GrassGro

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Final Report to DETYA on The GrassGro Teaching Project

(a CUTSD funded project 1999-2001)

by

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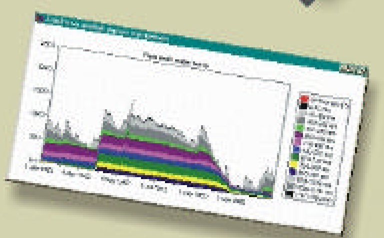
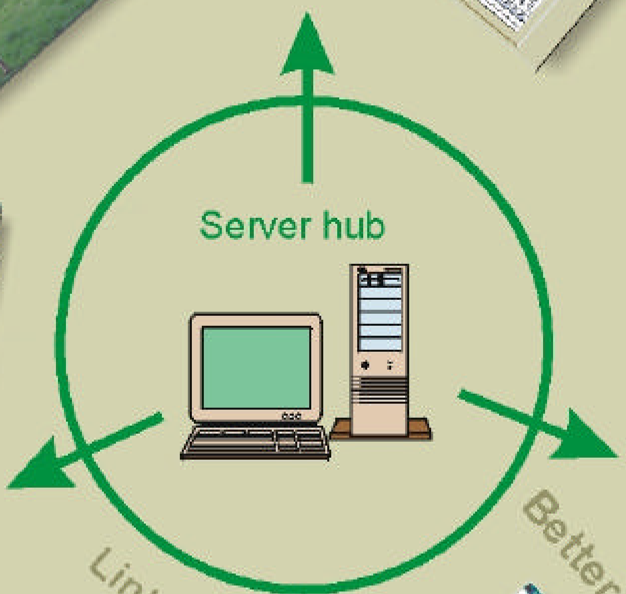
Understanding systems

Reinforcing principles

Self-directed learning

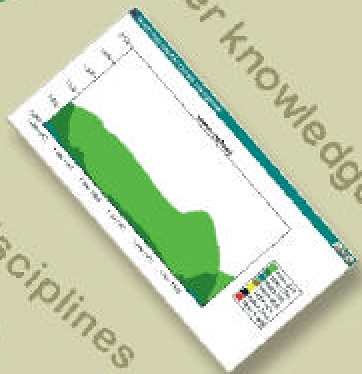




Problem-solving

Linking between disciplines

Better knowledge of DSS



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Abstract

A sophisticated computer decision support tool, GrassGro, which permits the simulation of grazed ecosystems (climate-soil-pasture-animal-economics) over long time frames in Australia, was adopted within the curriculum to enhance teaching and learning at the University of New England (UNE) within a national CUTSD funded project called the GrassGro Teaching Project (1999-2001).

The GrassGro software was implemented on a central server and access privileges arranged for trained staff and all students enrolled in units using the software. A total of 15 teaching staff have been trained by CSIRO in the use of GrassGro and modules have been developed for teaching in 16 complementary teaching units.

An evaluation of student and staff responses was carried out at an early stage of implementation of the project. In spite of the relatively limited exposure to this software by the time of their examination, a cohort of senior students in 2000 were found to have a somewhat greater level of understanding of complex ecosystem interactions than their counterparts in 1999, presumably due to their exposure to this project.

Surveys of staff and students were also carried out to determine in what ways the project was succeeding and to identify areas requiring improvement.

Those teachers who had used the software for teaching, reported favourably on its use and especially on its ability to engage students in active learning. Students also reported a substantial level of interest and desire to learn more from the use of simulations. In spite of students' limited experience with the software to date, the survey results confirmed the encouragement of problem solving, active learning, engagement, building on prior learning and skill development.

The project has been shown to possess many desirable attributes for enhancing student learning including a capacity to: engage and motivate students, provide realistic and interesting scenarios, be suited to experiential learning, create meaning, and enable self-directed and peer-directed learning.

Both students and teachers recognised the great potential offered by the GrassGro Teaching Project to increase integration and linkages between units and to link theory and practice in realistic scenarios, although both groups acknowledged that more needed to be done to realise this potential.

The aspects of the project which were identified as needing more attention included the need for: more explicit integration, concept maps within discipline areas, a resource book of published literature, increased technical support staff, and improved and more timely assessments.

To continue successfully beyond the two-year period funded by the current CUSTD grant, this project will require on-going support from the project partners (CSIRO and Horizon Technology) as well as institutional support from the University of New England for computing resources and trained staff to assist in delivering quality learning experiences to students. It will also require those staff participating to meet regularly to plan greater coordination of activities. Because the full effect of the project will not be seen until undergraduates have experience over the full four years of their course, it is recommended that the project continue until at least the end of 2003 so that the full impact of the project can be assessed.

The software can now be served out not only over the University's Intranet but can also be delivered 'live' over the Internet; the speed of simulation is limited only by the capacity of the server, not of the Internet connection. The implications of this are substantial for the future growth and evolution of this teaching project; this could lead to much broader interest and usage of such decision support tools in education as the means of providing controlled access is greatly simplified.

Details are provided of the key achievements within this project that permitted this software to be integrated into the curriculum. These include:

- the training of 15 academic staff in the software,
- the development of an integrated and linked plan of teaching to ensure complementary approaches by different lecturers,
- the setting up of an NT-server on which a single copy of the GrassGro software was installed for multiple concurrent users,
- the writing of initialisation files to enable constraints to be applied to particular software experiences
- the use of computer laboratories for teaching sessions where at least 20 simulations can be run concurrently
- the production of a GrassGro Portfolio to provide basic instruction and allow students to construct their own series of GrassGro experiences within a logical and explicit framework
- the setting up of classes and the execution of the various teaching modules and assessment and
- the methods used to limit access to the software to only those authorised.

Within the life of this project, specific learning modules have been developed for assisting with aspects of 16 separate units. These units are either core or elective units for the degrees of Agriculture, Rural Science, Natural Resources, Environmental Science, Science and/or Agricultural and Resource Economics. A further 10 units may also be candidates for some use of the GrassGro DSS.

To date, this project has provided a total of some 2000 student experiences in the use of various aspects of the software. All staff involved in the project at UNE have expressed the desire to continue to use this technology indefinitely and CSIRO has provided permission under licence for this to happen.

The application modules developed have been delivered over a controlled network domain providing secure access to those registered to use the software. In the future, distance learning modules may be provided via the Internet.

Information for other Australian Universities regarding this project is now being made available through this detailed report which has been sent to all tertiary institutions teaching agricultural and environmental science subjects and via a Web portal available at the University of New England (http://www.une.edu.au/dss).

Introduction

Need for understanding of systems

An understanding and appreciation of the complex interactions among climate, soils, plants, livestock, markets and risk in managed and natural ecosystems is a challenging task to convey to students. This has been recognised at the University of New England in its teaching at least since the influence of McClymont (1968). This understanding is necessary in today's world, where decisions about natural resource management and agricultural production are increasingly intertwined and the implications of mismanagement can be loss of sustainable resources or production. These problems require that professionals and academics in the area take a 'systems' view of the world and train applied science and management students in a context which helps them to relate their specialist training to the systems in which they will operate following graduation.

Improving the computer literacy of graduates

Improving the computer literacy of graduates is a national priority (DETYA); graduates in the natural resources and rural science areas are no exception. The availability of fast computing, which can readily compute complex biophysical interactions at daily time steps now provides a potential teaching medium which enables teachers to present credible evidence of the importance of interactions between a large array of factors associated with the management of natural and managed ecosystems. This can be done using computer-based, commercial, decision-support systems (DSS); some of these are comprehensive and have the capacity to predict the outcome of extremely complex systems in terms of biological, management and economic outcomes.

One such system is the commercial software package GrassGro (developed by CSIRO) which was released commercially in 1997. This package is somewhat unique in that it provides predictive outcomes (both biological and economic) from agricultural systems in a wide diversity of environments (potentially worldwide) and provides an almost infinite range of management choices to explore. It has been developed based upon an extensive published scientific knowledge base. Consequently, the program provides an ideal integrative tool for final year teaching in agriculture and natural resources but is too complex to be used for teaching in earlier years in an unconstrained form when students do not have the background knowledge to appreciate the component parts. This project has allowed this dilemma to be resolved.

Links between models and teaching

The detailed science, which comprises the model, is the basis of significant parts of earlier units. By making relevant components of the model available for students as inter-related modules, they can be used to reinforce concepts in units in years 1-3 whilst a familiar platform for subsequent learning is also established. It also provides the opportunity for students to reinforce concepts or test their own hypotheses/understanding by simulating long-term consequences of management decisions or of climate and thereby gain a better understanding of potential benefits, costs and risks. Because of the complexity of the system covered by GrassGro, it is essential that learning takes place over an extended period.

In can be argued that simulation models are probably the *only* way of getting the integrated research, upon which they are based, used on a wide scale. The difficulty of adopting complex scientific findings is even greater without tools such as GrassGro. One of the sub-models of GrassGro, GrazFeed has been used widely to guide farmers to modify feeding strategies through recent droughts, leading to savings of millions of dollars. It is anticipated that much of professional decision making in the future will be via the use of decision support systems, be they models of catchment management, animal genetics, insect population biology or grazing ecology and hence the relevance of this decision support tool.

Historical background

Historically, a number of applied science and management degrees at UNE (like many other tertiary institutions) have proceeded on the basis of introducing students to basic science and management theory and detailed mechanisms of plant, animal and ecosystem function and management. As students have progressed through their degree, units have become increasingly complex until, in the final year, students are expected to develop an overall ‘systems’ perspective but commonly without having been provided with an appropriate platform on which to base this part of their learning. At UNE, students in the Bachelor of Rural Science degree in particular, undertake systems units in 1st and 4th years but the means for close integration between years has been lacking.

