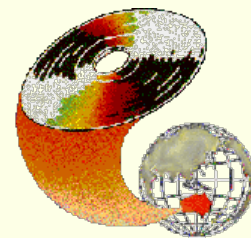


# Developing a multimedia package for teaching thinking skills



Dorit Maor and Rob Phillips  
Curtin University of Technology

This paper discusses the development of an interactive multimedia program to support the development of scientific inquiry skills amongst secondary students. The program simulates a complex learning environment based on observational data recorded from actual voyages to Antarctica. It is intended to put into practice a number of educational theories and approaches, and to create a constructivist, guided discovery learning environment, capable of supporting and facilitating the development of such thinking skills as analysis, synthesis, hypothesis generation and testing and the design of creative investigations.

This paper discusses some of the design decisions made in attempting to embody these ideas. We trace the evolution of the package through several stages of prototype development, building on a fairly basic, user unfriendly database to create an intuitive, interactive multimedia environment.

---

## Introduction

On a typical voyage to Antarctica, scientists from the Australian Antarctic Division record full details of any birds observed. There are currently approximately 75,000 records in this database of observations. We have attempted to use this rich source of data as a vehicle to promote scientific inquiry skills among secondary school science students. A constructivist approach has been used to guide the students in developing their own inquiry skills and to promote learning for understanding in the science classroom.

The first question that arose was how to access such a large amount of data in a way that could be easily assimilated? Previous work (Maor, 1993) had used a database query approach to interrogate the data. This utilised boolean queries in a very 'computer oriented' user interface. While this approach was the most obvious in terms of implementation (after all, the data is stored in a database, so why not use a database query language?), it abstracted the data from the contextual reality of a scientific inquiry. In particular it is difficult for students to make the connection between real scientific data from voyages to Antarctica and the displays appearing on their screens.

In this work, we have taken the view that a visual approach, using interactive multimedia (IMM) to simulate the shipboard environment, would be effective. We are attempting to create an attractive 'game like' interface in order to motivate the students. In attempting to situate the learning in the environment of an Antarctic research voyage, the design of the user interface requires extensive formative evaluation. This paper discusses the educational rationales for some of the design decisions made, and traces the evolution of the prototype through several stages.

## Theoretical framework

The promotion of higher level thinking skills amongst high school students is a significant goal of science education. Therefore, the teaching of science should be consistent with the spirit and character of scientific inquiry and with scientific values. "This suggests such approaches as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity" (*Project 2061*, American Association for the Advancement of Science, 1989, p. 5).

Furthermore, Burbules and Linn (1991) suggest that one of the goals of science education is to help students to develop the ability to generate fruitful and relevant questions, and frame them in an effective way for investigation. One way to do this is by asking students a variety of rich and complex questions in order to enhance their development of thinking skills. This involves requiring students and teachers to compare, to contrast, to justify, to synthesise - all skills which characterise flexible, creative and effective thinking. Variety in questioning also includes planned progression from simple to complex questions, from the specific to the general, as knowledge is constructed. Questions arise initially with the teacher, however the complementary and related questions raised by students are valued, and are used to extend the investigation into areas meaningful to the students.

Cooperative learning tasks, in which students work together as a team to conduct an investigation and to solve a problem, are also desirable for supporting and enhancing the development of thinking skills. Maor (1993) found that, when using a computerised database for instruction, a constructivist learning environment was effective. This environment emphasised social interaction and provided students with enhanced opportunities to develop higher level thinking skills, which included the ability to conduct complex investigations and to generate creative questions. Constructivist teaching/learning approaches focus on learners constructing their own understandings, and on social interactions taking place in the classroom.

The higher level learning described involves students in extending their own or other students' ideas by negotiating meaning and reflecting on one another's questions and tentative solutions. To promote higher level thinking skills, ideally students are allowed to negotiate solutions to problems, to select their own learning techniques, to evaluate learning outcomes, to analyse and discuss one another's creations and to generate their own questions.

