Review

The role of information technology in biology education: an Australian perspective

Mary Peat[1] and Anne Fernandez[2]
School of Biological Sciences[1], and UniServe Science[2], Faculty of Science, University of Sydney, Australia

The potential use of IT in secondary biology teaching is enormous, although it is a huge undertaking and fairly daunting to newcomers. Computer learning packages and the web can offer a variety of opportunities for learning, ranging from non-interactive content provision to highly interactive student-centred learning experiences. The learning materials in use in New South Wales (NSW) schools include information web sites, computer learning packages as tutorial or revision material, computer learning packages made by the students, virtual field trips, simulations, and virtual laboratories. In addition, students and teachers are using the web for communicating amongst themselves via email, newsgroups and discussion lists, videoconferencing for both local and global communications, and telecollaborative projects. This article will focus on materials used in student learning, and on the forms of electronic communication in use within the school system. A list of resources is provided.

Key words: Learning materials, Web communication, Information technology, Secondary schools, Australia.

Information technology in education

Using information technology (IT) as a learning tool has huge potential, but can be intimidating to the novice. In the early half of the century, hundreds of patents for technology based 'teaching machines' were lodged. These machines were used mostly for assessing learning and the feedback given was in the form of 'correct answer' or 'incorrect answer'. The dream of the 1950's, after the completion of the first business machine, was to use computers as patient teachers, scrupulous examiners, and tireless schedulers of instruction (Alexander and Mackenzie, 1998). It was thought that students would benefit from being able to follow their own learning pathway, at their own pace, and when it was convenient to them. Computers are now more powerful and faster, with improved capabilities in images and sound. For 30 years, computer assisted learning (CAL) packages have been helping students in their studies. Recently, several factors have developed simultaneously to alter the emphasis of the use of computers in learning. The most important is that the ubiquity of computer networks has opened up the world. There have also been three significant factors which have had an impact on education: first, the convergence in digital technology has provided user-friendly multimedia instructional platforms; secondly, the emergence of a cognitive learning theory that emphasises inquiry; and finally, there has been a marked change in the needs of society, whereby the work force of tomorrow needs to be encouraged to have the skills of abstraction, system thinking, experimentation, and collaboration (Awbrey, 1996).

Up to the mid 1990's, computers were thought of as providing an information resource, as a drill and test assessment aide, and as model makers (simulations). Computers are more than this today, and teaching IT skills in isolation from the educational context is no longer considered sufficient to make a difference to students. Instead of teacher professional development being directed specifically towards IT skills, it now focuses on 'teachers learning technology skills' which includes: curriculum applications; school planning; student-centred learning; and IT skills. Graham and Martin (1998) also stress that 'the purpose of introducing technology into the classroom should be to enhance teaching and learning, and its use should be structured and evaluated in these terms ... at the same time there is a need to recognise that students need to develop technological skills as an essential learning tool'. Laurillard (1994) emphasises that all technology-based activities should have a clearly defined purpose, address student needs, and be accompanied by some form of teacher guidance. Some Australian states now include the integration of information technology in the curriculum. The NSW Board of Studies is including integrated IT experiences in the new senior secondary (Years 11 and 12) science curriculum currently (1998 – 1999) under development.

Computer learning packages and the web offer a variety of ways in which learning experiences can be offered to students. These range from the non-interactive content provider to the highly interactive student-centred experience. All of them have educational potential, providing greater flexibility by creating

learning environments that are accessible to individuals with a variety of learning styles. IT can assist in overcoming many of the barriers faced by students.

In the 1996 survey of the use of IT in science teaching, UniServe Science (Johnston, 1996) found that the main uses could be classified as: pedagogical (information web sites, CAL packages, etc.); expository (teaching aides e.g. simulations during lectures, *PowerPoint* presentations); and apprentice (students learning to use the computer to develop professional skills). The most effective examples are those that encourage exploration and empowerment, rather than prescription and control. They enable the teacher to move from being 'a sage on the stage to a guide at the side'.

The use of CAL materials in instructing students is fairly well established in the school system, as it is in the university system. The Internet allows the mixing of teaching materials of published, commercial software programs (CAL) with resources of often unknown pedigree, background, and quality. Care is needed in sifting through these. The major advantage of the Internet might be considered to be the interactive communication capabilities afforded by virtual access, virtually anywhere, and virtually anytime. This paper will concentrate on how the use of IT and the web is changing student learning experiences. Emphasis will be given to information delivery and communication.

