# Computer Based Learning - Dealing with Increasing Knowledge Volume and Declining Teaching Resources

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## Abstract

Expanding knowledge in all disciplines, declining resources and staff for traditional lecture and practical or tutorial format in Australian Universities, and demands for knowledge construction and acquisition by students provides impetus for the development of new educational strategies. Computer assisted learning, (CAL) integrates large amounts of information and data in an active learning environment. CAL is an especially effective facility, through exercises that explore underlying processes and their interactions for students to develop knowledge and understanding. This paper recounts 15 years experience within agriculture and related disciplines, and addresses the sources of software and hardware, the special roles of dynamic simulation models, likely future developments and student responses to CAL. The paper shows that CAL is an effective means of teaching agriculturally oriented subjects that involve complex interactions, with student performance comparable to performance with other teaching strategies. Analysis of student surveys of acceptance of CAL shows both positive and negative responses, with resistance mostly related to low levels of computer literacy and perceived unfriendliness of some packages used.

## Introduction

Agriculture is a complex discipline with many interacting biophysical and socio-economic components, and its knowledge base is doubling every five to seven years. Traditionally, universities have taught agriculture via a reductionist approach, characterised by a high level of specialisation in courses and hands on practical sessions involving small classes. This approach cannot be sustained in a political environment that demands both more efficient teaching (ie less finds per student) and that some students gain a holistic or systemic view of agricultue, that emphasises understanding of the interactions between the components of agriculture. Together these forces caused an evolution in teaching, which was underpinned by the following notions:

- All students need a basic understanding of key discipline areas such as plant production, animal production, management and marketing, early in a course. Some students may choose to specialise in one of these fields, but a broad knowledge of fundamentals is also required for a students choosing an holistic approach.
- Teachers need to foster a key life-skill for contemporary professional agriculturalists - self directed learning. This means that a professional agriculturalist needs to recognise what knowledge is needed, where to get it and how to understand and apply the information.
- Students, in preparation for life as a contemporary professional agriculturalist, need to gain the motivation and confidence in their abilities, to embark on a lifelong process of learning and to readily adapt to a rapidly changing work environment.

- Teaching institutions need to meet an increasing demand for the preparation of material for study in the external mode or flexible delivery.

Computer assisted learning (CAL) is a promising technique to help meet these challenges. Some terms used to describe learning strategies that utilise computers are Computer Aided Instruction (CAI), Computer Assisted Learning (CAL), Computer Mediated Learning (CML) and Computer Supported Collaborative Learning (CSCL) (Magidson 1978, Beder 1996). CAI is defined as the use of the computer to assist in delivery of material by staff to students, or as a supplement to traditional teaching methods, and provides the opportunity for self paced learning. It has been used in this way since the early 1970's (Magidson 1978). CAL, CML and CSCL involve students in activities not associated with lectures - they have to become active participants in accessing the information to be learned, and seeking out the underlying concepts and rules in the knowledge (Bouchard et al. 1995). This paper describes the experiences of staff at the University of Queensland, Gatton College campus in using CAL over a fifteen year period to teach both components of holistic agriculture (i.e. agricultural systems) and reductionist agriculture (i.e. subject specialisation).

A fundamental issue underlying the use of these techniques is the dichotomy between teaching (staff activity) and learning (student activity). Increasing emphasis is now being placed on student responsibility for learning. Also, education must prepare people for the work place increasingly dependent on information, its transformation and use in strategic and operational management. Consequently, competence in computer use for analysis, transformation and interpretation of data on diverse topics becomes an essential objective of education. This is particularly true of the applied sciences, where numerous disciplines combine to produce an outcome that has validity and applicability in management of agricultural production, natural resources and service enterprises. To achieve these outcomes, we use computer models to (i) provide background training for novice managers of farming systems; (ii) undertake climate analysis (ii) teach students the principles of agricultural systems analysis using decision support systems; (iii) teach the underlying principles of plant growth and development, and crop and pasture agronomy using simulation models and decision support systems. In this paper we consider the philosophy and scope of CAL, activities undertaken, supply of hardware and software, acceptance of CAL by students, and future developments.