Often the units of years 1-3 have been taught somewhat in isolation with little recognition of links that exist with other units and discipline areas. As part of a teaching strategy for the applied degrees (BAgr, BRurSc, BNatRes, BEnvSc, BAgEc) a teaching platform that can provide links familiar to the students within and between years of the degrees should provide sufficient 'glue' between the various teaching years and units to allow students to develop an understanding of the relationships between the fine detail and the 'big picture'. In so doing the students should also develop an understanding of how the knowledge acquired from the ‘discipline’ teaching areas provides the basis for understanding, interpreting and predicting system problems and outcomes.

To date, individual academics teaching units throughout the School of Rural Science and Natural Resources have used a wide range of computer models and decision support systems to enhance the learning of students. Typically, the models which are available for students to interact with, are relatively simple and cheap to purchase and therefore not commercially significant. Lecturers may demonstrate in a single practical session the use of more comprehensive and expensive models using a single licensed copy; this was the case prior to this project using a beta test version of GrassGro. This meant that students were inadequately exposed to the science behind the models. Also, in such cases, they did not get to use such models themselves and hence their understanding of the models and thus complex systems was severely restricted. Also, the use of these computer aids to date has been somewhat *ad hoc* and has not provided continuity across years or between units.

Previous experience with GrassGro

Some use of the GrassGro model for teaching has taken place using a beta test version of the software at the University of Adelaide (Bellotti *et al.*, 1998). The authors of this report provide very useful insight into how one can integrate simulations into a curriculum and address the issue of assessment. One limitation this group found was the restriction caused by only having 12 licences of the software - thus limiting class sizes dramatically. Also, the use of the model did not involve the development of teaching specific learning modules throughout their courses and hence, students were not exposed to the same model throughout their undergraduate years.

GrassGro - the model

GrassGro is a recently developed commercial Decision Support System (DSS) compiled by CSIRO and licensed to Horizon Technology Pty Ltd. which was made available under license to UNE to incorporate into the teaching curriculum.

The diagram below shows some of the relationships between various parameters, weather data and management decisions in the GrassGro model.

Although the GrassGro model has been developed primarily for Australian conditions (Moore *et al.* 1997), it has also been used to simulate both native prairie pasture species (Meyers 1999) and utilisation of pastures and forages by beef cattle in Canada (Anonymous n.d.). Although data calibrating the model elsewhere may not be available, the fact that the basic principles governing plant and animal growth employed in GrassGro are universal, nevertheless means that the model is suited to simulating pastures and animal production anywhere in the world.

This type of software is becoming increasingly available in the commercial sphere, especially for use by agricultural technologists. With such software today, specialists can predict the consequences of below or above average rainfall on animal liveweight or wool growth as well as the productivity of pastures and the run-off or deep drainage from pastures which are important environmental parameters.

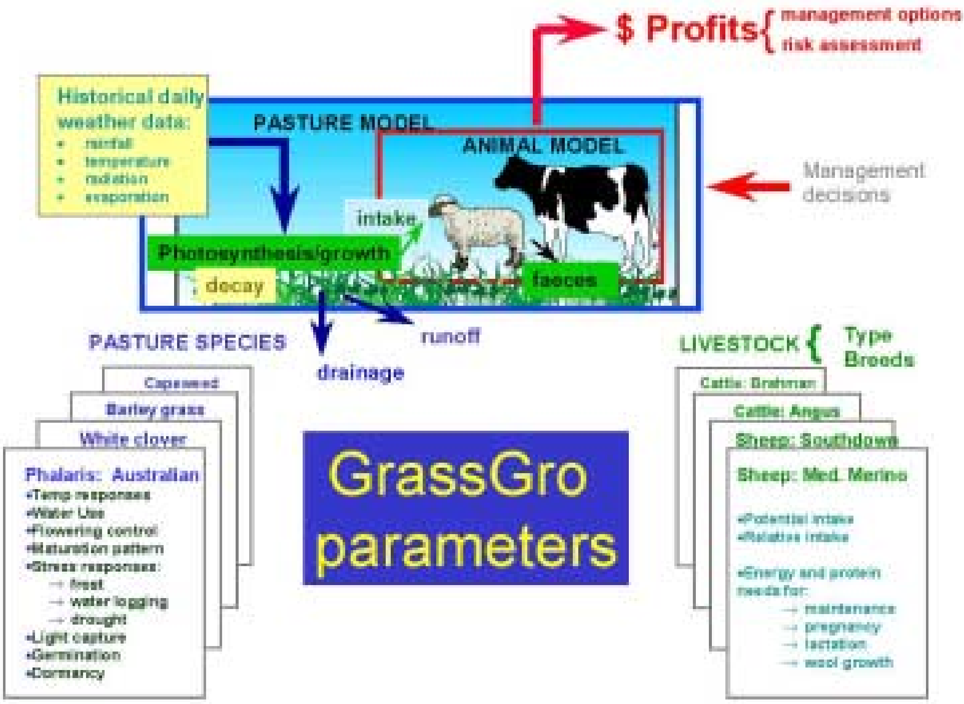

Figure 1. Diagram showing relationships between some animal and plant parameters, pasture and animal growth. (Source: J. Donnelly, pers. comm.).

A recent example of an applied simulation demonstrates GrassGro's utility for developing useful grazing strategies by assessing the risk over many years of weather data of supplementary feeding over dry summer/autumn periods in Victoria (Alcock *et al.* 1998). As noted by (Biggs 1999a), "university teachers should get students to tackle real non-textbook problems, as this is what they are being trained for".

It is vital that Universities provide up-to-date technology to its undergraduates so they learn to be competent with current technology that will be of use to them and their clients after they graduate.

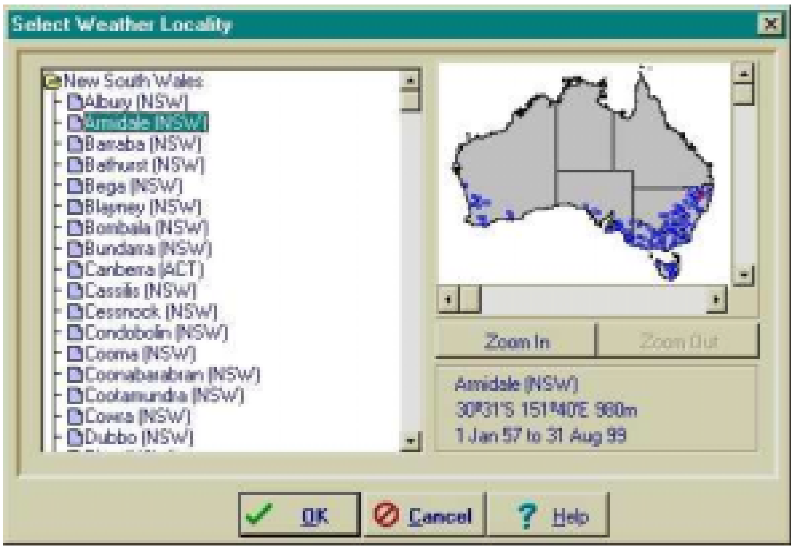

Figure 2. Location selector in GrassGro enabling selection of numerous sites throughout southern Australia for simulations.

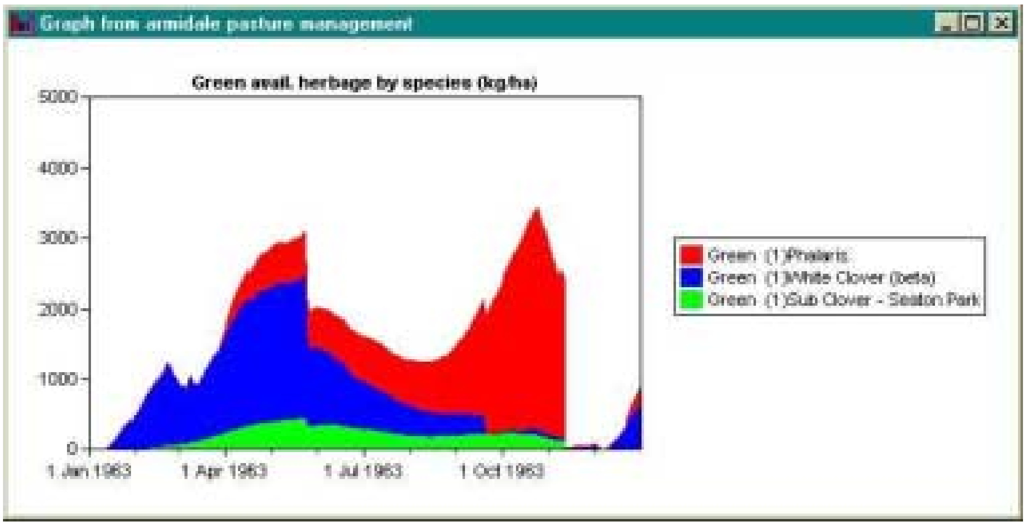

Figure 3. One of 49 possible output graphs from GrassGro showing the changes in available green herbage from three pasture species over a particular year for one location.