Table 1 Numbers of NSW students studying a science in their final year in 1996 – 98.

Science Subject	*Number of students 1996*	*Number of students 1997*	*Number of students 1998*
Biology	14 199	14 412	14 930
Chemistry	10 383	10 180	10 283
Geology	239	235	265
Physics	9404	9149	9322
General science	2057	2047	2008
Science for life	4350	3914	3601

Biology in Australian schools

The majority of students in Australia are required to study general science for the first 4 years of secondary school. They then specialise for the final 2 years, and those interested in science may, in most states, opt to do one or more of physics, chemistry, biology, geology, science for life, and general science. The largest candidature in NSW is for the biology course, and many of these students also take another science subject (see Table 1). Students studying biology in NSW are required to cover a number of core areas and one of several electives (see Appendix).

The following is a cataloguing of materials available on the web and/or as discrete CAL packages, with an indication of the use of each type of material. Information is given in the resources section at the end of the paper.

Learning materials

Information web sites

In this category are sites which offer a reservoir of information for both teachers and students. Much of this information is not authenticated (caution should be exercised in recommending net-surfing without clear guidelines) and much of it is in a non-interactive 'textbook' mode. The advantage of information on the web is that it can easily be updated, and thus offers students access to current information. This is a considerable advantage over aging textbooks, e.g. following the aftermath of a coastal oil spill. Students also become more aware of the fact that information has a shelf life (web sites come and go, and web information is constantly updated).

Two information sites used for teaching biology are:

- The Genetics Society of Australia web page contains links to on-line educational resources for biology teachers; and
- The Australian Academy of Science web site provides teachers and students with accurate and up-to-date information about scientific issues reported in the media. All topics include: key text which gives a balanced summary of the main points; glossary of commonly used scientific terms; activities; further reading; and useful sites. Two of the current topics that relate to biology are: 'Pointing the bone at osteoporosis' and 'Getting our heads around the brain'.

Good quality web sites are invaluable sources of information for all students, and allow them to make decisions on the direction of their learning. A recent on-line resource for students studying for their final year examinations — NSW HSC On-line — is currently being evaluated with respect to effective student learning (Jeffries and Davies, 1998).

CAL packages as tutorial or revision material

Computer assisted learning (CAL) is particularly powerful for concept reinforcement. The main perceived benefit of this type of program is the increase in student motivation. In addition, viewing the animations as a class facilitates discussion and may bring to light misconceptions which can then be dealt with at class level.

There are a number of packages directed specifically at the Australian market. *Acacia Revise Biology* is a study companion and revision resource appropriate to senior biology courses in most Australian states. CSIRO (Commonwealth Scientific and Industrial Research Organisation)'s *Dynamic Rainforest* (including teacher

Figure 1 Life in the canopy of an Australian Tropical Rainforest from the Dynamic Rainforest

notes and student activities) captures the life, colour, and complexity of Australia's unique tropical rainforests (see Figure 1).

Many CAL packages are now also available on the web. For example, *The Heart: An Online Exploration* takes the student on an on-line tour to learn about heart development, structure, function, blood, and blood vessels.

There are many computer aided learning packages available. Some offer high levels of interactivity and encourage students to be active learners, others are more like page-turning exercises, offering little that is not available in a book. Some packages are designed to provide collaborative learning opportunities through interaction and interactivity in the teaching and learning process (Souleles, 1998); others are designed for one-on-one activity.

Tutorials specifically designed with high student interactivity are more likely to engage the student in higher cognitive processing (Franklin and Peat, 1998). CAL designed to allow for multidirectional movement through the package accommodates the different preferences students have when interacting with the materials. Students are being encouraged to take responsibility for their learning.

CAL packages created by students as a learning experience

Ebert and Strudler (1996) use *HyperStudio* with secondary students to develop interactive multimedia projects covering aspects of water pollution, water cycles, and related topics. This is an example of using a simple authoring tool to get students to create materials through project work. The process of making their own multimedia projects is a powerful learning tool, and the computer skill base is increased. A variation on this scenario is to ask students to assess the value of a software product with respect to a particular task. Reissman (1999) found that this approach challenged students and helped to develop their critical thinking skills.

