Threshold Learning Outcome 3: Inquiry and problem-solving

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The Threshold Learning Outcomes (TLO) 3 Inquiry learning and problem-solving closely references TLO 3 for science (Jones et al. 2011). TLO 3.1, identifying contemporary issues and opportunities in agriculture is unique to agriculture TLO3.

The Good Practice Guide for TLO 3 for science (Kirkup & Johnson 2013) provides a comprehensive review of the literature supporting inquiry learning and problem-solving, its development, successful delivery and implementation within higher education. This chapter highlights the main similarities and identifies the key differences between TLO 3 for science and TLO 3 for agriculture by:

1. providing background information on the role of inquiry learning and problem solving in professional agricultural practice
2. a discussion of learning strategies and activities that could be used to develop TLO3
3. providing case studies that are working examples of the development and implementation of learning strategies and assessment across year levels of undergraduate programs in agriculture and agribusiness
4. highlighting the challenges and opportunities that exist for the implementation of inquiry learning and problem-solving in an undergraduate program.

Threshold Learning Outcome (TLO) 3: Inquiry learning and problem-solving states that, upon completion of a bachelor-level degree in agriculture or a related sub-discipline, graduates will critically analyse and address dynamic complex problems in agriculture by:

3.1 Identifying contemporary issues and opportunities in agriculture.

3.2 Gathering, critically evaluating and synthesising information from a range of relevant sources and disciplines.

3.3 Selecting and applying appropriate and/or theoretical techniques or tools in order to conduct an investigation.

3.4 Collecting, accurately recording, analysing, interpreting and reporting data.

(Botwright Acuña et al. 2014a)

The role of inquiry and problem-solving in agriculture

Agriculture is a multidisciplinary profession that requires an understanding of a range of complex systems based on physics, chemistry and biology incorporating mathematics at all levels (Parr et al. 2007) and includes non-science discipline areas such as business, economics and finance, geography and the social sciences.

Sciences such as chemistry, physics and biology that are considered to be 'pure' sciences, underpin broader discipline areas within agriculture such as animal production and management, crop and pasture production and management, soil science, plant and animal health, and managing food production under climate change as well as quality and safety across the food supply chain.

Agriculture graduates therefore need to be able to exhibit a breadth and depth of knowledge across science and non-discipline areas such as social science, economics, management and environment. These are discussed in the chapter addressing TLO 2 *Knowledge of Agriculture*. However, students' ability to apply this knowledge to problem-solving in real-life situations is integral to their success as a graduate (McSweeney & Rayner 2011).

Agriculture graduates must be problem-solvers. They must be able to identify problems and issues (often relating to production), evaluate options and potential strategies, and implement appropriate and innovative solutions while maintaining focus on potential social and economic implications. The agriculture graduate of the future must be able to respond to the potential impacts of climate change on productivity; to changing consumer demands; and to changing global markets within the contexts of family, community and national social structures. Solutions will depend on goals set by enterprise focus, family structure, social implications, markets, financial opportunities and constraints, and future planning. Furthermore, goals tend to be interactive, in that they are based on a combination of factors related to economic, sustainable and social factors (the triple bottom line).

TLO 3 is integral to students in agriculture where an inquiry-based approach builds on prior knowledge, understanding and skills. Capstone units, usually incorporated in the final year of undergraduate agriculture programs, encourage the integration of understanding (TLO 1) and knowledge (TLO 2) across a range of science-based and non-science disciplines within an agricultural context. Students have the opportunity to utilise their skills in inquiry and problem-solving and to show that they have become self-directed and independent learners (as required for TLO 5).

In the workforce, agriculture graduates are expected to take leading roles in identifying, investigating and solving problems in a range of working environments including research, extension and engagement, advisory or consultant services, and production. Graduates who enter the workforce as life-long learners and who are able to apply inquiry and problem-solving skills can integrate new knowledge throughout their career. Agricultural knowledge is changing and adapting to new environments, markets and technologies and, with increasingly globalised economies, the rate of change is ever-increasing. Agriculture graduates need to be at the centre of innovation and be capable of balancing environmental, economic, social and political demands and dynamic interactions with a range of stakeholders (Engel & van den Bor 1995).

Learning approaches to develop inquiry and problem-solving skills

Agricultural education pedagogy includes the focused development of problem-solving and critical thinking skills in undergraduates (Parr & Edwards 2004), which are achieved through a number of active/participatory learning approaches. Students subsequently attain a deeper level of understanding (Marton & Säljö 1976). These approaches may include guided and more independent inquiry-based learning, problem-based learning, small scale investigations (including field work and case studies) and project-based learning. These approaches may provide learning from student-centred (active) rather than teacher-delivered (passive) experiences. Research has shown that higher quality learning outcomes are achieved through strategies that encourage student-centred learning (Baeten et al. 2016; Baeten et al. 2010).