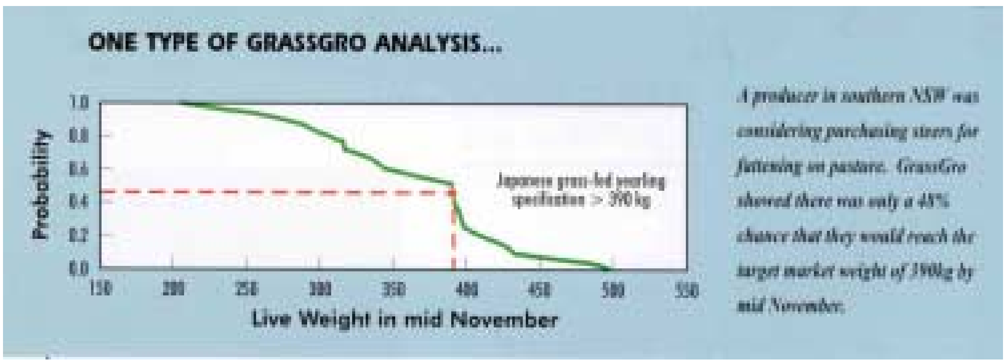

Figure 4. An example of one type of risk analysis that can be carried out using GrassGro (source: CSIRO/Horizon Technology GrassGro brochure).

Justification for selecting GrassGro as the teaching/learning tool

Sophisticated software and the availability of vast amounts of data and information in the workplace mean that graduates today need to be computer literate. In addition, graduates who will be working in either natural or managed ecosystems need to be aware of the science behind significant decision support software. This project enables graduates to have a significant understanding of both the software and the science behind at least one significant and comprehensive decision support tool (GrassGro).

The reasons for choosing such software were firstly that students would be motivated by being able to build upon prior experiences through using a common computer program throughout their undergraduate career, secondly that GrassGro has a substantial published literature related to it, and thirdly that developing skills using modern, valuable, commercial software which is likely to be highly relevant to them in their careers following graduation.

Links to the literature

The computer program, GrassGro, is based upon some 15 years of research in grazed pasture ecosystems by a wide range of scientists, especially those in CSIRO Plant Industry and Animal Production, and uses much information from the published literature. The publication of the scientific paper by Moore *et al.* (1997) describing GrassGro and its antecedent publications directs teachers to a rich source of published literature from which to draw principles and concepts. The paper by Moore *et al.* describes the science behind the model developed by the CSIRO team. The GrassGro software is marketed by Horizon Technology under license to CSIRO.

Systems capability

GrassGro is a comprehensive decision support tool, based upon systems science, which provides a powerful tool to aid the learning process concerning complex ecosystems; its availability provides a unique opportunity for the advancement of teaching methods in applied science and management. The program is capable of calculating plant and animal responses to a wide range of soil and daily weather conditions. It is capable of being adapted for any pasture species in any region of the world although, to date, it has been most thoroughly tested in the high rainfall temperate zone of Australia. There is little doubt that, by modifying plant parameters, it can be adapted to the growth of forbs and other herbaceous components of vegetation more important in natural ecosystems than in agriculture.

University context

The project is consistent with the University of New England's (UNE) Vision which states in part that "our teaching will be ... challenging in its academic content, relevant to students' future professional and civic lives - a learning experience which will motivate students to keep on learning". The project is also appropriate in support of UNE's "commitment to high quality, relevance and interdependence of teaching, research and professional service." This project is also relevant to specific objectives within UNE's Teaching and Learning Plan, namely:

- Objective 1.1: "UNE will continuously improve its awards, teaching, teaching materials, student support and environment to optimise students' learning" and
- Objective 2.2 of UNE's Strategic Plan, namely: "UNE will provide world class flexible learning delivery, building on the University's strengths and international reputation in distance education."

UNE is currently rapidly increasing the number of its units available in external mode, especially in the science area. This project assists in that process by ensuring more consistent learning approaches between sub-disciplines which include learning about system interactions.

The project assists in meeting UNE's objective of providing substantial staff support in the area of flexible learning opportunities: "The Teaching and Learning Centre will conduct a range of staff development and support programs to assist staff to develop and implement flexible and innovative approaches to teaching and learning."

The GrassGro Teaching Project

Chronology of project

The GrassGro Teaching Project (GTP) grew out of a unanimous decision made by some members of the School of Rural Science and Natural Resources to adopt the decision support tool, GrassGro, as a systemic teaching and learning tool for many units taught both internally and externally. By linking many parts of complex systems, it is well suited to our endeavours in our undergraduate teaching within our School. The project was enabled by securing a national CUTSD grant in 1998.

In the GTP, by exposing students to this software throughout their undergraduate career, students are coming to a deeper understanding of system interactions and a better appreciation of the usefulness of models. They will also have enhanced competencies in the use of computers in the workplace. An added advantage is the bringing together of teachers to use a central modelling approach in teaching, leading to greater understanding by both the students and their teachers.

The steps involved in conducting the GTP have been summarised in Figure 5. The interations that have occurred have involved the feedback and/or involvement of many staff, some from the Teaching and Learning Centre, as well as teaching colleagues and technical staff and students.

With hindsight, it is apparent that this teaching project was more ambitious than many other efforts to introduce computer aided instruction into a curriculum. Typically such innovations are made within a single unit. Attempting to implement this project across a number of degrees and at least nine units has meant that the project has had to be modified as it has progressed. For example, some of the problems of access reported by students could not be anticipated until the network distribution of the software had been implemented. As the project matured, the limitations imposed by the lack of time available for many key staff to contribute was a factor that has had to be taken into account.

Educational goals

Two educational goals have been addressed in this project:

1. The software has provided a platform for effective teaching of complex biophysical systems to reinforce more basic disciplinary teaching and thereby to improve student learning and increase collaboration among teachers.
2. By providing a consistent learning tool, students have been able to become familiar with the tool as well as develop an understanding of the conceptual links between disciplinary units. Such familiarity with a consistent program enables a deeper understanding to be developed throughout the students' undergraduate years.

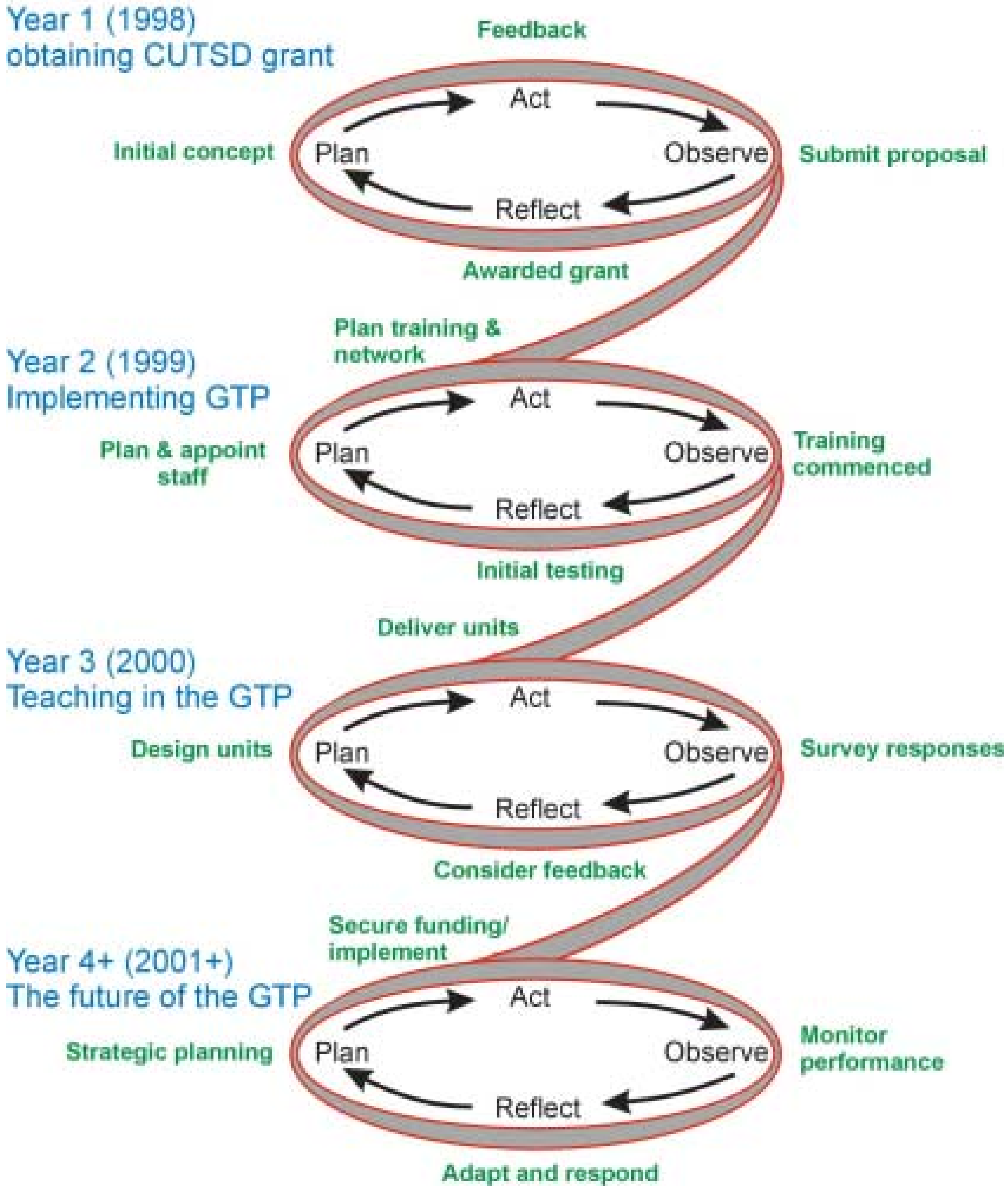

Figure 5. Schematic chronology indicating the various stages of evolution of the GrassGro Teaching Project and its evaluation.