Virtual field trips, simulations, and virtual laboratories

To recreate an experiment or field experience electronically allows students to take part in activities not available in the lab. Two packages available to schools — *Investigating Lake Iluka* and *Exploring the Nardoo* (see Figure 2) — allow learners to participate in authentic activities in realistic and relevant fields (in this instance, field ecology). The packages provide experience of, and appreciation for, multiple perspectives, by allowing users to access and collect media information and construct their own understanding of the basic ecological concepts involved (Harper, 1997).

Ecotrekker: An environmental mystery introduces students to issues in coastal ecology and the scientific approach to monitoring environmental problems. The package includes teacher notes, student activities, and worksheets. *Ecotrekker* was recently used with a group of NSW Science Gifted and Talented students. Although a number of them felt it was a rather simplified model, it did help them focus on the environmental issues being addressed. Some of the students commented that: 'It showed me problems I never knew about and now I can see that where I live there are also water problems'; 'The graphs showed how the problem developed over time'; 'It made me more aware of how fish levels could be disturbed'.

Virtual field trips help students develop the skills and ideas required before visiting a field site or allow the students to 'visit' inaccessible sites of biological interest. *A virtual field trip — plant collecting in Western New South Wales* can be used with the NSW biology elective, The Australian Environment. The virtual field trip *Blue Ice: Focus On Antarctica* takes participating classes on an Internet journey in either of two concurrent units — 'Food Webs' (Life Science) and 'Weather/Climate Change' (Earth Science). Students collect and analyse data, research wild life and weather topics, and interview scientists.

On-line simulations and demonstrations can be powerful triggers to the learning process. For example, *Cells Alive* presents microscopy of living cells and organisms.

Virtual laboratories are useful when real laboratories are not available. Examples include *The Interactive Frog Dissection* which leads the student through a dissection, and *Virtual FlyLab* which allows students to play the role of a research geneticist. The latter is an educational application, where they learn the principles of genetic inheritance by mating virtual fruit flies and analyzing the resultant offspring.

With declining teaching budgets and increasingly busy curricula, virtual field trips are powerful aides to classroom success. Bitner *et al.* (1999) have found that the use of virtual field trips increases students' abilities to solve real world problems and to integrate the use of several applications in the production of multimedia presentations. Simulations and virtual laboratories help create authentic experiences often not possible in the school system, and using them encourages discovery learning which is considered by some to be the key to developing deep, flexible, and transferable knowledge.

Communication

At the base of all good teaching and learning models is effective communication, and today's schools are turning to the use of both asynchronous and synchronous computer-mediated communication to enhance the learning experience of students.

E-mail, newsgroups, and discussion lists

E-mail communication is one of the major uses of the Internet in schools, as it provides a fast, simple, and achievable way for

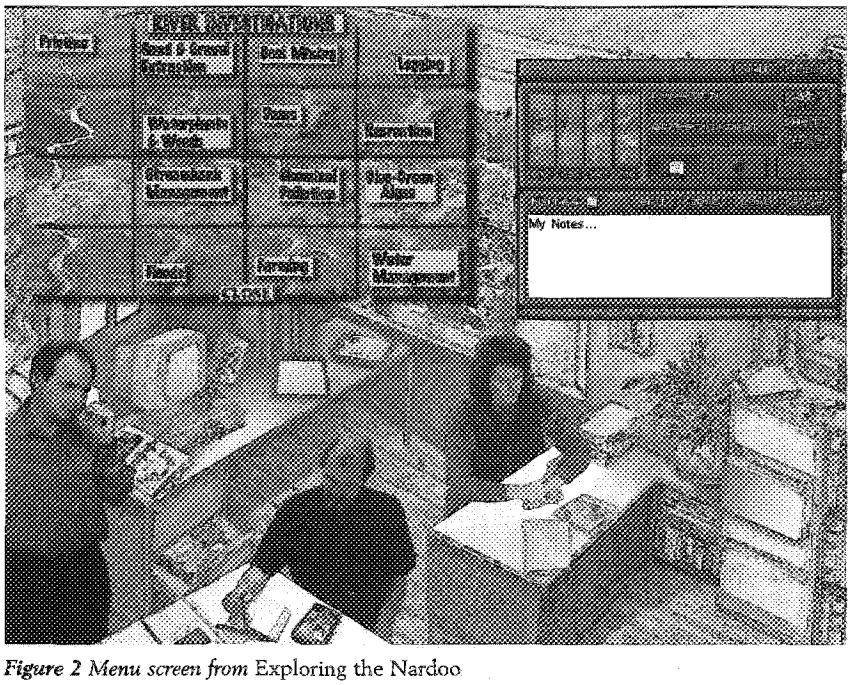

Figure 2 Menu screen from Exploring the Nardoo

students and teachers to communicate with other people and schools in Australia, and around the world (Cooke, 1996). High levels of connectivity between home, the school, and the community facilitate extended learning experiences, including mentoring opportunities with professionals outside the school (e.g. CSIRO, National Parks and Wildlife), and these can help develop the characteristics of lifelong learning.