While computer applications are believed to have much potential for science education, generally this promise is not supported by empirical evidence. The reason for students not learning higher level thinking skills is that students do not have sufficient opportunities to engage in intellectual tasks while they are interacting with the computers. The technology today, according to Heppell (1994), has advanced to a point where the question is not "what can I do?" but rather "what do I want to do"? and, therefore, has the potential to provide students with opportunities to engage in intellectual tasks. However, according to the IEA international study of computers in education, the integration of computers into school life is still at the beginning stages, even in the most advanced countries (Pelgrum & Plomp, 1993). Nevertheless, Plomp and Voogt (1995), argued that for science education simulations, microcomputer based laboratories and databases can facilitate understanding of science concepts as well as the development of science process skills. In particular we want to guide the students through a scientific inquiry process consisting of the following steps:

- identify the problem
- generate an hypothesis
- plan an investigation
- collect the data
- interpret the data
- reflect on, compare and negotiate proposed solutions.

This raises the question of how to design computerised learning environments that foster constructivist learning. Recently, David Jonassen (1994) published an article in *Educational Technology* which suggested that the construction of knowledge might be facilitated by learning environments which

- provide multiple representations of reality
- avoid oversimplification by representing the natural complexity of the real world
- focus on knowledge construction, not reproduction
- present authentic tasks
- provide real world, case based learning environments
- foster reflexive practice, and
- support collaborative construction of knowledge through social negotiation, not competition.

The software that we have developed is guided by these characteristics. To create the constructivist

features of this learning environment, the new multimedia package is intended to simulate real world learning environments, provide multiple representations of data, engage students in personal construction of 'reality', enable the students to generate their own investigations and promote social negotiation and reflection on real life issues.

In addition, the learner is guided by a coaching and scaffolding approach which familiarises the user with the different functions of the program and the possibilities of activities. The scaffolding approach provides support for the students through the advice of a virtual agent or mentor. Gradually the support is removed to enable the learner more control of the learning. It is envisaged that further support will be given by the teacher in the classroom.

## **A voyage to Antarctica**

In developing the multimedia package *A voyage to Antarctica*, we wanted to provide opportunities for students to develop higher level thinking skills. In order to achieve this, students should be actively involved in the learning process. Research (Maor, 1993; Maor & Taylor, 1995) has shown that a largely constructivist approach to teaching and learning in computerised learning environments provides significantly greater opportunities for students to be involved in negotiation of their own learning, and to generate creative questions for which they design and conduct their own complex scientific investigations. The teacher can challenge students with questions that stimulate discussion about the computer program. In one class included in Maor's 1993 study, discussion between teacher and students was an integral part of the program, and students often negotiated meanings and argued their ideas in the whole class forum. By verbalising and reflecting on their own thinking, students became aware that they were performing an active role in their own learning processes. The teacher's constructivist oriented pedagogy enabled the majority of students to develop higher level thinking skills such as thinking critically, asking creative questions and undertaking inquiry oriented problem solving.

The IMM package *A voyage to Antarctica* is intended, therefore, to create a learning environment in which students are offered enhanced opportunities to develop higher level thinking skills. During the initial stages of using the software, relatively closed questions will be provided to the student. The questions suggested will gradually decrease in specificity, and increase in conceptual difficulty, as students demonstrate higher level inquiry skills. Finally, students will be encouraged to construct their own original investigations, following their individual interests and incorporating their existing knowledge.

## **Description of the program**

The basic premise of this program is that students can develop scientific inquiry skills by taking a simulated journey to Antarctica. We simulate the journey of a typical Antarctic exploration ship, such as the *Aurora Australis*, using actual scientific data based on observations of seabirds made by scientists from the Australian Antarctic Division during these journeys for many years. Currently, 75,000 records of data on up to 29 observation variables are available.

A key design aim was to enable flexible interrogation and display of the data without the complex boolean queries used in previous version (National Information Technology Committee, 1984). For example, in previous versions, in order to answer the question "What sort of birds were found when the wind speed was greater than 35 knots and the air temperature was less than -5° C" students were expected to perform queries such as

*Select data where Wind Force > 8 and Air Temp < -5*

This required students to use a specific syntax which prevented some students from engaging in inquiry learning and developing inquiry skills.