Improving student learning

The key to the improvement of student understanding by the use of GrassGro is the demonstrable relevance and the credibility of the simulated outcomes. Greater relevance is brought about by i) better linkage with theory from lectures (or external teaching material); ii) the availability of the software to allow students to work through detailed scenarios in their own time; and iii) by showing detailed outputs from the scenarios (GrassGro currently allows 49 graphical views of various parts of simulated systems). Seeing these end points is intended to enhance student understanding.

Setting pre-simulation activities, and collecting data for the appropriate part of the program appears to lead to students to being able to critically evaluate the outcomes. In previous experiences with GrassGro by Horizon Technology (R. McCook, pers. comm.), it appears that working with GrassGro for 1 to 2 hours appears to be a maximum focus time before discussion about conceptual issues and more general discussion amongst the group develops, albeit related to assignments.

The control of the software by the lecturer using initialisation files to constrain functionality is intended to enable an appropriate focus on specific relationships in different discipline areas. The simulations allow the reinforcement of concepts using visual as well as written or verbal modes of teaching.

Outline of tasks involved in the project

Over the past two years, the following tasks have been achieved:

Decision Support Specialist

The appointment of a half-time Decision Support Specialist (Ms. Helen Daily) to this project allowed UNE to build on the experience Ms. Daily had with GrassGro at University of Adelaide, where beta versions of GrassGro had been trialed in teaching situations with final year Bachelor of Agriculture and Bachelor of Agricultural Science Students. The creation of this specialist position enabled implementation of GrassGro across degrees at the University of New England in a strategic manner. Oversight of the whole degree structure was facilitated by having a single specialist working with lecturers in different disciplines. Familiarity with generalist rural science and natural resource degrees was useful in ensuring that, when fully implemented, students would have a step-wise progression through degrees encountering GrassGro consistently, and building experience and skills with each exposure.

Selection of units

Units were selected for inclusion in the GrassGro teaching project based on lecturer interest in the project, feasibility of developing a GrassGro teaching exercise, and with the strategic aim of covering all relevant disciplines. In the initial stages, units that trialed GrassGro included “Agriculture, Natural Resources and the Environment” (1^{st} year), “Ecology and Adaptation of Agricultural Plants” (2^{nd} year), “Animal Production Systems and Products” (3^{rd} year), and “Problem Solving in Farm Systems” (4^{th} year). Complexity of exercises ranged from extracting and analysing weather data, through to illustrating scientific principles, and finally to using GrassGro as a decision support tool. In time, repeated exposure to GrassGro at all year levels, in disciplines as varied as Agricultural Economics to Natural Resource Management, will increase student knowledge of the program itself, and will also provide a framework for building an integrated understanding of ecosystems and their management.

Training of Lecturers

CSIRO provided training for some 15 lecturers with a two-day initial course; after some weeks of use by lecturers, a follow-up one-day revision session was provided. Additional training was supplied by CSIRO on two occasions for the Decision Support Specialist where validation issues and deeper understanding of the models driving the program were explored.

Initialisation files

Prior experience at the University of Adelaide had shown that exposure to a sophisticated and complex program such as GrassGro can be overwhelming for some students in the first instance (Bellotti *et al.*, 1998). Given the prolonged exposure being implemented at UNE, it was important that students did not have early negative experiences, which might undermine the whole project. CSIRO provided guidance in editing of initialisation files so that all student experiences could be “constrained” thus allowing a lecturer to choose which options students would be able to alter for a particular practical module. These editable initialisation files were also crucial to freeing lecturer time in class. While students could see the entire simulation, there were aspects of the simulation where inputs had been provided for them that could not be altered. Thus, the practical could then deal with, for instance, just the grazing management regime, leaving soil and pasture parameters fixed for this practical.

Network delivery of GrassGro

University of New England's enthusiastic and supportive Information Technology Directorate (ITD) staff were integral to the success of this project. The challenge was to make each student's experience of GrassGro individual, customised to the needs of the unit. They found many ways to enhance the student experience. Rather than use stand-alone desktop versions of GrassGro, we opted (with license approval) to serve GrassGro over the University's internal computing network, thereby increasing the potential sites on campus where GrassGro could be used, including the residential colleges. ITD ensured secure and individual access for enrolled students, who logged on to the server, chose their unit, and were presented with only the simulation files pertaining to that unit. In some cases this included simulations with research parameter sets. This allowed different simulations to be run for each unit, with constraints applied to appropriate units. ITD also developed a drive mapping solution that ensured that individual students did not overwrite the simulations of their classmates, yet could re-visit their own simulations at a later date.

Modules developed for 16 units

The decision support specialist developed GrassGro modules with input from lecturers in 16 units. The process involved ascertaining where the exercise would fit into the unit structure, what might have been attempted previously, and what objectives the lecturer had for the exercise. The decision support specialist researched the area, developed simulations to provide the basis of the exercise, and then drafted student practical handouts. These were designed to guide students in their simulation, both with the mechanics of using the GrassGro software, and prompting relevant unit objectives. Handouts and simulations were supplied to lecturers for review, direction and testing. Testing occurred on the network environment, with input and initialisation files being sent to ITD for loading to secure staff-only access areas of the server.

The lecturers ran modules, and gave feedback to the decision support specialist who made changes as required. In subsequent iterations of units, the original simulations and handouts were checked for currency with the routine GrassGro upgrades that took place. GrassGro version changes generally resulted in more plausible simulations since refinements had been made to parameters and models.

Table 1 below highlights the breadth of units for which GrassGro modules have been developed for teaching.

The approach taken in each of these units is shown in Table 2. At this stage, most of the focus has been on demonstrating or discovering principles through the use of the GrassGro software.

Table 1. Listing of units for which GrassGro modules have been developed.

Unit Name	**Student exposures per year**
First year	
Agriculture, Natural Resources and the Environment	180
Sustainable Resource Use and Environmental Management	172
Second year	
Ecology and Adaptation of Agricultural Plants	60
Animal Metabolism, Digestion and Nutrition	46
Principles of Ecology	40
Australian Terrestrial Ecology	N/A
Farm and Resource Management	69
Third year	
Plant Protection	39
Crop and Pasture Management for Sustainable Agriculture	44
Animal Production Systems and Products	31
Animal Function, Health and Welfare	34
Applied Animal Nutrition	30
Fourth year	
Problem Solving in Farm Systems	27
Constraints to Animal Production	15
Wool Production	7
Sustainable Land Management	27
Total	821

Table 2. Approach taken within several units currently using GrassGro learning activities (Source: Daily *et al.*, 2000).

Unit -	**Activity**	**Approach**
RSNR110 – Agriculture, Natural resources and the Environment	Climatic variation in southern Australia – 1.5 hour practical	Key principles demonstrated for 4 environments in Australia, students given limited self discovery options but guided to obtain and handle simulated data
RSNR120 – Sustainable resource use and environmental management	Interaction of soil type and overgrazing – 1.5 hour practical	Key principles of the impact of high stocking rates on soil water and plant mass are examined for different soil types
AGRO211- Ecology & Adaptation of Plants	Environments and Species phenology – 3 hour practical	Principles of phenology of annual and perennial pastures in contrasting environments demonstrated and students given some options with which to 'experiment'
ANUT221 – Animal Metabolism, Digestion and Nutrition	Pasture quality and animal nutrient requirements – 3 hour practical	Principles of animal nutrient requirements demonstrated; students use model to problem solve.
ECOL210 – Principles of Ecology	Survival strategies for plants in different environments – 3 hour practical	Survival strategies for theoretical plants investigated over range of historic climate sequences.
AGRO321 - Crop and Pasture Management	Pasture growth - species variation with year, season and location – 3 hour practical	Principles of between-season and between-year climatic variation on pasture growth rate for a number of environments and species using both demonstration and self-discovery.
ANPR311 – Animal Production Systems	Wool quality and management – 3 hour practical	Exploration of the impact of shearing time and twinning on wool characteristics.
ANPR321 – Animal Function, Welfare and Health	Reproductive variation with season and breed – 3 hour practical	Principles of seasonal effects on reproduction examined used as Decision support in problem solving scenarios
AGSY410 – Problem Solving in Farm Systems	Problem solving on farm scenarios – 2 X 3 hour practicals + self discovery	Decision support for property management scenarios

Computing details and initialisation files

Consultation with CSIRO and Horizon Technology led to the decision that the model version used be a fully implemented version of GrassGro with control over aspects of running the model being left in the hands of the lecturer who can edit various initialisation (.ini) files to suit their purposes. This had the twin benefits of maximising the flexibility of use by the lecturer and minimising the maintenance requirements on the software provider (i.e. only one version of the software needed to be updated).

In setting up a teaching scenario, a lecturer constructs a GrassGro work file (.GRW) as is done in the normal use of this software to describe the system the students will use in a practical session. The lecturer then copies the GRW file(s) onto the teaching network and edits the common GRASSGRO.INI file to limit the students' ability to alter the set up. Students are then able to view the contents of the disabled dialogs but not change them. The items which the lecturer can configure and/or disable are typically:

- enterprise (turn individual livestock enterprise choices on or off)
- historical vs tactical (model can be run using historical weather data continuously [historical] or alternatively, with the same starting values but for different years [tactical]).
- date range (can be restricted or left open to fill in any range of dates for climatic data available).
- number of paddocks (limit to the value in the GRW file)
- output choices (limit to brief or normal)
- management (all or none)
- livestock (all or none)
- costs & prices (all or none)
- soil characteristics (all or none)
- pasture characteristics (all or none)
- access to the locality selection process

One of the most challenging computing aspects relating to this project was the control of multiple user accesses to a single software installation. Users are now identified and authorised, when logging on, and can be given different privileges (e.g. control for teaching staff) and all users can save their own scenarios and results in their own computer directory. This allows students to develop and save their own unique simulations and build on them over time.

