An evaluation of an inquiry-based computer-assisted learning environment

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Abstract

This study focused on students' development of inquiry skills in a computerised learning environment. Seven Year 11 classes (n = 120) interacted with a computerised database *Birds of Antarctica* and curriculum materials while the teacher used an inquiry approach to learning. The research involved investigations of the change in the learning environment as perceived by students and their teachers and students' development of inquiry skills. It was found that, after the use of the computerised database in an inquiry-oriented learning environment, students perceived their classes as more investigative and open-ended, and their inquiry skills had improved.

Introduction

In spite of its promise, the impact of inquiry-based science teaching has been largely disappointing. Classroom observations reveal examples of the absence of inquiry teaching and learning or opportunities for higher-level learning (Tobin, Kahle & Fraser, 1990). Weiss (1987) and Tobin and Gallagher (1987) report that most science curricula emphasise learning of facts and place little emphasis on higher-level cognitive learning. Many programs that claim to be inquiry-based show little evidence of inquiry on the part of students (National Research Council, 1989; Stake & Easley, 1978; Tobin & Gallagher, 1987). Recent research has shown that inquiry-based curricula have failed to promote inquiry-related higher-level thinking skills; thinking critically, asking critical questions, reasoning and solving problems amongst students of school science (Shymansky & Kyle, 1992; Tobin & Gallagher, 1987; Weiss, 1987).

However, we should not ignore the practical constraints that exist in the classroom. Teachers are not free agents. There are inherent management problems associated with inquiry teaching when the teacher has a whole class of students to look after. Inquiry-based approaches are likely to continue to fail to promote higher-level cognitive learning until a way is found to alleviate the management problems.

The use of computers in the science classroom has the potential to overcome the management difficulties normally associated with inquiry-based learning, and therefore to promote the goal of higher-level cognitive learning. In the past, however, the majority of students characterised their experiences with computers in schools as giving them a negative attitude towards using a computer. Students recalled experiences for which they were involved in drill and practice exercises, or they keyed in computer programs from books or played what, in their eyes, were trivial computer games (Bigum, 1987). In contrast, the computerised learning environment in this study was combined with an inquiry approach to teaching and learning and emphasised learning for understanding.

Aims

The major purpose of the present study was to evaluate the effectiveness of inquiry based learning which used a computerised database in promoting inquiry skills. The aspects of the evaluation covered in this paper are; students' perceptions of the nature of the learning environment, and the performance of students on inquiry skills tests.

Curriculum materials

The curriculum materials that were used during the five-month study comprised the database *Birds of Antarctica* (National Information Technology Committee, 1984), which had been designed for use with IBM-compatible personal computers, and an instructional student booklet.

The *Birds of Antarctica* database had been designed to expose students to real life scientific information based on data generated by research scientists on a voyage to Antarctica in 1982 (National Information Technology Committee, 1984). It was chosen because of its potential for helping students to develop a wide range of inquiry skills. The database contains 636 observations of seabirds gathered by scientists during the Australian National Antarctic Research Expedition. The software had the initial aim of demonstrating application of information technology with a specific focus on databases. Later, the research data were transferred to a form of educational database for high school students. The database comprises observations of sea birds, together with meteorological information, times, dates and the ship's positions and activities. The data can be accessed by the student and presented in several ways including tables and graphs.

An instructional student booklet was designed by the researchers to guide students' use of the database. The booklet provides a series of carefully structured and graded worksheets that guide students towards the attainment of scientific inquiry skills, ranging from the ability to conduct relatively simple investigations based on a single variable to the ability to design and conduct complex investigations involving multiple variables. An advantage of the booklet was that it released the teachers from a primary instructional role, and provided opportunities for them to monitor closely students' progress and to intervene with subsidiary instruction. Another advantage was that the completed booklets provided a record of each student's work, and enabled analyses of the development of their scientific inquiry skills. Although students interacted individually with the computerised database and the curriculum materials, integral parts of the learning process involved discussions between teacher and students, students constantly negotiating meaning and students arguing their ideas in the whole-class forum.

Methods

The research study, which took place in four schools in the metropolitan area of Perth, involved 120 students in seven classes. The students interacted with the computerised database and curriculum materials while the teacher used an inquiry approach to learning. Students were actively involved in asking questions based on the information from the database and designing investigations accordingly. This usually led to discussions in the classroom and to further investigations.

