward involvement in earth science activities. This instrument was constructed by selecting and modifying survey items from an existing questionnaire, the Attitudes Toward Biology Instrument developed by Cheng and Yang (1995). Thirty items were finally used as both pretest and posttest to determine students' attitudes toward the subject matter. Reliability was established through internal consistency. The Cronbach's reliability coefficient was estimated to be around 0.90.

Instructional Method: The PSCAI developed and employed in this study emphasized the following five-staged problem-solving processes with the following characteristics:

(1) Presenting problem: Students were first shown a video clip of the debris flow hazard occurred in Nan-Tou Province of Taiwan in 1996. Then they were asked to identify facts associated with this specific problem on the natural hazard, and they 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 facts, and analyze the problem situations.

(2) Planning solutions: The purpose of this stage was to encourage students to prepare and implement their plans by analyzing and investigating the research questions, i.e., the factors causing the debris-flow hazards.

(3) Collecting necessary information: Students were assigned a virtual and private research office equipped with a variety of materials and information such as shelves of books for references, geologic maps, precipitation data and animated weather-satellite images for data analysis and interpretation. Students need to look through all the necessary materials in association with the debris flow hazard.

(4) Carrying out plans: Students need to go through a virtual field trip to conduct geological investigations provided by the PSCAI and to find out the solutions to the debris-flow hazard problems.

(5) Evaluating results: Student prepared final reports of their work and presented project results to their classmates by explaining and communicating with each other.

The LIDI in this study stressed direct lectures given by teachers, use of textbooks and other materials, and clear explanation of important concepts to students; occasional demonstrations with regular computer-internet usage and after-internet discussions. In preventing computer-novelty effects and evading media-comparison debates (Clark, 1983, 1985, 1994), the LIDI was also supplemented with several sessions of computer-internet access for gathering related information on the debris-flow hazard. Besides, class discussions after the Internet sessions between the teacher and the student and among students were also embedded in this teaching format. The key feature of this instruction was providing students with clear and detailed instructions and explanations. The teacher undertook the task of transferring science knowledge to students.

Procedure: A pretest-posttest control-group experimental design (Campbell and Stanley, 1966) involving 8 classes was adopted. The participants in both groups were tested and
surveyed before and after the one-week intervention. During the one-week period, each group received an equal amount of instructional time and was provided with the same instructional materials and assignments. Topics covered during this period of time included: Typhoon Herb and the Debris-Flow Hazards.

**Data Collection and Analysis:** A number of variables such as tenth-grade earth science students and the same instructional content and duration were held constant. The independent variable was the format of instruction and the dependent variables were student achievement and attitudes toward earth science subject. A multivariate analysis of covariance (MANCOVA) was conducted on these two dependent variables with pre-treatment measures as the covariates to detect any significant differences between the experimental and comparison groups. A level of confidence was set at a .05 level of significance.

To further understand how the two groups will be affected by the treatment in terms of student' different levels of intellectual and perceptive activities. An analysis of covariance (ANCOVA) was conducted on the posttest scores with the pretest scores as the covariate to detect any significant differences between subjects in the PSCAI group with those in the LIDI group. A level of confidence was set at a .05 level of significance.

Results

**Science Achievement**

A multivariate analysis of covariance on the posttest scores with students’ pretest scores as the covariates suggested that students taught using the PSCAI scored almost significantly higher than did students in the comparison group, F (1, 290) = 3.106, p < .079, as shown in Table 1. Table 2 summarizes the ANCOVA results in comparing students’ sublevel-achievement scores. Students in the PSCAI groups also exhibited significantly greater gains than the comparison groups at the knowledge level of cognitive domain F (1, 290) = 9.789, p < .002. Nonetheless, there were no significant differences between subjects in the PSCAI group with those in the LIDI group at higher cognitive levels of test items, F (1, 290) = 1.176, p < .279, and F (1, 290) = .230, p < .632 (see Table 2, comprehension and application levels).

**Attitudes Toward Earth Science**

A multivariate analysis of covariance performed on the posttest measures with students’ pretest measures as the covariates indicated that the differences between the two groups were significant, F (1, 290) = 9.631, p < .002 as presented in Table 1. Table 3 shows the results of ANCOVA analysis on students’
subscale-attitude measures toward earth science. There were almost significant differences between the groups in terms of score gains at all three subscale attitudes, as measured by the Attitudes Toward Earth Science Inventory.