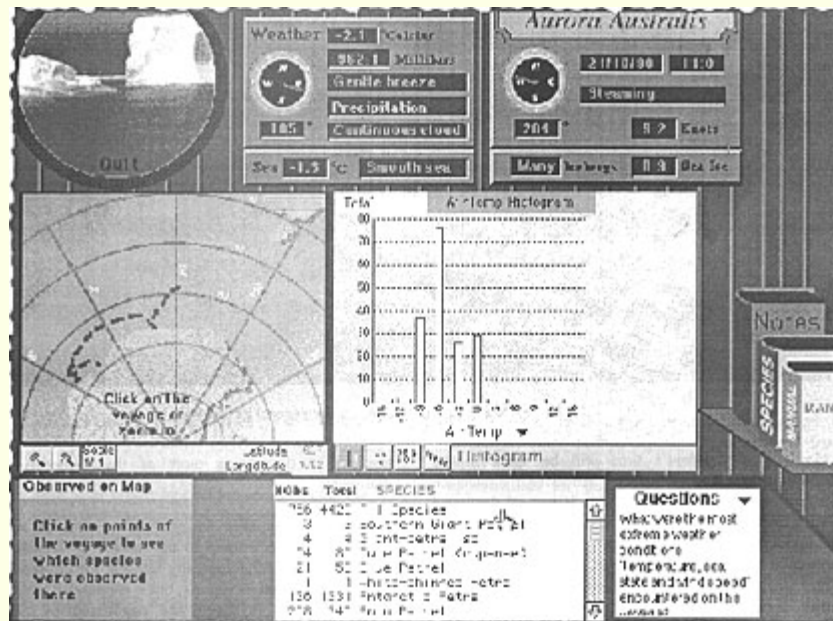
It was felt that appropriate use of graphs together with some simplifying assumptions would enable a rich range of data and queries to be visualised. Access to the data was simplified by imposing the restriction that only one voyage could be investigated at a time. A second simplification was that selections from the

data could only be made on one variable at a time. With one variable selected, up to two other variables can be compared by graphing them either as histograms, scatterplots or two-dimensional frequency plots. In this way, the interrelationships of up to three variables can be viewed at the same time, without complex boolean queries. The use of graphs also allows a range of values of one or two variables to be displayed simultaneously, thus facilitating comparisons of the information. Other data displays include tables of data, summaries and simple statistics such as minima, maxima and means.

## Prototype 1

Given these basic design aims, together with a constructivist approach, a first prototype was developed. While other parts of the ship were envisaged for future versions, development here focussed on the analysis and display of the data, in order to determine whether the assumptions made above about data interrogation and display were valid and feasible.

The user interface is that of a laboratory on board ship (shown in Figure 1), with *control panels* which display weather conditions and voyage data. A *map* shows the progress of the voyage, and current weather conditions are seen through the *porthole*. The observation details are displayed on the *desk*. Data is interrogated principally through graphs: histograms, scatterplots and two-dimensional frequency plots. Students are guided through their work by a carefully designed series of questions which are progressively more open ended.



**Figure 1:** The 'laboratory' on board ship in the first prototype.

[Unfortunately some detail has been lost in reducing the image to fit on the page.]

All possible representations of the data were displayed at the same time in this prototype. Advantages of this were that multiply linked representations of the data could be displayed. For example, clicking on the map would display the weather conditions for that location in the control panels. Selecting a species would highlight the occurrences of these birds on the map.

Prototype 1 was reviewed by a group of peers on several occasions, and despite the attractive graphic style, it became clear that the interface contained several deficiencies. The most striking of these was that the screen was too cluttered. While there were advantages in displaying all variables simultaneously, the visual overload meant that it was difficult for the eye to know where to look. On analysis, it also became clear that this screen was trying to display two distinct types of data; individual observations from a particular data record (map and control panels); and aggregated data such as that displayed in the graphs. The user interface needed to be simplified and the functionality of the data displays more clearly defined.



A further problem with the first prototype was that its response time was too slow. Subsequent versions needed to be more responsive to be useable by students.