Because it is important to take into consideration students' perceptions of the learning environment when a new curriculum or learning approach is being evaluated (Fraser, 1986, 1989), the *Computer Classroom Environment Inventory (CCEI)* was developed to assess students' perceptions of a learning environment which involved both the inquiry learning approach and the use of a computerised database. The five scales of the CCEI measure students' and teachers' perceptions of *Investigation, Open-endedness, Organisation, Material Environment* and *Satisfaction*. Table 1 clarifies the meaning of each of the five scales and gives scale descriptions and sample items, together with information about scale allocation and scoring. The total score for a particular scale is simply the sum of the scores for the five items belonging to that scale. The first item in each block assesses *Investigation* (the extent to which students in this class are encouraged to engage in inquiry learning). The second item in each block assesses *Open-endedness* (the extent to which the computerised learning environment emphasises an open-ended approach to inquiry). The third item assesses *Organisation*; the fourth item assesses *Material environment*; and the last item in each block assesses *Satisfaction*.

The cognitive outcomes of the study were evaluated by the *Inquiry Skills Test (IST)* which was designed to assess students' outcomes on the following three scales. The *Interpretation* scale measures the degree to which students are able to interpret information from tables and graphs and to compare the results of different investigations. The *Analysis* scale measures the degree to which students are able to draw conclusions from test results, explain relationships between two or more variables, and suggest explanations for data. Third, the *Application* scale measures the degree to which students are able to generate questions or hypotheses to extend the investigations and design appropriate information-retrieval techniques to answer each question or to challenge each

Table 1. Descriptive information for each scale of the *Computer Classroom Environment Inventory*

Scale name	Description	Sample item
Investigation	Extent to which the student is encouraged to engage in inquiry learning.	In these computer sessions, I find out the answers to questions by investigation. (+)
Open-endedness	Extent to which the computer activities emphasise an open-ended approach to inquiry.	In this class, the teacher decides the best way for me to proceed with my work. (-)
Organisation	Extent to which classroom activities are planned and well organised.	I find that the computer sessions are well organised. (+)
Material environment	Extent to which the computer hardware and software are adequate and user friendly.	The computers are not suitable for running the program that I use. (-)
Satisfaction	Extent to which the student is interested in using the computer and in conducting investigations.	In this class, I like using computers to learn. (+)

Note Items designated (+) are scored 1, 2, 3, 4 and 5, respectively, for the responses Never, Seldom, Sometimes, Often and Very Often.

Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3.

Table 2. Descriptive information for the *Inquiry Skills Test*

Scale name	Description	Sample item
Interpretation	Extent to which the student is able to interpret graphs and tables and compare results from different investigations.	According to the table, what happened to the number of nests from 1988 to 1989? a Both species decreased in number of nests. b Species x decreased in number, species y increased c Species x increased in number, species y decreased d Both species increased in number of nests.
Analysis	Extent to which the student is able to draw conclusions and explain relationships between variables.	The comparison will enable the scientists to: a decide why more tourists came this year. b calculate the number of birds next year. c see whether the number of nests increases or decreases. d find out the reasons for the differences in numbers.
Application	Extent to which the student is able to generate questions and design appropriate investigations to challenge each question.	What question can you ask that is related to the previous finding about the location of the nests? a Where did the birds come from? b What did the birds look like? c What factors influence the locations of the birds? d What did the eggs look like?

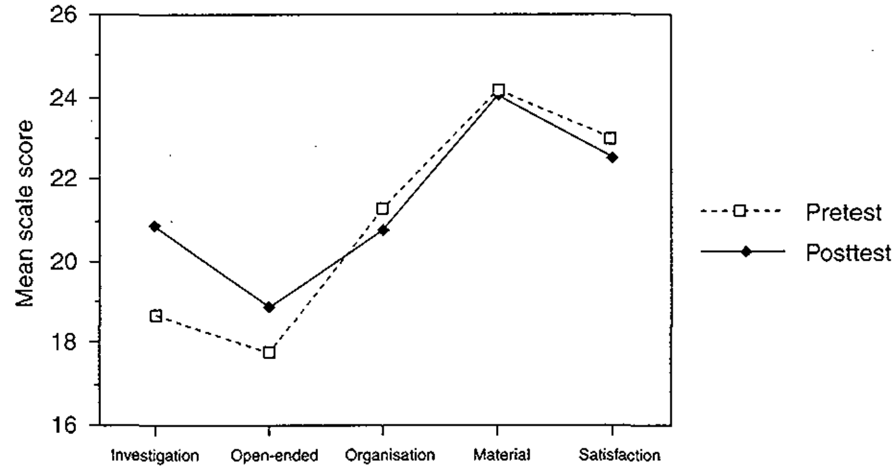

Figure 1. Students' prceptions of the learning environment (N = 120)

hypothesis. See example from the *Inquiry Skills Test* in Table 2.

One hundred and twenty students and six teachers responded to the *Computer Classroom Environment Inventory* and to the *Inquiry Skills Test* at the beginning of the study and five months later at the end of the program.