Project evaluation

An evaluation of this project was carried out to assess the outcomes for both learners and teachers at the University of New England (UNE). The project aimed to enhance student knowledge of the complexities and interactions within natural and managed grassland ecosystems, to enhance computer competencies, and to encourage more interaction among lecturers within a number of degree courses – ultimately to improve learning outcomes for students.

Evaluation of learning outcomes

It was important that the effectiveness of the GTP was measured so that UNE could determine if it is worthwhile to continue to use such as approach to enhance learning beyond the end of this CUTSD project. Also, because of UNE's obligation to make the findings of the GTP available to other Universities, after completion of the project, it was desirable that the quality of the outcomes resulting from it could be reported on.

This evaluation assessed the impact of the CUTSD grant on learning outcomes and teacher perceptions and described the GTP within a teaching and learning framework.

The hypothesis was that, by repeated and varying exposure of students to learning of a complex DSS throughout an undergraduate course, they developed some integrated understanding of linkages, subtleties and relationships which make up the DSS software, and thereby increased computer competency and system understanding. The GTP aimed to develop this competency principally by controlling the complexity of the learning environment from simple tasks in 1st year to increasingly complex tasks in their subsequent years culminating in the unconstrained use of the software in their final year of study.

A range of investigative tools, such as questionnaires and interviews, were used with both students and staff to gauge how effective the GTP was.

Objectives of evaluation

- To determine the effect of the GTP on student learning about complex systems.
- To assess to what extent the GTP has enhanced students' ability to use a complex DSS.
- To gauge the level of interest in the use of DSS for teaching and interaction between academics.
- From the above, to learn how the project might be developed in the future for the advantage of graduates, their employers and, ultimately, for wider use in tertiary education.
- To place the GTP in a teaching and learning context.

Methods

Systems understanding

The changes in student learning that resulted from exposure to the GTP were assessed by Assoc. Prof. Geoff Hinch by examining two cohorts of 4^{th} year students in both semesters of 1999 and 2000. These examinations comprised questions relating to the understanding of ecosystem interactions.

Surveys of students and teachers

The surveys of students and teachers were designed to elicit feedback relating to principles of good teaching and learning. Chickering and Ehrmann (2000), for example, have reported on the seven principles many have found to be important in developing technology approaches to teaching and learning and these principles are posed as questions in the surveys. In addition, the components of experiential learning noted by Kolb (1984) are included in the surveys.

As stressed by Biggs (1999b), it is what the *student does* rather than what the teacher does that is important in engaging students in higher learning. Hence the challenge in the GTP was to set sufficiently varied and challenging tasks to get the students motivated to learn more.

Thus, the surveys included questions to determine:

- To what extent was contact between students and teachers encouraged?
- were problem-based activities involved?
- was cooperation among students encouraged?
- To what extent was reflection and/or deep learning required?
- Did the GrassGro project encourage prompt feedback compared to other teaching and learning activities?

All of the teaching staff involved in the project were surveyed in late 2000 to assess responses to a wide range of questions designed to assess many attributes of the GTP. These included questions relating to approaches to learning, the potential for and reality of desirable learning outcomes, and an assessment of the quality of computing facilities and access provided.

Results

Student responses to using GrassGro

Systems understanding by two cohorts of 4th year undergraduates

One of the authors (GNH) undertook to study the effect of the project on student understanding over time.

To achieve this a bank of some 30 questions relating to systems understanding was developed by GNH, the coordinator of Agricultural Systems 410, and was put to both the 1999 and 2000 cohorts of 4th year students in AGSY 410. Half the questions were put to the students early in 1st semester and half at the end of 2nd semester of each year. In this way, it was hoped that the effect of the GTP might be measured as the cohort in 1999 had received virtually no exposure to GrassGro whereas the 2000 cohort had received exposure in up to 3 practicals using GrassGro in 3 different units.

Testing groups: There were 5 replicate groups of 3 students in each test (randomly allocated question combination at each time)

Years: 1999 and 2000

Semesters: 1st and 2nd

Total observations: 116 (58 observations from each cohort)

Marks were scored as percentages.

There was no significant interaction between year and semester. However, the results in Table 3 and Table 4 show a slight but nevertheless significant trend (P=0.086) towards better understanding from 1999 to 2000 which may be attributable to the limited exposure these students experienced had to the GrassGro teaching project. However the significant (P=0.07) increase in understanding from 1st to 2nd semester cannot be attributed to the implementation of the GrassGro project as it is averaged across years.

Table 3. Results of quiz to assess systems understanding by two successive cohorts of 4th year students over two semesters in each year (Source: G. Hinch, pers. comm.).

Year	**1999**	**2000**
Average mark	55.2	63.8

Semester	**1**	**2**
Average mark	55.0	64.0

Table 4. Analysis of variance table for student quiz results (Source: G. Hinch, pers. comm.).

Source of Variation	**DF**	**Sum Squares**	**Mean Square**	**F-ratio**	**Probability**
Full model	2	44.9	22.4	3.1	0.048
Year	1	21.6	21.6	3.0	0.086
Semester	1	23.3	23.3	3.2	0.074
Error	113	810.8	7.2		
Total	115	855.7			

Agronomy 211 - 2000 (internal)

A standard evaluation of this Unit was conducted by the Teaching and Learning Centre during the last lecture at the end of Semester 1, 2000. Included in this survey of 15 questions was 1 relating to the use of GrassGro in one practical session: "The GrassGro Decision Support practical helped me to understand how plant adaptation works". The answers from the 25 respondents on a 6 point Likert scale showed an average of 4.3 (between slightly [4] and moderately [5] agree) with a standard deviation of 1.1. This was the lowest rating of all 15 statements about the unit suggesting that the experience was not seen as particularly helpful in increasing understanding. However, the survey results also showed this question to have the highest standard deviation indicating that there was a larger spread of opinion in response to this question than any of the others. Thus, some students found it did increase understanding whilst others did not (in fact only 3 responded in the negative).

There were several unsolicited comments made in the open-ended section of this survey. The only comments made in relation to GrassGro were under the following two headings:

How could unit be improved?

- "More work with GrassGro as it is obviously going to be a great tool."
- "More GrassGro pracs."
- "There may be a need for more GrassGro practicals."

What were the weakest aspects of this unit?

- "The GrassGro practical was not of much help to my learning."

Thus, this survey suggested generally an increased understanding and an interest in more learning through this medium.

Thus, it appears that although there was not strong support for the proposition that the GrassGro experience enhanced their understanding of plant adaptation, there does appear to be some recognition of the potential for more to be gained by more (and perhaps better designed) exposure to the software.

Agronomy 211 – 2000 (external)

The small cohort of students (mostly mature age) who undertook this unit were given one practical experience using GrassGro (similar to the internal students above) to demonstrate the differences in adaptation between annual and perennial pasture plants in two different environments. The answers to a survey found that 100% of students found the experience to be either good or very good. Comments about GrassGro received from an open-ended questionnaire included:

- “Good to get experience of modelling although the accuracy of the answers was difficult to determine.” This shows some insight into the limitations of such models.
- “Very useful – I am glad it was included and would love to know more.”
- “Very exciting model. Would have liked more time to look at a real-life scenario of how model would fit into a farming system.”
- “Very good. Well run.”

In this case, with mature age students, it seems that they were well satisfied with the experience and wanted more. This may suggest that some of the internal students do not yet understand the significance of this tool for investigating plant adaptation and other aspects of grazing systems. This may be able to be addressed by making the purpose of the modelling exercise clearer to students.

4th year Rural Science undergraduates (2000)

This cohort of final year students had experienced 1 to 3 practical sessions using GrassGro (out of an eventual potential of 16 units). Thus, they had not benefited from full exposure from their 1st year of undergraduate training. Nevertheless, in spite of this limitation, these students were provided with a survey similar to that given to teaching staff (see below) in order to determine their responses to a wide range of aspects of the GTP.

The results (available in detail upon request from the senior author) show a degree of divergence of views among the respondents. In spite of admitting some frustration with the time consumed in completing assignments, responses show clearly that the software enhanced a number of attributes associated with quality teaching and learning such as cooperation among students, active learning, investment of time, high expectations, different ways of learning, key concepts, building on prior learning, integration, and has great potential for linking theory and practice and for creating linkages between a range of units.

On the negative side, students felt that, at this stage, the potential that exists was not yet being realised. In particular, this project had not facilitated prompt feedback and had not yet realised sufficient integration. Improvements identified as needed were to ensure that knowledge is enhanced as well as better assessment processes and improved access to the software.

Some answers to open-ended questions by these 4th year students indicated some frustration with the software suggesting that they had had insufficient opportunity by this time to gain experience with the software (e.g. “It is difficult and time consuming to use”, “Need more demonstrations on how GrassGro works”, “Takes a long time to complete a task. Needs the integration of many units.”).

In spite of these negative comments, it was clear from the detailed survey responses (data not shown) that these students, recognised that there is considerable potential for enhanced learning opportunities to be realised with more and improved implementation of this teaching initiative.

