Computer-Assisted Instruction + ? = Earth Science Learning Outcomes:
Three Case Studies

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Abstract
This paper summarizes three companion Computer-Assisted Instruction (CAI) case studies in a series for the last several years. These studies were designed to investigate a variety of impacts of an Earth Science Computer-Assisted Tutorial (ESCAT), developed by the research team, on students' Earth science achievement and their attitudes toward Earth science in senior high schools. The pretest-posttest control-group experimental design was adopted by all the three studies. Quantitative data were collected on students' pre- and post-treatment achievement and attitudes toward Earth science measures. The multivariate analysis of covariance (MANCOVA) and analysis of covariance (ANCOVA) revealed that (a) the ESCAT has its promise; (b) the “problem-solving” design of the ESCAT is generally better than the “non-problem-solving” design of the ESCAT; and (c) the “teacher-directed” ESCAT seems producing statistically greater student gains than the “student-controlled” ESCAT. These findings suggested that instruction, such as the ESCAT, should be more broadly developed and widely employed in the secondary earth science classrooms.

1: Introduction

While a number of previous studies and meta analyses have primarily focused on the comparative efficacy of computer-assisted instruction versus traditional instruction (Chang, 2001a, 2001b; Christmann et al., 1997; Fletcherflinn and Gravatt, 1995; Kulik and Kulik 1986, 1991) there are relatively fewer inquiries exploring how various teaching formats or system designs of CAI influence student science learning outcomes in the secondary classroom. Therefore, these studies in a series were designed to investigate a variety of impacts of an Earth Science Computer-Assisted Tutorial (ESCAT), developed by the research team, on students' Earth science achievement and their attitudes toward Earth science in senior high schools.

2: Software and instructional methods

Topics covered in the ESCAT included “Typhoon and the Debris-Flow Hazards”. At the end of July 1996, Typhoon Herb roared through Taiwan and brought about a huge rainfall over the course of three or four days costing many lives and property damages resulting from flooding, landslides, and a large-scaled debris-flow hazard. The computer program is designed to aid students to become more knowledgeable about the hazards. The structure of the ESCAT is built upon a virtual, private research office comprising a variety of Learning Sections (LS): tables-and-graphs, news-report, newspaper, bookshelf, computer, virtual-field trip, and Test as the primary interface elements. The LS tables-and-graphs contains mainly graphics and animation including local maps, geological maps, topography maps, animated weather-satellite images, and precipitation data and information for data analysis and interpretation. The LS news-report covers all the relevant TV news reports in the video format on the events of a debris-flow hazard, which occurred in Nan-Tou Province of Taiwan in 1996. The LS newspaper reports the print news in association with the debris-flow hazard. The LS bookshelf consists of science textbooks explaining the occurrences of natural hazards and other matters for further references and readings. The LS computer comprises a series of Video CD presenting the local geological and weather characteristics. The LS virtual-field trip allows students to conduct several geological investigations in order for them to learn facts related to the debris-flow hazard and develop an understanding of the natural events. Finally, the Test Section contains 10 randomly selected test items from a pool of 30 multiple-choice items to examine students' understanding of science concepts.

To summarize, the ESCAT developed and employed in this study emphasized the following characteristics: (1) Large amounts of information and data on the subject of the debris-flow hazards are represented in different formats such as video, graphics, animation, and sound; and (2) The information and data can be accessed through various paths. The detailed design, development, and components of the multimedia CAI can also be found in...
3: Instruments

The dependent variables were primarily measured through the use of (1) the Earth Science Achievement Test (ESAT) to assess students’ Earth science achievement and (2) the Attitudes Toward Earth Science Inventory (ATESI) to measure students’ attitudes toward Earth science. The ESAT (Chang 2001a) is a 30-question multiple-choice test designed to measure students’ earth science achievement. A panel of specialists, including three university professors and three high school teachers, established the content validity of ESAT. The reliability coefficient of 0.76–0.78 was reported in these studies. The ATESI (Chang and Mao 1999) consists of 30 items intended to investigate students’ attitudes toward earth science with three subscales assessing attitudes toward the earth science subject, attitudes toward learning of earth science, and attitudes toward involvement in earth science activities. Internal reliability was shown to be adequate; the Cronbach’s alpha was estimated to be around 0.90 in these studies.

4: Research design

A general pretest-posttest comparison-group experimental design (Campbell and Stanley, 1966) was adopted by these studies as shown in the following diagram:

\[\text{Group 1. R O X}_1 \text{ O} \]
\[\text{Group 2. R O X}_2 \text{ O} \]

\( R = \text{random assignment} \)
\( X = \text{experimental treatments} \)
\( O = \text{pretest or posttest} \)

The first study \((n=294)\) compared “ESCAT versus LIDI (Lecture-Internet-Discussion Instruction)” outcomes; while the second study \((n=155)\) evaluated CAI effectiveness with versus without “problem-solving” design and the third one \((n=232)\) weighed teacher-directed CAI against student-controlled CAI approaches.

5: Data Analysis

A number of variables, such as the involvement of tenth graders and equivalent instructional content and duration, were held constant. The independent variable was the format of instruction or design of CAI and the dependent variables were student achievement and attitudes toward earth science as a subject. A multivariate analysis of covariance (MANCOVA) was performed on the two dependent variables with pre-treatment measures as the covariates to find any significant differences between the experimental and comparison groups. The Wilks’s lambda (?) test was employed to test the difference between these two groups on the set of achievement and attitude adjusted posttest means. The level of confidence was set at a 0.05 level of significance.

6: Results and Discussions

The results indicated that (a) the ESCAT has its promise and is superior to the LIDI method; (b) the “problem-solving” design of CAI is generally better than the “non-problem-solving” design of CAI; and (c) the “teacher-directed” CAI seems producing statistically greater student gains than the “student-controlled” CAI, yet with only practical significance of small to medium effects sizes. As a result, these findings could serve as bases for development of “problem-solving” based computer-assisted instruction. Furthermore, it is also suggested that instruction, such as the ESCAT, should be more broadly developed and widely employed in the secondary earth science classrooms.

7: References