## Prototype 2

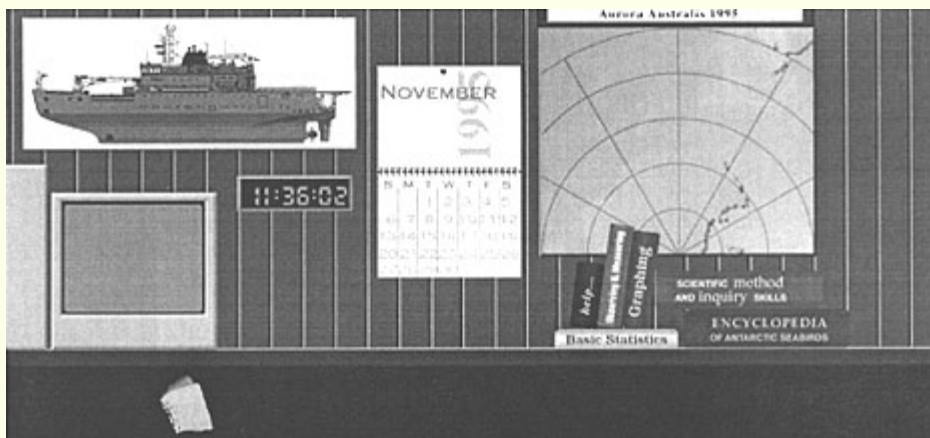
Evaluation of prototype 1 demonstrated that the proposed method of data visualisation was effective. Development then focussed on addressing the problems identified in the first prototype and on a more comprehensive design of the simulation aspects of the project.

Instead of simply placing students in a room 'on a ship, we sought to situate student learning in a simulated research voyage to Antarctica. By using simulations and aspects of computer gaming, we hoped to enhance the interest and commitment of students. In the sense of the simulation, the student begins the journey as a junior researcher. The student's goal is to move up through the levels of a 'scientific career' - from junior researcher to senior researcher. At initial levels, only some observation variables will be available to the student. At subsequent levels, more variables will be made available, so that more complex queries can be made of richer data.

A set of data from an existing voyage is used as the basis of the simulated voyage. At given time intervals, relevant records of data are displayed as if they have just been observed, but on an accelerated time scale.

The student will perform various activities on the ship, in various locations, in order to reinforce the experience of a voyage. Navigation is achieved by a map of the ship on the wall of each room, as shown in Figure 2, with rooms cut away and highlighted. Clicking on each room takes you to that room. The locations are the

- training room, where the student can learn about the tasks required
- observation deck, for observation and to familiarise students with the range of ornithological variables available
- bridge, for observation and to familiarise students with the range of navigation and meteorological variables available
- laboratory, where most of the real scientific work occurs. This incorporates most of the functionality of the first prototype galley, where potential social interactions will take place.



**Figure 2:** The revised laboratory used in the second prototype

A key design goal of the program is for students to be able to reinforce their learning by making notes and reports, and discussing their findings with colleagues. This is implemented through a notebook, which is carried everywhere to record ideas, observations, hypotheses, and to report findings.

Most of the student's time will be spent in the laboratory, as before (Figure 2). However, the interface is

less complex because the data is not all displayed simultaneously. Aggregated data is displayed and manipulated on a 'computer', whereas individual observations are displayed on a map and control panels. Both the map and the computer expand to fill most of the screen when they become active.

Background material of several types will be available in the form of books to support the learning. These support materials are

- information about the scientific method and inquiry skills
- information about graphing
- information about basic statistics
- encyclopaedic information about seabirds observed in Antarctica.

The student is mentored by a simulated research scientist, who provides scaffolding to the learning by advising appropriately when required. The mentor communicates with the student by simulated email. A series of questions are presented to the student to guide them through the scientific inquiry cycle. This involves identifying the problem, generating an hypothesis, planning an investigation, collecting the data, interpreting the data and reflecting on the solution through discussion and negotiation with peers and teacher. During the initial stages, the questions provide many hints and suggestions on how to approach the problem. The following section provides an example of an email dialogue between mentor and student. Subsequent questions contain progressively less scaffolding and are more open ended. Part of the formative evaluation process will involve students and teachers in developing more of these questioning dialogues.