**Philosophy and Scope of Teaching with Computers**

We see computer based learning as part of a total teaching and learning approach. We recognise the dichotomy of staff teaching and resource based (including computer based) learning, and contend that each is complimentary of the other. The second dichotomy we recognise is the analysis of data and integration of information in a decision making environment. We see each as supportive of the other, in an educational sense. We have used computers to help teach agriculture in both undergraduate and postgraduate programs. Of the software available, we have mostly used dynamic simulation models, decision support systems and databases to demonstrate interactions between the components in the system and to provide understanding of underlying processes. Students usually undertake a series of exercises to meet specific objectives for each software package that we regularly use (Table 1) during practical classes in a computer laboratory with a workstation for each student. In this way, and with carefully prepared exercises, the instructor is a 'guide from the side, rather than a sage from the stage' (McNaught et al. 1997). Students also have access to the computer laboratory outside of regular teaching hours to finish and or revise work.

**Table 1. Example of software use in teaching agriculture**

| Software and supplier | Purpose in teaching |
|---|---|
| RAINMAN. (Queensland Department of Primary Industries) (Clewett et al. 1994) | Climate analysis. Spatial variation in the reliability of rainfall, influence of Southern Oscillation, occurrence and probability of drought, using historical records of rainfall, temperature and evaporation. |
| FEEDUP (Queensland Department of Primary Industries) (Rickert et al. 1990) | Interactions between seasonal growth of beef cattle, stocking rate, land clearing, land degradation and historical climate and prices at four locations in tropical Australia. In the interactive mode students 'experience' season-by-season management; in the automatic mode students test 'what if' scenarios and conduct for simulation experiments. |
| WHEATMAN (Queensland Department of Primary Industries) (Cahill et al., 1998) | A dynamic daily model allowing assessment of interactions of planting time and cultivar selection, analysis of risk of damage by frosts, effects of fertiliser use, neamatode, disease and weed infestation, effect of Southern Oscillation outlook on crop yield, economic analyses. |
| PERFECT (Queensland Department of Primary Industries) (Littleboy et al. 1993) | A dynamic daily model of spatial and temporal variation in dryland cropping in relation to historical rainfall (80 years), soil types and cultural practices. Scenarios are evaluated in terms of productivity, reliability and sustainability. |
| WINGRASP. (Queensland Department of Primary Industries) (Clewett et al. 1999) | A dynamic, daily model of soil, plant and cattle subsystems for tropical and subtropical tussock grasslands of Queensland. Default inputs and parameters, including historical climate records, are supplied for any location, which can be selected from an on-screen map. |
| FEEDMAN. (Queensland Department of Primary Industries) (Rickert et al. 1996) | Evaluates beef cattle production on a customised farms in south eastern Queensland. Management options simulated in respect to prevailing rainfall, soil types, choice of forages, number, breed and class of cattle, market prices, and period of grazing. |
| WATERSCHED (Queensland Department of Primary Industries, 1993) | Scheduling of irrigation of crops using daily rainfall and evaporation data, using pre-determined criteria for soil water deficit |
| AUSIM-Maize (Carberry and Abrecht 1991)<br>CERES Sorghum (SAT) (Birch et al. 1990)<br>Modified version of AUSIM-Maize (Birch 1996) | Dynamic simulation models, using daily time steps, used for assessing adaptation of a defined genotype to a range of environments, assessing crop management options e.g. planting time, assessing the most appropriate genotype for specified environments and planting times, predictions of crop ontogeny, leaf canopy production, dry matter accumulation and partitioning, harvest indices and the overall efficiency of the plant, to teach plant adaptation, environmental effects on plant development and 'high level' plant physiology. |

Two separate but related definitions of a model illustrate the potential advantages we see in using dynamic simulation models in teaching.

- A model is series of mathematical expressions that mimic the behaviour of underlying processes and their interactions. Thus they allow students to gain awareness of the response surfaces and spatial or temporal trends pertaining to components in the system, outcomes that are often appropriate for undergraduate teaching.