Teacher responses to using GrassGro

A total of 15 academic staff have now received training from CSIRO in the use of GrassGro. Of these 4 used GrassGro in 1999 and/or 2000 whilst another 5 have used it in 2001. The remainder are yet to finalise plans to use it for teaching.

Of the 14 surveys distributed to staff (i.e. to all except the author), responses were received from 6. This response rate of only 43% is thought to be because many of the questions were most relevant to those staff who have actually used GrassGro for teaching. Hence, responses were received from those three who have used it for teaching as well as three who are most likely to use it for teaching in 2001. The author of this project (and survey) did not complete a survey even though he has used GrassGro in practicals in several units over the past two years. Although his experiences with the software are not recorded in the data collected, it is worth noting that his experiences in using GrassGro for teaching have been increasingly positive over three years to the point that he is using it with more success each year and achieving excellent student outcomes.

The survey results (available upon request from the senior author) clearly indicate the great potential that exists for this project to reap substantial teaching/learning benefits. Among the benefits, the GTP was thought to be generally effective in delivering the seven principles of using technology suggested by Chickering and Ehrmann (2000) except two associated with encouraging sufficient time at task and encouraging students to perform at a high level.

There is considerable agreement that the GTP can meet or is meeting the four components of experiential learning suggested by Kolb (1984) of experience, conceptualisation, reflection and active experimentation.

Staff who responded see more potential for the use of GrassGro in the BRurSc degree than in the BNatRes degree.

The teachers saw great potential for integration between units and linking theory to practice but recognised that the reality is inadequate to date. There was agreement that the GTP allows students to build upon prior learning, to improve their skills and knowledge, and increase their understanding of concepts and problem solving. However, it is clear that the assessment of GrassGro exercises has not been adequately addressed to date.

In contrast to the 4th year students who found the access to the computing facilities inadequate, the teaching staff found them to be adequate. This suggests different perceptions of what is adequate. Nevertheless, the opinions of students on this matter still need to be taken into account. One feature of the computing facilities that was not adequate for staff was the procedure used to create initialisation files to constrain GrassGro simulations to only those aspects to be covered in a particular practical session. Some improvement appears necessary also for mapping network drives and facilitating the writing of reports by students using results from their GrassGro simulations.

Staff varied in their opinions on the need for more staff support for the GTP, ranging from agreement to strong disagreement with the proposition that sufficient staff were available.

Responses to the open-ended questions (Table 5) indicate that the provision of prompt feedback is an issue that needs addressing. This is related to the need for more staff recognised again here. A suggestion is made that there should be some regular interaction between an interest group of staff using GrassGro for teaching.

Finally, staff have identified that there is a need for a continuing 'champion' of this project as well as continuing institutional support if it is to succeed over the longer term. This comment applies equally to any other institution attempting to use this software in an integrated way in the curriculum.

Table 5. Summary of responses by teaching staff to several open-ended questions.

Open-ended questions	Selected responses
In what way is prompt feedback provided?	Interpretation of results leads to identification of key variables and discussion on how to optimise decisions Marking means that about a week between the completion of work sheets and feedback. Not necessarily rapid enough. Students fill in a "template" report during the practical and can question lecturer if uncertain. Went through output sheets and returned them. Assessment would be straightforward because students were given defined tasks using saved simulations.
How do you know GrassGro encourages students to spend sufficient time at task?	Potentially yes (because students were genuinely interested) but my use of it was structured to be completed within a 3 hour prac class From the submitted report on activities/achievements during the practical session.
If possible, please provide an example of students exploring different ways of learning	Group activity: 2-3 students per computer. On-screen views of pasture quantity and quality available as potential animal feed. The use of actual simulations allows students to test inferences based on first principles. This is a wonderful learning tool. Visual representation of stocking rate effects on run-off - collaborate to discuss and discover why this occurs.
How do you currently assess student understanding?	By using a template to record results on the day, and by requiring a critical discussion of results to be handed in later. Question students during the practical. Non-assessed answer sheets for a 3-hour workshop with defined exercises. Good scope for having an assessable prac in 2001 Question sheets designed to show skills of finding correct information.
Any other comments?	I'd like to see a technician within School with a dedicated job of supporting GrassGro prac classes I see a lot of potential for inter-disciplinary teaching using GrassGro (Rural Science/Economics). This may occur once students reach 3rd year after being exposed to the program during their first two years. Problem solving skills not as yet shown although in longer term when I work out correct tasks this might be true An important issue is who the "champion" will be in the future. Need a champion/leader to drive the GrassGro process. I think I will need further assistance - setting up/checking new files and trouble shooting. It will also require appropriate access for external students. I am not convinced as yet that students that have unconstrained use of GrassGro will necessarily learn through its use - this is a function of the limited time available. Needs to be an ongoing School supported "project" for the investment already made to be maintained. There is a need for GrassGro users to form an on-going "interest group" and meet perhaps 2 times per year. There is a need for a long-term commitment from UNE, CSIRO and Horizon Technology to make the investment in changing the approach to teaching worthwhile.

Portfolio

A survey conducted during 2000 alerted us to some shortcomings of student understanding of the linkages between units. This may have been partly due to the fact that no students had been exposed to an entire iteration of the GrassGro rollout at that stage. Nevertheless, we took the opportunity to strengthen the integration of modules using GrassGro.

This led to the development of a 'portfolio' document which has been made available to each student enrolled in units with a GrassGro module, through funding from the School of Rural Science and Natural Resources. The Portfolio's Table of Contents is shown in Appendix 1. This document has been produced to improve links between disciplines for students and teachers alike, and be expanded to include relevant literature sources. The portfolio provides a record and reference point, and a framework for students to see how various disciplines link and build on one another. It supplies much of the "mechanics" of GrassGro software use, freeing lecturer and practical time for the scientific objectives of the unit. As students gain increasingly complex skills and knowledge, they will be challenged to explore GrassGro as a decision support tool to aid in decision making in complex ecosystems.

The portfolio grows as the student (regardless of degree) progresses through units that make use of GrassGro. On completing their degree, each student will have a portfolio containing different information depending on which units they have chosen. When students become comfortable with using the GrassGro program, and realise that they can practise useful and work-related skills that they have some familiarity with (rather than participating in unrelated technologies and learning), they may use the portfolio to choose units specifically because of their GrassGro content. This will aid recruitment into elective units for lecturers who choose to support this initiative.

Discussion within a Teaching and Learning context

In all teaching and learning it is crucial to engage students in the learning activity (Biggs and Moore 1993). It appears, that at this early stage of the GTP that considerable success has been achieved in enhancing student learning and engaging both students and teachers. This can be seen from the multiple sources presented above including the examination of two cohorts of students, surveys of two second year classes, a 4th year class, and the teaching staff, all of whom answered questionnaires including open-ended questions. Thus, in coming to this conclusion, this qualitative assessment of the GTP has incorporated a number of measures of success or 'triangulation' as suggested by Mallarat (1994) and Wagner (1999).

Problem based learning

One of the most notable features of the GTP has been the recognition, by students and teachers alike, that the GrassGro software is well suited to problem based learning. This is important as it is through problem based learning that students get to be actively engaged in the learning process (Biggs and Moore 1993). It also leads to students 'owning' the problem, greater interaction among teachers, students and peers, and involves active learning. Also, in the case of GrassGro, the knowledge base is ever present. These are all desirable features of problem based learning, as pointed out by Biggs and Moore (1993).

As noted by (Ryan 1996) graduates need to be trained to solve ill-structured problems and it is for this reason that a problem based approach is desirable. The access to this packaged 'knowledge' in the GrassGro DSS is important in professional disciplines relying on substantive data (in this case the interaction between climate, soils, plants, animals and financial returns).

Without a knowledge base, problem based learning can be ineffective as suggested by a dentistry student from the University of Adelaide who stated: "the introduction of problem-based learning was a waste of time if the students did not have sufficient knowledge of the subject or grasp the vocabulary" (Candy *et al.* 1994). This suggests there is a need to complement the GrassGro experience by providing more knowledge describing the principles behind the software. In the future, it is planned to demonstrate the main equations used within the model (A. Moore and M. Freer, pers. comm.).

GrassGro has the capacity for students to explore virtually limitless scenarios of pastures, soils, animals, etc., all against a climatic history stretching back up to 100 years across Australia. Thus students should be able to be encouraged to structure their own curriculum (to an extent) by thinking about problems that interest them most. Provided that students are given a clear conceptual discipline map (Ross 1997), they should not get lost in this activity.

In developing problem based learning exercises it may be useful to categorise them as Ross (1997) has done into: problem oriented, problem-based and problem-solving sub-components of the curricula.

Flexible learning

Flexible learning is highly desirable in order to achieve quality learning outcomes. This is a particular feature of the GrassGro software that, especially after some adequate training, students are able to engage in learning appropriate to their own background. This has been suggested by McLoughlin (1999) who stated that recognising individual differences through flexible approaches is vital to accommodate the variety of learning styles which students (and teachers) possess.

When contemplating how the GTP has performed and how it could be improved, it is useful to consider the good teaching and learning principles for higher education outlined by Ramsden (1992a):

1. *Interest and explanation*. Based on the surveys of students, GrassGro appears to achieve this.
2. *Concern and respect for students and student learning*. This has not been documented in this project to date although it may well be a feature of the approach taken by the teachers involved.
3. *Appropriate assessment and feedback*. There appears to have been insufficient consideration given to this important aspect of the project.
4. *Clear goals and intellectual challenge*. The software and the science behind it are certainly intellectually challenging but the problem is to ensure that the experience is challenging without being overwhelming. To achieve this, the goals and inter-relationships between units need to be made explicit (see Portfolio).
5. *Independence, control, and active engagement*. This is a particular feature of the GrassGro software and it appears to get students actively engaged.
6. *Learning from students*. Again, interaction among students appears to have been enhanced by this project. It is likely that, with more effort in creating challenging simulations, that the teachers will also learn a lot from the students carrying out such activities.