Students are required to produce reports in their notebook and send these to the mentor by simulated email. It is not technologically feasible for the mentor to analyse the student reports, but it is intended that the reports will be reviewed and negotiated by other students and the class teacher. A very important educational design goal is to promote social construction of knowledge by having students discuss, argue and defend their interpretations with other students. In a networked environment, reports from other students can be viewed online, thus initiating online computer mediated discussions as well as discussions in class. However, in classrooms without networks, face to face discussions will be carried out while gathered around a screen, or over printouts.

## **Representative dialogue between student and mentor**

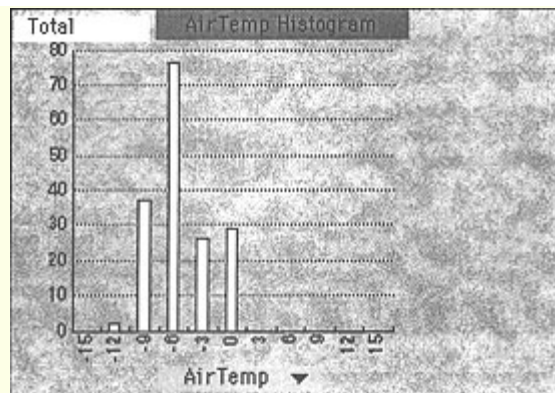
Students receive information and guidance by simulated electronic mail on the 'computer' in the laboratory. Essentially, the senior scientist, or mentor, sets a series of assignments for the junior scientist, or student. Students are expected to respond by submitting a report generated in their notebooks. The mentor responds to the student identifying the parts of the scientific inquiry process performed (shown here in bold), and posing follow up questions.

The mentor puts the initial question in this form

It gets pretty cold on some of these voyages. Sometimes it is stormy for weeks. I remember back in 1981 that it was a really bad voyage. Why don't you try to find out what were the most extreme weather conditions. You might try to make some histograms of variables such as the air temperature, wind force, etc.

Start your report by clicking and dragging the graph onto the notebook. Add your own comments. Send me your report by attaching it to an email message when you have finished.

The student had to select the specific voyage for 1981, and then had to plan an investigation of how to find the most extreme weather conditions. The student is advised to select a histogram as shown in Figure 3, but can choose other modes of investigation. A hint was given to try air temperature and wind force, although other meteorological variables are available. A graph is produced with associated statistics on it. The student drags the graph onto the notebook for later reference, adds some comments and emails it to the mentor.



**Figure 3:** Histogram of air temperature for the 1981 voyage

The Mentor responds by pointing out some of the processes the student may have gone through, and poses a follow up question

We have just been through the initial stages of a scientific investigation. I *identified the problem* and you *planned the investigation* by choosing to display the data in histogram form, and selecting the relevant variables for display.

Looking at your results, I seem to remember the weather was worse than that. It must have been in 1980 or 1982. Can you check this out for me in the same way you did the first investigation? After you collect the data in your notebook, send me your interpretation of the results.

The student selects voyages for 1980 and 1982 and creates the same graphs as before, and drags them onto the notebook so the three graphs for 1980-1982 can be compared and the stormiest voyage identified. Students who selected air temperature and wind speed to investigate may have a different interpretation from those who chose only one variable. This provides opportunities for discussion between students. The mentor responds

Great! You may have noticed how we did this. I *generated an hypothesis*. (The weather was worse in 1980 or 1982). You followed the same *plan of investigation* as the previous time, and used this to *collect the data*. Finally, you *interpreted the data* and sent me the report.

One of the most important parts of any scientific investigation is to *reflect on your interpretation* to see if it is really useful and can be justified. One way to do this is to attempt to display the data in a different form, perhaps by selecting the most extreme conditions observed, and displaying the selected data as a table. Another way to check your interpretation is to compare and contrast your conclusions with those of other students.

Send me a revised report justifying your interpretations.

The student selects a different representation of the same data to confirm their interpretation. The students then discuss their interpretations with other students and find that there is a range of possible interpretations of the same problem.

Depending on the variables selected, different students could arrive at different interpretations at this stage, and the mentor gives much briefer advice now on how to proceed.

What other investigations can you do to verify your conclusions? Be sure to *state your hypothesis* clearly in your report before starting.

It is appropriate at this stage for students to discuss with their teacher their experiences and the reasons for the range of interpretations. The dialogue goes on to ask students to identify which birds were observed at these weather conditions.