Newsgroups and discussion lists are mailing lists on which students and staff can place a message (e.g. a request for information about a topic, or a contribution to an ongoing discussion) or tap into current topics of discussion. Usually they are subject specific (e.g. the newsgroup k12.ed.science) and can be used either within e-mail as in a discussion list (and thus anarchical in their flow), or within a web browser as in a newsgroup (which allows threaded lists). Teachers can take advantage of the information offered via newsgroups by simply adding the particular group to a list within their web browser, whereas discussion lists generally require you to subscribe.

The advantages lie in enhancing communication between staff and students within a school community and within the greater global community.

Videoconferencing for local and global communications

Hudson (1997) observes that 'the [Australian] education sector is already exploring the possibilities of using videoconferencing to provide greater access to information and expertise for students ... [and for] teachers to interact with students across vast distances'. In 1999, the Melbourne Zoo Education Service offered videoconferencing to schools in Victoria. In the first phase, the Zoo anticipates working with schools distant from Melbourne. It is envisaged that this pilot will develop into a series of programs to offer students a zoo experience. Videoconferencing is expected to compliment the Zoo's new Internet site. Students will be able to learn about the animals prior to the videoconference (or zoo visit) and follow up this experience with a variety of on-line activities.

Global classrooms allow students to access and share resources and ideas in the international and national arena. This helps students build their verbal and listening skills. A videoconference held between students in New York and Australia in June 1997, as part of the SAXophone (Students All over the world eXchanging over the phone) project, pursued local environmental issues, such as recycling, pollution, and wetland damage (Moss *et al.*, 1997). A significant outcome of the project has been the increased student interest and understanding of other cultures.

Telecollaborative projects

Telecollaborative projects (Harris, 1996) can be used to encourage discussions of a general nature. For example:

- *Eco-Schools Australia* is part of an international strategy (OECD Environment and Schools Initiatives, ENSI, program) to share ideas about environmental education projects;
- *Endangered Species: An On-going SchoolWorld Project* is researching and reporting on Endangered Species from around the world; and
- *Project Atmosphere Australia On-line* in which students record, forecast, and measure elements of the weather, as well as collect weather folklore and write about the impact of weather on the lives and livelihoods of members of their community.

It is important that the student learning goals that are specified for the activity are tied directly to the curriculum. Care and forward planning are essential for the success of a telecollaborative project — everybody needs to know the plans, the timelines, and the objectives. EdNA (Education Network Australia) provides a noticeboard for teachers seeking on-line project partners for collaborative projects.

Real world science collaborations

Students can participate in real science activities around the world. By investigating real and important world problems such as water quality or population growth, by sharing data and collaborating with other schools, and by involving scientists with student investigators, science is brought to life for the students. The perceived advantages are increased motivation and interest in science. However, successful use often requires: a change in teaching style; assistance for teachers and students in analysing the data; support from scientists; and additional time for introducing new innovations into the classroom. (Wiburg, 1994).

The WWW has opened up the opportunities to use real world problems or information to supplement traditional teaching resources and methods. Lynch and Walton (1998) describe how data from the Chesapeake Bay National Estuarine Research Reserve in Virginia may be used for teaching concepts in environmental science and ecology. Slater and Beaudrie (1997 – 1998) point out that to use real science data from the web effectively, the instructional activities need to be based on a sound pedagogical foundation and teachers must provide students with a simple structure for navigation. They describe the Network Montana Project which has created 52 on-line lessons to demonstrate the variety of ways that the web may be used to conduct scientific investigations at all educational levels. The hydrosphere activities may be useful for biology lessons.

Australian biology students are involved in:

- *Global Learning and Observations to Benefit the Environment* (GLOBE) which is a worldwide science and education program coordinating the work of students, teachers, and scientists to monitor the global environment; and
- *Waterwatch* which is a national volunteer water quality monitoring and education program involving landcare groups, schools, other community groups and individuals throughout Australia.