Results

Students' perceptions of the learning environment

To investigate changes in students' perceptions of their classroom environment, *t*-tests for matched pairs were conducted. For the *Investigation* scale, students' perceptions changed significantly ($p < 0.001$) towards a more investigative type of learning environment. From classroom observations, it appears that higher investigation score emerged because students engaged more often in inquiry learning and had opportunities to develop their inquiry skills as a result of interacting with the program. At the beginning of the program, students stated their hypotheses but did not try to support them. As the study progressed, students tried to give support to their initial hypotheses by designing new investigations. For example, students tried to find the relationship between birds' behaviour, their locations, and the ice condition in the area where the scientists recorded the observations. Based on their own experiences with the database, students were able to formulate hypotheses about bird species that they expected to find in particular latitudes and particular ice conditions.

For the *Open-endedness* scale, there was a significant change ($p < 0.001$) in students' perceptions. This suggests that the computer activity and the learning activities provided a more open-ended approach to inquiry than the students had experienced before the implementation of the computerised program. For example, entries in some students' booklets showed a transition from constructing narrow questions to formulating complex questions that were not confined to the content of the database. At the completion of the program, students were asked to act as researchers on the voyage and conduct their own investigation using the database as a source of information. For the *Organisation* scale, students perceived a small, but still significant ($p < 0.05$), decrease by the end of the program. Students did not perceive a significant change in the *Material Environment*; they generally perceived the facilities, hardware and software to be in good working condition. For the *Satisfaction* scale, students' perceptions generally indicated a relatively high degree of satisfaction both at the beginning and end of the program.

The results are summarised graphically in Figure 1 which shows the mean scores for students' perceptions of the classroom environment before and after implementing the program. Figure 1 illustrates that increases in students' perception scores occurred for the *Investigation* (0.7 standard deviations) and *Open-Endedness* (0.4 standard deviations) scales. The graph highlights that students perceived a learning environment which allowed more investigative and more open-ended work. Students' reactions to the program reflect the program's objective to promote inquiry skills. On the other hand, there was a small but statistically significant decline in the perceived level of *Organisation*. This is to be expected as inquiry learning is likely to free students to investigate, enable them to interact freely with the computer database and with other students in the class, and to expect less authority and a less teacher-centred approach. These phenomena in the classroom led some of the students to perceive a less organised environment.

Teachers' perceptions of the learning environment

Comparison between the teachers' perceptions and the students' perceptions at the completion of the program revealed a similar pattern (see Figure 2). However, teachers perceived the actual classroom environment more positively than the students on the three scales of *Open-endedness, Organisation* and *Material Environment.* Both groups perceived a similar environment on the *Investigation* scale, and only on the *Satisfaction* scale were teachers' perceptions less positive than the students' perceptions. From interviews

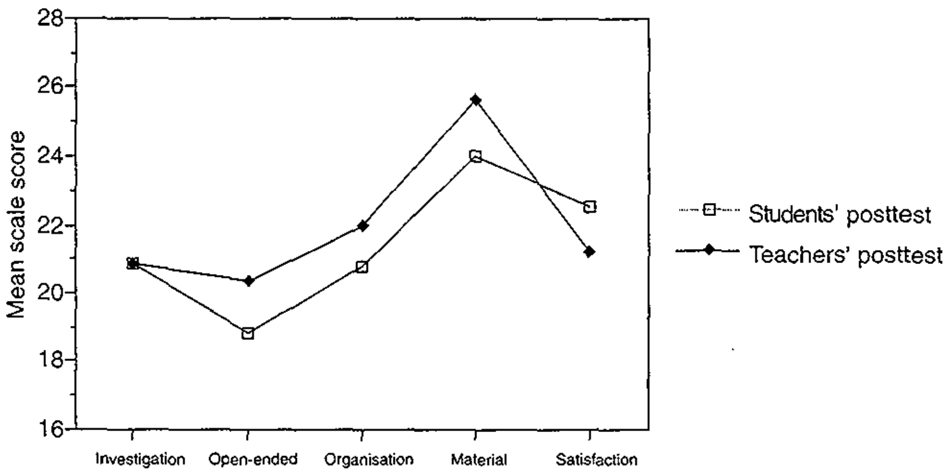

Figure 2. A comparison of teachers' and students' perceptions of the learning environment

the teachers' main concern was that it took too long for the students to complete the program and the task seemed too difficult for some students. Also interviews suggested that the students were more positive about the program than the teachers anticipated and felt that they benefited from this learning experience.

The results, which showed that the teachers perceived the classroom more positively on several scales of the learning environment than did their students in the same classrooms, are similar to the pattern emerging in other studies in school classrooms (Fisher & Fraser, 1983). These studies inform educators that students and teachers are likely to differ in the way in which they perceive the environment of the same classroom.