The dialogue approach used in the above example is a potentially powerful way of initiating communication between the student and the computer. Laurillard (1993), in her discussion of the ideal teaching-learning process, identified the lack of discussion between computer and student as one problem of computer based educational programs. The dialogue shown here simulates this discussion to some extent. The major drawback is that the computer is not able to interpret the student's report and adapt its response accordingly. Further advances in artificial intelligence will be required before this is feasible. However, the teacher's role is important in providing students with feedback and initiating discussion.

## Summary

This paper describes the design and formative evaluation of an interactive multimedia package based on data collected during research expeditions to Antarctica. It traces the evolution of prototypes through the early stages of development. The aim of the program is to help students develop scientific inquiry skills. This is accomplished through simulated research expeditions to Antarctica.

The design of the program is based on previous research by Maor, and on a framework of sound educational theory. It attempts to take the theoretical issues of inquiry learning and a constructivist learning approach and implement these in an interactive multimedia environment. The underlying data and the educational issues are both very complex, and this has made the design of an intuitive user interface a challenging task. Ongoing formative evaluation will surely lead to more revisions of the program.

In addition to the formative evaluation already described, and that still to come, summative evaluation of the completed package will take place during the next two years. This research will investigate how the use of computers in inquiry based secondary school science classrooms can promote the goal of higher level cognitive learning. It will encourage teachers to adopt constructivist teaching approaches in their attempt to emphasise learning for conceptual understanding. Qualitative ethnographic methods will be combined with quantitative information based on students' and teachers' perceptions about their learning environment in order to explore the rich and complex world of students and teachers interacting with a computerised learning environment.

As part of the research we will conduct a series of workshops for teachers intended, firstly, to empower teachers to become comfortable in using computers in science classrooms and, secondly, to enhance teachers' understanding of, and ability to use, personal and social constructivist approaches to teaching and learning in the computerised learning environment.

## References

- American Association for the Advancement of Science (AAAS) (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics and technology*. Washington, DC: AAAS.
- Burbules, N. C., & Linn, M. C. (1991). Science education and philosophy of science: Congruence or contradiction? *International Journal of Science Education*, 13, 227-241.
- Heppell, S. (1994). Learning and the children of the information age. In C. McBeath and R. Atkinson (Eds), *Proceedings of the Second International Interactive Multimedia Symposium*, 200-203. Perth, Western Australia, 23-28 January. Promaco Conventions. <http://www.aset.org.au/confs/iims/1994/hj/heppell.html>
- Jonassen, D. H. (1994). Towards a constructivist design model *Educational Technology*, 34, 34-37.
- Laurillard, D. M. (1993). *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology*. London, Routledge.
- Maor, D. (1993). *An interpretive study of the development of students' inquiry skills in a computerised classroom environment from a constructivist perspective*. Unpublished doctoral dissertation, Curtin University: Perth, WA.



Maor, D. & Taylor, P. C. (1995). Teacher epistemology and scientific inquiry in computerised classroom environments. *Journal of Research in Science Teaching*, 32, 839-854.

National Information Technology Committee (NICT) (1984). *Birds of Antarctica, Antarctic science database, User manual*. Hobart, Tas: Elizabeth Computer Centre.

Pelgrum, W. & Plomp, T. (1993). *The IEA study of computers in education: Implementation of an innovation in 21 education systems*. Oxford: Pergamon Press.

**Authors:** Dr Dorit Maor  
Science and Mathematics Education Centre  
Curtin University of Technology  
GPO Box U1987, Perth WA 6001  
d.maor@info.curtin.edu.au Tel: +619 351 7381

Dr Rob Phillips  
Computing Centre  
Curtin University of Technology  
GPO Box U1987, Perth WA 6001  
r.phillips@info.curtin.edu.au

**Please cite as:** (1996). Developing a multimedia package for teaching thinking skills. In C. McBeath and R. Atkinson (Eds), *Proceedings of the Third International Interactive Multimedia Symposium*, 242-248. Perth, Western Australia, 21-25 January. Promaco Conventions.  
<http://www.aset.org.au/confs/iims/1996/lp/maor.html>