- A model is a collection of hypotheses that explain the operation and interaction of the processes in a system. Thus, each hypothesis and their interactions can be tested and modified through research. Indeed, our postgraduate teaching often involves the research needed to improve the mathematical description of underlying processes. Models can be regarded as a repository for past research and a precursor for new research.

The above philosophy can be applied at the cellular, plant, field, farm or industry levels and we use a wide range of software depending on the objectives of the subject and scale of focus. Commonly class exercises demonstrate an understanding of the science behind the processes, interactions between processes, spatial and temporal variations in the system, and the implications an opportunities for management. According to course level, we require students to analyse the application of one or more equations in a model, to enhance their understanding of modelling of biological processes, and to ensure that students appreciate the limitations of application of equations to biological systems. For example, a series of equations in AUSIM-Maize to predict individual leaf area and a single equation for the same purpose (Dwyer and Stewart 1986) generalised by Birch et al. (1998) are assessed for biological and scale validity.

**Supply of Software and Hardware**

Most of the software listed in Table 1 is available commercially and was designed to assist farmers and resource managers in decision making, rather than for use in classrooms. We see the advantages of using such decision support software outweigh the disadvantages. Advantages include (i) students gaining experience in commercial software relevant to local farming systems, (ii) such commercial software is well presented, functional, and has technical support, and (iii) the software is often available at a discount, provided it is used for teacing. Disadvantages include (i) the need to adapt the content of practical classes to suit the features of the software and (ii) inbuilt student assessment and feedback features are not present. Some of the decision support software we use could be modified for teaching, but so far we have not undertaken that task. There is also potential for new software to be designed and developed specifically for teaching. Because the biophysical and managerial principles of farming systems have wide application, the overheads and benefits from software development would best be shared by several institutions agreeing to cooperate in developing teaching software, rather than individual institutions developing their own.

To date, our University has supplied both the software and hardware for student use. This approach has one major advantage, the work environment is controlled and standarised. Because all students have access to similar software and type of computer, lessons can be prepared in advance in accordance with the hardware specifications. The main disadvantage with the approach is the substantial capital outlay in setting up the computer laboratory and in the ongoing costs for technical support and maintenance, particularly if large classes are involved and if the laboratory is accessible for students for up to 18 hours each day. The alternative approach is to require students to supply their own computers. Whether or not such a demand is morally acceptable in a 'free' education system is debatable, however, one other difficulty is apparent - the student work environment is varies widely. A survey among a large group of students who were enrolled in an introductionary applied science subject at the University of Queensland in 1998 (Table 2) indicated wide variations in access to personal computers. About 50% owned a PC, 46% had access through a friend or relative but 4% had no access.

The quality of hardware also varied widely, only about 20% had a high performance chip, the latest operating system and a CD-ROM drive. Students enrolled in the external mode tended to be better supplied than internal students, although the sample size for external students was small. It follows that minimum hardware requirements would need to be specified if students were required to supply their own computer, and in doing so, a large proportion would need to upgrade to have a relatively modern PC. Another approach is to lease appropriate computers and software to students at the time of enrolling in a course, but this does not avoid the high establishment and maintenance cost.

**Table 2. Results of a student survey on access to privately owned personal computers at the start of a degree in applied science at University of Queensland in 1997**.

| Item from survey | Internal mode of teaching | External mode of teaching |
|---|---|---|
| Number in sample | 189 | 25 |
| Proportion who own a PC | 48% | 72% |
| Proportion without access to a PC | 4% | 4% |
| Proportion with PC and Pentium chip | 22% | 48% |
| Proportion with PC and Windows 95 | 21% | 44% |
| Proportion with PC and CD Rom drive | 37% | 52% |