Communication technologies are capable of supporting a wide range of learning styles as information is presented in ways that are flexible to individual needs and abilities. This leads to enhanced student learning. The addition of global communications allows students to develop collaborative global relationships and cultural understandings. Communicating directly with people from different parts of the world is extremely exciting and motivating for both teachers and students.

Conclusion

Teaching and learning in science is at an exciting time. IT, and all that this entails, has the potential to dramatically change the way we teach and learn. Most schools within Australia now have access to the web. This widespread availability and the astronomical daily growth of resources offers science teachers the opportunity to provide their students with up-to-date information and a myriad of meaningful experiences. Currently the use of IT in biology education in our schools is still in the hands of the early adopters, however, with the improved access, communication, and staff professional development, wider use is imminent. If this is approached in a coordinated, collaborative man-

ner the benefits will be tremendous. Teacher satisfaction and professional development will occur, and student interest and enjoyment of science will improve, as will their performance.

There still remains the issue of selecting appropriate materials and fitting them into the curriculum. Although UniServe Science is primarily a tertiary service, it also maintains school teaching resource web pages **(http://science.uniserve.edu.au/disc/schools.html)** and conducts workshops for school teachers to assist them in finding and choosing appropriate IT-based material and integrating it into the curriculum.

This paper focused on the learning materials and communication facilities offered by the use of IT in biology education. An additional role of IT in education is the facilitation of assessment in both formative and summative modes. The issues surrounding IT-based assessment will be explored in a subsequent paper.

Appendix

Biology syllabus areas

Core areas: C1 Cells; C2 Flowering plants and their requirements; C3 Mammals and their requirements; C4 Reproduction; C5 Diversity; C6 Ecology; C7 Plant and animal adaptations; C8 Genetics and evolution; C9 Human disease.

Elective areas: E1 The Australian environment; E2 Structure and function of cells and tissues; E3 Control and coordination; E4 Classification and the species concept; E5 The human species; E6 Genes in action; E7 Human environmental impact.

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Web sites and other resources

The Genetics Society of Australia, **http://gsa.angis.org.au/Education/**

The Australian Academy of Science, **http://www.science.org.au/nova/**

NSW HSC On-line, **http://hsc.csu.edu.au/**

Acacia Revise Biology CD, **http://www.nh.com.au/**

Dynamic Rainforest CD, **http://www.publish.csiro.au/**

The Heart: An Online Exploration, **http://sln.fi.edu/biosci/heart.html**

HyperStudio (Ebert and Strudler, 1998)

Investigating Lake Illuka and *Exploring the Nardoo* (Harper, 1997)

Ecotrekker: an environmental mystery CD, **http://www.publish.csiro.au/**

A virtual field trip – plant collecting in Western New South Wales, **http://www.anbg.gov.au/cpbr/australian-plants/australian-plants.html**

Blue Ice: Focus On Antarctica, **http://www.onlineclass.com/BI/blueice.html**

Cells Alive, **http://www.cellsalive.com/**

The Interactive Frog Dissection, **http://curry.edschool.Virginia.EDU/go/frog/**

Virtual FlyLab, **http://vflylab.angis.org.au/**

Melbourne Zoo, **http://www.zoo.org.au/**

Eco-Schools Australia, **http://www.environment.gov.au/education/aeen/ecoschools/ecoschol.htm**

Endangered Species: An On-going SchoolWorld Project, **http://www.schoolworld.asn.au/species/species.html**

Project Atmosphere Australia On-line, **http://www.schools.ash.org.au/paa/paa.htm**

EdNA (Education Network Australia), **http://www.edna.edu.au/EdNA/**

Chesapeake Bay National Estuarine Research Reserve in Virginia, **http://www.vims.edu/cbnerr/**

Network Montana Project, **http://www.math.montana.edu/~nmp/**

Global Learning and Observations to Benefit the Environment (GLOBE), **http://www.globe.gov/**

Waterwatch, **http://www.waterwatch.org.au/welcome.htm**

UniServe Science, **http://science.uniserve.edu.au/**

Dr Mary Peat is the Director of First Year Biology in the School of Biological Sciences, The University of Sydney, NSW 2006, Australia. Tel. +61 2 9351 2100; Fax. +61 2 9351 2175 E-mail: maryp@bio.usyd.edu.au. Ms Anne Fernandez, Educational Technologist, UniServe Science, Faculty of Science, The University of Sydney, NSW 2006, Australia. Tel. +61 2 9351 5783; Fax. +61 2 9351 2175; E-mail: afernand@mail.usyd.edu.au