Thus, the GTP appears either to comply with or could be modified to comply with all 6 of the above principles. The challenge is to implement these changes.

Motivation

One of the key aims in any learning activity is to encourage student motivation. Biggs (1993) has pointed out that a student's involvement with a particular task is a function of his or her expectation of success multiplied by the value assigned to a particular task. Also Biggs (1999b) has stated that "Motivation is a product of good teaching, not its prerequisite." By leaving some decisions to the student, Biggs (1999a) states that this can lead to additional creativity from the student who may then 'surprise' the teacher with an unexpected outcome.

Additional ways in which motivation can be increased include to engage the student in a high level of concentration, to encourage independent study (Gunn 1999), and to allow realistic workplace scenarios (Kennedy *et al.* 2000).

In the case of GrassGro, exercises could be created whereby each student may be able to specialise in running simulations for a location in Australia of their choice. Thus, given training in how to select the climatic data for, say, Hamilton (by clicking on the appropriate dot on a map of Australia - see Figure 2), a student may then become more interested in modelling outcomes for a location important to that individual student.

Quality learning outcomes are also suggested to arise from exercises which are either self-directed and/or peer assisted. Candy *et al.* (1994) provided an example of a self-directed learning approach at UWS Hawkesbury where experiential learning is the mode followed by teachers of agriculture. This encourages students to be self-directed. However, it may be that without sufficient content knowledge, students may never gain a sufficient sense of structure which can be so important for making meaning out of complex material.

Workload issues

It was notable from the student comments that they found they had to work hard to complete assignments. This is not necessarily undesirable as Cashin (1994) found when assessing student ratings of teaching that the relationship between student learning and workload/difficulty was positive. This means that setting a high workload can lead to good outcomes, provided that the student does not become overloaded. Strategies to avoid students becoming overloaded include developing an explicit curriculum, ensuring that the learning will be valuable over the long-term, and through enhancing motivation (Knapper 1995).

Active learning

An important aspect explored in the surveys was the degree to which students engaged in active learning. Engel (1997) has noted that, especially for effective adult learning, desirable features include: active learning, integrated learning, cumulative learning and learning for understanding. All of these features are suited to being cultivated through the GTP and indeed many have already been recognised by students exposed to the project (e.g. responses from the external Agronomy 211 students).

Integration and focus

Several outcomes of the staff survey point to the need for better integration and focus for the project if it is to continue successfully. Engel (1997) states that "the aims of problem based learning must be seen to be supported in every facet of the curriculum and in the way it is implemented. Each subject needs "to develop a 'discipline map' that provides a hierarchical overview of the principles and concepts which the subject experts expect students to learn". It is clear that this needs to be implemented for the GTP and steps have already been taken to develop such plans.

Taylor (1997) stresses the "importance of specific units forming a whole, particularly in relation to modularisation, if we are to avoid a fragmenting experience for the student." As noted by Vermunt and Verloop (1999) it is important to avoid 'inert knowledge domains' which can come about when components "are studied in isolation from one another and are therefore difficult to access."

Depth of learning

In relation to depth of learning, it is apparent that there will be some conflict between the depth of learning and the breadth of coverage that will be possible. This tension has been recognised by (Biggs 1999a) who states however that, given sufficient integration, developing understanding can lead to great satisfaction in students.

In relation to developing critical thinking skills, it appears that the words of Boulton-Lewis (1998) are particularly appropriate when one considers the attributes of the GTP.

> "One of the goals of higher education is surely to produce graduates who can be involved in rational decision making and leadership roles in society".
> "Critical thinkers are those who seek reasons, attempt to be well informed, use and acknowledge credible sources, consider alternatives and other points of view, withhold judgement until they have sufficient evidence and seek to be as precise as possible".
> "A deep approach to learning is one in which the student is interested, intends to understand the material, and hence to relate parts to a whole, to integrate it with existing knowledge and to apply it in real world situations" (Boulton-Lewis 1998).

The development of an understanding of concepts is particularly important in understanding broad applied science applications such as the modelling of grazed ecosystems simulated by GrassGro. As students differ greatly in their approach to learning (Biggs 1999b), we need a constructivist approach so that meaning is not imposed "but is created by the student's learning activities" (Biggs 1999b). He states: "Education is about conceptual change, not just the acquisition of information".

Assessment

Biggs and Moore (1993) cite Elton and Laurillard (1979) as stating: "The quickest way to change student learning is to change the assessment system." This quote seems appropriate in the context of the GTP as it is apparent from the survey data that prompt and appropriate formative feedback has not yet been developed for most units.

Assessment is one component of the project identified as needing improvement and thus it is worthwhile to consider how this might be improved. The SOLO taxonomy (Biggs 1999a) provides a systematic way of describing a learner's performance. If this were to be employed, it may be feasible to construct learning activities that encourage students to engage in deep learning (Biggs 1999b). Thus higher order learning may be able to be assessed according to the student's ability to hypothesise, reflect and generalise (extended abstract) or to explain causes, analyse, or relate (relational) as opposed to just describing or listing events (multistructural) (Biggs 1999b).

Assessing metacognition (thinking about thinking) is a challenging task (Ryan 1996). This author suggests that questions can be used in order to display metacognitive processes such as: What information do I have? What is the problem? How do I know this is the problem? What are my ideas/hypotheses about the problem? How can I test them? Do I need more information? What is my goal? What is my plan to achieve my goal? These suggestions could be of use in developing an understanding of the level of metacognition encouraged by the GTP.

In their analysis of the OzSoils multimedia package, McLeod, Daniel, and Lockwood (1998) found that many students made good use of higher order learning strategies but failed to use the extent of opportunities available. This points to the need to be explicit when designing such higher order learning tasks.

If assessment is to be successful, it needs to be constructively aligned with the objectives of the learning exercise (Biggs 1999b). If this is done, then shallow learning exercises can be avoided.

In some cases, peer tutors have been used to good effect in enhancing student learning as well as providing useful learning for the tutors (Ritter 1994). It may be possible to develop ways in which senior students could assemble some form of credit by participating in peer tutoring of less experienced students.

A number of interesting assessment possibilities occur in the literature (e.g. those listed by Ryan (1996)). These include a Modified Essay Question (MEQ) from the University of Newcastle's Medical Faculty in which students must answer questions sequentially without scanning future questions nor going back to look at the past answers.

Another case study used a mixture of assignment types to cater for different students' learning needs such as interviews, reports, data analysis, reflection, etc. (Ryan 1996).

Yet another interesting example from Ryan (1996) is one of creating a research poster which may be able to be adapted to form a research report based on GrassGro simulations. This could then include: developing a research strategy, critical assessment of peers' research strategies, completion of a simulation, presentation of findings, and assessment of peers' presentations.

Ultimately, it is what students *do* that is the important thing (Biggs 1999b). The challenge in the GTP is to set sufficiently varied and challenging tasks to encourage students to become motivated and actively engaged and thereby to learn more.

Continuing improvement of the GTP will require a re-think on appropriate and prompt feedback. In these times of declining human resources, and with an increasing focus on WebCT as a means of delivery at UNE, it may be worth considering the development of computer based tutorial material for use in association with the GTP. In other areas, colleagues have used WebCT to serve out timely mini-tests on practicals which are mostly automatically assessed and which permit students to obtain prompt feedback. These facilities also include the capacity to serve out random questions from a selection so that what each student's experiences are not the same. This helps lessen the tendency for copying among students (P. Lockwood, pers. comm.).

Whereas Ramsden (1992b) provides some instances of quality computer tutorial feedback in the literature, he expresses concern over the use of multiple choice type questions. One wonders whether, some 8 years later, whether the technology and know-how regarding multiple choice questionnaires hasn't improved sufficiently to justify their use. After all, as pointed out by Ramsden (1992b), "students generally find timely feedback far more useful than delayed comment" and therefore anything that provides accurate and timely feedback is probably an improvement on the alternative.

Student/teacher interaction

A positive feature of the staff and student surveys is that they suggest better student/teacher interaction has already occurred. According to Vermunt and Verloop (1999), it is important to promote congruence and constructive friction between students and staff. This can be achieved by teachers supporting and influencing the thinking processes used by students. Ideally the teacher can act as diagnostician, challenger, model learner, activator, monitor, and evaluator.

Computer aided learning and its effectiveness

The needs of society are changing rapidly and there is an increasing need for graduates to be able to update their knowledge whenever necessary (Vermunt and Verloop 1999). Decision support systems such as GrassGro, will be important tools in the future to enable such updating to occur. This important and changing requirement of society needs to be made explicit to students involved in this project.

Whereas the literature indicates that computer aided learning can be very effective (Kohlmeier *et al.* 2000), it is nevertheless difficult to evaluate (Lockwood and Daniel 1997) and, especially difficult to examine different cohorts of students to assess changes in competency (Lockwood and Daniel 1997). Nevertheless, by using a wide range of data sources, it is possible to 'triangulate' measurements of success (Mallarat 1994). In the case of the GTP, we have been able to gauge the level of knowledge of agricultural systems and have surveyed the responses of students in a range of units and stages as well as obtaining feedback from teaching staff. From these data sources, it appears that there has already been measurable change in student knowledge. Also there has certainly been a change in computing competency as students have obviously become more competent in using this complex software.