Student achievement of inquiry skills

The specially designed *Inquiry Skills Test* was administrated to provide data concerning students' inquiry skills achievement. An item analysis of the test showed a reliability coefficient of 0.74. As illustrated graphically in Figure 3, there was an increase in students' mean scores on the total *Inquiry Skills Test* and on the subscales. Students' ability to investigate and solve problems increased significantly for the total test (0.5 of a standard deviation) and the three subscales of *Interpretation, Analysis* and *Application*. A larger effect size was found for the *Interpretation* scale (0.8 of a standard deviation) and the *Application* scale (0.5 of a standard deviation) than for *Analysis* scale (0.3 of a standard deviations). These effect sizes are greater or comparable to the average effect size of a 0.4 standard deviation that was found by Fraser, Walberg, Welch, and Hattie (1987) in a synthesis of meta-analysis of 7827 past studies. Overall, the results of the *Inquiry Skill Test* suggest that, after five months of interaction with the computerised database, a meaningful improvement occurred in students' achievement of inquiry skills.

Discussion

The use of the *Computer Classroom Environment Inventory* mainly gave an indication of whether students' and teachers' perceived opportunities to investigate in this new learning

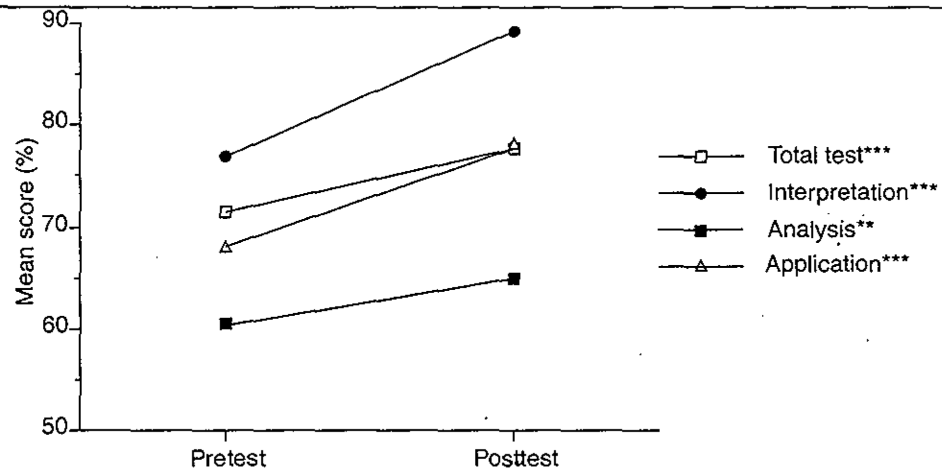

Figure 3. *Inquiry Skills Test* mean scores for whole sample (N=120)
**p<0.01 ***p<0.001

environment and whether the program encouraged open-ended learning opportunities. Overall, the results indicated the positive effect of the program in promoting perceptions of a more investigative and open-ended learning environment. The increase in students' perception scores on the *Investigation* and *Open-ended* scales suggests that the program created a supportive learning environment for the development of inquiry learning. The general reactions of students and teachers to the program reflected the objective of the program to promote inquiry skills. The inquiry-oriented computerised learning environment in this study permitted students to develop inquiry skills. This environment is one step further in preparing students for "tomorrow's society" (Yeany, Yap & Padilla, 1986) by providing opportunities for students to be inquirers and to design investigations, as recommended by science curriculum reformers (American Association for the Advancement of Science, 1989; Shymansky & Kyle, 1991, 1992).

On the whole, information emerging from analysis of the test data suggests that an improvement occurred in students' inquiry skills as a result of interacting with the computerised database and being involved in inquiry-oriented learning activity.

A qualitative component of the study reported elsewhere (Maor, 1993; Maor & Fraser, 1993; Maor & Taylor, 1994) suggested that the use of a computer database freed students from having to collect and organise data before undertaking investigation. The database enabled students to focus on their problem-solving techniques and promoted the development of inquiry skills such as analysing relationships, discovering commonalities or differences between groups and events, and looking for trends or patterns. The data in the computerised database can be used to help students construct and test hypotheses and clarify their thinking to themselves and to each other by asking creative questions.

Note

Since the original study was conducted, the scientific database *Birds of Antarctica* has been upgraded to form a more user-friendly and more attractive program for student use on the personal Macintosh computer. Teachers who are interested to use the program for classroom teaching or research are encouraged to contact the authors.

A copy of the *Computer Classroom Environment Inventory* is available from Dr Dorit Maor at the Science and Mathematics Education Centre of Curtin University of Technology.

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