**Acceptance by Students**

The student cohorts differ considerably in their computer literacy. For all students, the acceptance of our approach to using several forms of computer based learning has been determined from informal and requested feedback, anecdotal evidence and formal assessment (Tertiary Education Institute 1998) of subjects based largely or partly on the approaches outlined in this paper. Also, student performance in examinations provides an additional way of determining the educational success of our approach. Table 3 shows a representative selection of positive and negative comments form students, and Table 4 compares student performance in a subject that is heavily reliant on computer based learning, and long term average results for all forms of delivery at The University of Queensland. Positive anecdotal and informal evidence that is positive is usually provided by the more capable students - the formal instruments are anonymous, so such a statement cannot be made of them. However, formal assessment of teaching and learning, as distinct from examinations, reveals spread in the data - with significant numbers accepting and enjoying CAL, and another group that resists it. Nevertheless, the results of assessment of student learning compare favourably to expectations based on long term results of students in our University (Table 4). There is evidence of both high performance (maximum expectation for marks above 75%) but a significant group of poor performers (18% of students achieving <50%.). Our results confirm other reports on resistance to CAL usually due to lack of competence with computers, and lack of confidence in the programs used (Loss and Thornton, 1997, Rice 1997). The major criticisms we have received related to the ‘user – unfriendliness’ of some of the packages we have used, limited availability of computers outside normal working hours, and that students should be taught, not have to learn and discover for themselves.

**Table 3. Six most representative positive and negative feedback comments on the use of computers in instruction**

| Positive feedback | Negative feedback |
|---|---|
| Good comparisons of effects, learn a lot, and learn more quickly | Some bugs in programs |
| Makes lectures more meaningful | Need more computers |
| I’ll be able to use these programs in my job (farm manager) | Several comments on resistance to CAL |
| Great help to be able to analyse so much data quickly and meaningfully | Some programs difficult to follow, user unfriendly |
| I like the ability to do economic analyses of many options quickly | Output needs to be more useable e.g. Output should be portable to other programs such as a Spreadsheeet |
| Its good to be able to change inputs and assess effects on outputs | Why do this, it will all be different o the job |

**Table 4. Comparison of performance students in an agronomy subject which has at least 50% CAL and long term results of examinations at The University of Queensland using consolidated results from 5 years of subject offering (1994-1998) (151 students).**

| Mark range (%) | Proportion of students who used CAL in mark range (%) | Long term average proportion (%) of students in mark range |
|---|---|---|
| 85 – 100% | 7 | 3 - 9 |
| 75 – 84% | 18 | 10 - 18 |
| 65 – 74% | 27 | 25 - 35 |
| 50 – 64% | 31 | 35 - 40 |
| 47 – 50 | 5 | 0 - 5 |
| <47% | 12 | <20 |

## The future

We see increasing use of computer based learning, related to the dilemma presented by declining teaching resources coupled with ever increasing knowledge, and stimulated by the increasing computer literacy of tertiary students. Students now graduate from high school with basic computer skills. It is from this base that future approaches such as ours can build.

We anticipate a much greater diversity of models with much enhanced capability, that are also more user friendly. Importantly, feedback loops and embedded pre –test (What do I already know?), formative (How am I going?) and summative (used for assignment of student grades) assessment instruments should be included. These should link assessment activities and the level of challenge in the exercises being undertaken to the rate of progress of students, with the aim of enhancing the learning autonomy of students (Beder, 1996). Ultimately, we expect that an approach similar to ours will become indispensable in both undergraduate and post-graduate teaching. Our reasoning is not purely educational, nor purely resource and information driven. We reason that an emerging market exists for detailed situation analysis and modelling of potential outcomes in agriculture, environmental impact of human activities and their management, development planning and ecotourism. These activities will require the analysis of large amounts of data, and synthesis of possible outcomes, and find use in research, agricultural and environmental extension, and advice to governments and industry. There will be increasing application of both simulation modelling and decision support (scenario investigation) in legal circles – currently the technology is not well recognised for evidence generation and analysis. In all of these applications, two approaches are applicable – future (prospective) analysis, using "What if?' type scenario analysis, and retrospective analysis using 'What is most likely to have happened and why?' questions. The experience gained from our approach engages these questions and fits them well to meet the demands they will face in professional employment

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