Discussions and Implications

The effectiveness of CAI in the classrooms has been substantiated by several meta-analyses in a variety of grade levels and subject areas (e.g., Bangert-Drowns, Kulik, & Kulik, 1985; Kulik, 1983; Kulik and Kulik, 1986, 1987, 1991; Kulik, Kulik, & Schwalb, 1986). These studies reported that CAI generally produces positive outcomes on the achievement of students at different educational levels. The results of the present study provide empirical evidence, to a certain extent, to sustain this supposition. It may be because the PSCAI developed by the study encourages students to understand the natural hazard problem, to identify scientific facts associated with that particular problem, to collect necessary data and information, and to elaborate their solutions.

The results of the present study also provide evidence of the success of the PSCAI in its effects on students’ knowledge level of Bloom's cognitive domain. This suggests that the PSCAI might be able to enhance students’ ability to acquire knowledge in earth science. It may be inferred that the PSCAI approach encourages students to actively search for information and to solve the problems at their own paces, and hence assists students to vigorously construct their own meaningful learning. These findings are also in line with previous studies (for example, Boettcher, Alderson, & Sarcucci, 1981; Tjaden and Martin, 1995), which demonstrated CAI in favor of teaching factual content. The results may also be attributable to learning strategies proposed by the PSCAI, which emphasized students’ understanding of a central issue or problem (the debris-flow hazard), gathering and collecting information associated with that issue, and elaborate their own results. These strategies are considered productive in the learning process for acquiring knowledge in earth science.

On the other hand, sublevel achievement investigation showed no significant difference on the higher-level achievement test items of students between the experimental group and the comparison group. It maybe because that the nature of the application test items on “the debris-flow hazards and the typhoon” topic was too difficult for both groups of students. Since students usually have the most difficulties in applying concepts to a new situation because it involves an integrated and holistic understanding.

Results from this study also revealed that students in the experimental group showed significantly more positive attitudes toward the subject matter than those students in the comparison group. The results are consistent with those of other studies (Gardner, Simmons, & Simpson, 1992; Levine, 1994; Lu, Voss, & Kleinsmith, 1997; Olugbemiro, 1991; Yalcinaip, Geban, & Ozkan, 1995; Whiting, 1985), which found that CAI significantly improved attitudes toward
science among students. It seems that the PSCAI might have helped students “virtually” conduct science investigations and feel doing real science in the classrooms, leading to more positive attitudes toward science. In addition, students’ attitudes toward the subject matter, attitudes toward learning of earth science, and attitudes toward involvement in earth science activities were nearly increased, maybe it is because the PSCAI provided the students with “virtual” science investigations and required them to work on their own projects and problems rather than depending upon the teacher’s explanations. In which case, students assumed the role of “knowledge pursuer”, resulting in a more or less development of those affective domains.

Many researchers including the author have suggested employing different modes of instruction to improve students’ problem-solving ability or achievement in earth science (e.g., Champagne and Klopfer, 1981; Chang and Barufaldi, 1999; Chang and Mao, 1999, Russell and Chiappetta, 1981). The results of the present study added the success of the PSCAI to the knowledge of how different instructional method can be used to assist students’ learning of earth-science concepts. Furthermore this study generated evidence to support the notion that the PSCAI is more effective in enhancing the acquiring or understanding of earth-science concepts and increasing science attitudes toward science than is the LIDI method.

The research dealing with CAI at the secondary school earth-science classrooms is limited and sparse. The study extended further understanding on this research subject. Conclusively, the research has demonstrated that instruction, which integrates both problem solving and computer-assisted instruction, can lead to improved student achievement and attitudes toward the subject matter. It is therefore suggested that the PSCAI should be more broadly developed and widely employed in the science classrooms. At last, the results of current study could not only provide science researchers and educators important information regarding “problem-solving” based computer-assisted instruction but also serve as bases for future development of “problem-solving” based instructional strategy on the computers or internet.

References

Journal of Geoscience Education.


Lu, C. R., Voss, B. E., & Kleinsmith,