The literature contains numerous examples of the use of computers and technology to enhance learning. A number of programs have been developed for medical training including the multimedia software An@tomedia which was found to be especially useful for enhancing learning (Kennedy *et al.* 2000). Students were surveyed after 1 hour of use of the program whereas in the case of the survey of UNE 4th year students, the survey was done in a separate class and some days after their last use of the software; hence their responses may have been somewhat less focused than if they had just finished a practical using the software. It is notable that in the case of An@tomedia, over 90% of students said they would prefer to have their own copy of the software. This appears to be the case in the survey of 4th year students as there was some frustration with facilities for accessing the software.

Solutions to this problem of ease of access include improving the ease of logging on which will depend on collaboration and resources from the University Information Technology Directorate and secondly, to better explain to students the reasons for restricting access to this commercially valuable software which can only be made widely available under a strictly controlled license.

Another multimedia program used to enhance student learning is OzSoils (Lockwood and Daniel 1997) who have surveyed students in detail and have found the software to have been a particularly effective complement to traditional lecture and practical material.

In evaluating computer aided instruction (Gunn 1999) has found it desirable to consider a range of issues including: Learning objectives; Hardware and software issues; Effective use of technology - is implementation effective?; Instructional strategy - Needs to be appropriate to discipline; Design quality - good graphical design and resource levels; Teaching method and learning support - may involve shifting expectations and Motivational factors.

Regarding the hardware and software issues referred to by (Gunn 1999), the GTP has considered these in some detail and, provided that adequate software support from CSIRO and adequate login and server resources continue to be made available by ITD, these problems should be resolvable. Nevertheless, it is important that close liaison continue to occur with the hardware technicians and software developers so that unnecessary problems are avoided (Koumi and Daniels 1994)

Institutional support and integration

As pointed out by Davis and Harden (1999) in relation to quality problem based learning activities for medical education, there is a need for the activity to be supported within the curriculum, a clear discipline map, a knowledge base to be associated with the software, a continuum of learning, principles and concepts to be discovered, an organised framework and for the scenarios posed to be of high quality. With effort, all these features can be achieved by the GTP.

Gunn recognises that integration is a key issue at the institutional level and it is this that may fail without institutional support. The initiative needs to fit well with the overall direction of degrees and ethos. Also there is a need for the institution to look favourably on such initiatives with regard to resources (Gunn 1999). In the case of the GTP, this is likely to involve a continuing commitment to IT resources as well as to adequate staffing.

Instructional strategy

More attention needs to be given to the instructional strategy employed when using GrassGro simulations. Given sufficient planning, it should be possible to develop quality focused scenarios that are able to be tailored to individual student's interests in order to engage interest and to ensure that each student completes the task themselves. Of course, in some cases, team efforts would be desirable as they simulate the work place situation for many.

Computer access

The quality of the computer access privileges and interface design needs to be questioned in light of the perceived problems experienced by students (but not by staff). As recognised by (Anonymous 1994) the entire process of engaging students in the learning process requires careful design. There is a need for a carefully designed framework and set of principles, which provide the scaffolding for students to build upon. Ideally this should be developed by the team of teachers involved in the project so that it is conceptually linked with existing courses. In this way, learning can become more flexible, with more student engagement, more-targeted communication, and more-attuned instructor involvement whilst increasing the responsibility of the student for his or her own learning (Collis 1998).

Graduate attributes

Ideally, the GTP should contribute to the attainment of graduate attributes. By designing appropriate modules, it should be possible to provide experiences relevant to 6 of the 8 attributes adopted by the University of New England:

- *Knowledge of discipline*. This can be encouraged through exercises relying on either the published literature or knowledge gained from the extensive Help files in GrassGro.
- *Global perspective*. As the design of GrassGro is based on ecophysiological principles, it should be possible to run scenarios for any location in the world for which climatic data are available. Thus students should be able to learn some of the effects brought about by cold continental climates, altitude, latitude, droughts, flooded conditions, etc.
- *Information literacy*. This will be encouraged by using GrassGro as a tool to access vast stores of historic data as well as develop predictions. Knowledge of how sophisticated predictive software functions is becoming increasingly critical for our graduates as technology advances rapidly in the workplace (including on-farm).
- *Life-long learning*. This will be encouraged by the GTP as it provides many of the experiences noted by Candy *et al.* (1994) to be important for life-long learning. These include: self-directed and peer-assisted learning, experiential and real-world learning, problem-based learning, and reflective practice and critical self-awareness.
- *Problem-solving*. This is an integral part of the GTP and the reason why GrassGro was chosen as the simulation program of choice.
- *Team work*. Already it is clear that students enjoy working collaboratively on GrassGro assignments that are challenging. Although individual competencies will mostly be focused on in early years, more experienced undergraduates will benefit from tackling larger systems problems as teams.

Concluding comments

In conclusion, allow me to contemplate something of the future for projects such as the GTP. It was pointed out above that society needs new teaching models, and new, more rapid methods of accessing reliable information and predictions. Education still needs to deliver an understanding of robust principles and concepts but today, these can be incorporated in sophisticated models rather than buried in obscure textbooks.

The world of the Internet and on-line teaching and sophisticated computer tutorials and feedback is developing rapidly. Although the GrassGro software program itself may become outmoded in time, I would suggest that UNE is well placed to continue to develop a capacity to serve out a range of important models and decision support systems, delivering them efficiently and securely from a central server to all students both on- and off-campus. Much of what has been learned in the GTP can be applied to these other programs as well.

The last cycle of the chronology diagram shown in Figure 5 (2001 and beyond) suggests strategic planning, funding of resources and continued monitoring will be necessary for the project to continue to succeed. As the first cohort of students to be exposed to GrassGro in 1st year was in 2000, it will not be until 2003, that UNE will have a 4th year cohort who have been exposed to the full complement of experiences with a wide range of aspects of the software across the four years of the degree. Thus, it would seem prudent that the project be continued until at least the end of 2003 in order that the full impact of the project can be assessed.

Lowe (2000) has stated recently "Much university education in technical areas is fundamentally inadequate … It is still based on the out-dated model of transmission of a fixed body of knowledge, and so doesn't prepare graduates for the real world of rapid change". Addressing this as an opportunity for students to learn new technologies systemically through their degrees using a comprehensive DSS is one way that this out-dated model can be turned around.

Passerini and Granger (2000) have shown how the Internet has opened up a "new generation of distance education (fourth generation), introducing sophisticated delivery tools and creating a paradigm shift with profound implications on the design of distance education courses".

Relan and Gillani (1997) point that under the Global learning organisation in 1996, 40,000 students and teachers used an archaeological expedition in real time via the Internet to explain the 9th century collapse of the Maya civilization. Students had virtual hands-on experiences and helped the archaeologists answer the questions.

Such experiences are a long way from the traditional 'chalk and talk' and it encourages one to contemplate new forms of distance education. Indeed, already, UNE has demonstrated in principle that GrassGro can be served out over the Internet. Permission has now been granted to develop this mode of delivery further. As the speed of the computer simulation depends only on the speed of the server and not the Internet connection, it presents a viable means of running the software from any location in the world with Web access.

As pointed out by (Thorpe 1995), distance education can include constructivist and cognitive approaches to learning - we just need to design ways of achieving it. One way of assisting both internal and external students to understand their GrassGro experiences better, and especially to link theory with practice, will be to create a Resource Book of published literature which will act as a catalyst for exercises across a range of disciplines.

The project which we embarked on in 1998 turned out to be a far more ambitious project than any of the original proponents would have ever believed at the time. In fact, it is true to say that we were naïve in thinking that this two-year project would be a finite event. It is likely that we have commenced an action learning process that will embroil many of us for years to come. Having come so far, it is difficult to see us stopping after having travelled only a short distance along an exciting path that is ever lengthening. We look forward to the continuing journey.

Future Opportunities

The approach taken has provided an excellent vehicle for improving student understanding of complex ecosystem interactions. Use of a consistent platform (in our case, the GrassGro software), has enhanced collaboration between lecturers from different disciplines, and produced common documentation across degrees. These two aspects have been keys to the success of the project. This has sparked enthusiasm to expand the efforts at University of New England to make better use of Internet delivery of software, to increase the numbers of models to eventually create a unit in decision support systems.

Details of further developments regarding continuation and expansion of this project will continue to be made available as they occur through the University's Web portal at http://www.une.edu.au/dss.

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Appendix 1 - Table of Contents of GrassGro Portfolio

GrassGro™

Portfolio

by

Helen Daily, Jim Scott, Geoff Hinch, Lisa Lobry de Bruyn, and Jim Reid

Version 1.0

March, 2001

University of New England

The University of NEW ENGLAND

GrassGro Teaching Portfolio

A teaching initiative at the University of New England to provide a structured approach to teaching and learning about complex ecosystems, Decision Support Systems and to enhance computer competencies.

This portfolio is intended for distribution to undergraduates within the Degrees of Agriculture, Rural Science, Environmental Science, Natural Resources, Agricultural Economics and Agribusiness at the University of New England.

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We are also in debt to the interested students and our teaching colleagues who have become involved in this project.
The active participation and in-kind support by Drs. John Donnelly and Andrew Moore and of Ms. Libby Salmon, the GrassGro trainer, of CSIRO Plant Industry and of Mr. Rob McCook of Horizon Technology is greatly appreciated.
GrassGro™ is a trademark of CSIRO Australia.
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