The importance of active learning

Passive learning, including traditional delivery methods such as lectures, demonstrations and instructed activities, is considered information transmission and is less successful in developing independent, life-long learners able to identify, investigate and develop solutions for the issues and opportunities that co-exist in agriculture. Active learning centres the learning experience around the student with activities, introduced in the classroom, encouraging student activity and engagement in the learning process (Prince 2004). The teacher becomes a facilitator, providing opportunities to learn independently and through peer interactions (Froyd & Simpson 2008). Based on Dale's "Cone of Experience", students retain less than 50% of information delivered by traditional approaches and are less able to critically analyse and evaluate information. On the other hand, students involved in active or participatory learning experiences have retention rates up to 90% (Dale 1946).

Reviews comparing passive and active learning provide a range of opinions and support for the learning strategies but generally conclude that active learning has an important role in the education of undergraduates in the areas of history, political science, science, psychology and agriculture (McCarthy & Anderson 2000; Michael 2006; Minhas et al. 2012; Prince 2004) and is a preferred learning strategy for most students (Savery 2006).

The implementation of active learning strategies has been shown to achieve an increased level of sophistication of students' knowledge around science (Clough 2006; Deng et al. 2011; Lederman 2007); similar principles can be applied to the teaching of agriculture. Traditional delivery and learning strategies are less likely to deliver an agricultural graduate with the range of communication, analytical and critical thinking skills that are required into the future.

A variety of active learning strategies are available to support the development of inquiry and problem-solving skills in agricultural graduates. These strategies include:

- Inquiry-based learning ranging from process-oriented guided inquiry learning (POGIL) to open student driven inquiry
- problem-based learning
- project-based learning – including field studies.

The value of active involvement in the learning process was recognised by Confucius around 450BC: "I see and I forget; I hear and I remember; I do and I understand".

Developing inquiry learning and problem-solving skills

Inquiry-based learning reflects science as being a question-driven, open-ended process (Edelson et al. 1999) providing an active learning environment in which the student becomes the focal point for learning by building on existing frameworks through meaningful experiences (Parr et al. 2007). Students engage in the learning process as individuals and/or groups to ask questions, solve problems and explain and actively discuss concepts (Kirkup 2013; Kirkup 2015; Michel et al. 2009). Collaboration is an important component of inquiry learning, developing teamwork skills (TLO 5) to investigate questions and encourage working together in a relaxed environment that promotes discussion, creativity, teamwork and problem-solving abilities as well as enabling students to take active responsibility for their learning (Krumwiede & Bline 1997).

Using ill-structured (or ‘real-life’) problems or scenarios that are open-ended requires students to draw on existing knowledge, identify gaps in knowledge and design a study to address the problem. Students need to grasp that these problems are likely to have more than one possible solution (Savery 2006) and to be open to a range of possible solutions.

Selecting problems that are relevant to the discipline area and will capture student interests is important. As new information is found in the process of inquiry the question may change. Students are encouraged to develop their own opinions and views through exploration – rather than to accept “textbook views” (Howitt & Wilson 2015). Students are also encouraged to discuss and justify their views through the collection, collation and presentation of evidence (Kahn & O’Rourke 2004; Kuhn et al. 2000; Michael 2006) to the class encouraging reflection and consolidating principles and concepts (Kirkup 2015; Savery 2006). Collaboration is critical for the distribution of knowledge, the development of social interaction skills, and the emergence and solving of cognitive conflicts (Bell et al. 2010; Hmelo-Silver 2004) and the building of teamwork skills that are so important in the professional workplace (as indicated in TLO5).

Inquiry learning can be integrated at all stages through a degree program with students having increasing levels of independence as they develop both skills and confidence (Bell et al. 2005). For example, experiments need to be more structured in the first year and open-ended in the final year so that students can develop experimental design and implementation skills (Kirschner et al. 2006; Wang & Coll 2005). A first year case study in this chapter (Case study 3A: How does planting density affect crop growth and development?), is an example of a glasshouse experiment clearly structured to allow students to develop preliminary skills in experimental design, recording and analysis. Skills are further developed through the degree so that, by third year, students are capable of designing and implementing open-ended investigations (Case study 3N: Scaffolded research trial, presentation and report).

Improved learning experiences have been demonstrated across a range of disciplines that underpin agricultural production including biology, physics, chemistry, physiology, psychology and engineering (Michael 2006), particularly where these have been supported by new technologies (Kuhn et al. 2000). Similar outcomes were recorded in agricultural discipline areas such as plant biology (Loveys et al. 2014), crop production and marketing (Rhykerd et al. 2006), plant pathology (Shi et al. 2011) and biotechnology (Friedel et al. 2008). Studies with graduate students found that students involved in inquiry- and problem-based learning activities were better able to demonstrate deeper understanding of the concepts (Capon & Kuhn 2004).

Table 3.1 (adapted from Kahn & O’Rourke, 2004) summarises the current issues facing higher education and provides details of the positive outcomes and solutions that can be delivered by implementing inquiry-based learning.

The development of inquiry and problem-solving skills should be viewed as a continuum with activities scaffolded so that students show a progression in the development of inquiry independence as they move through the degree. Research shows that scaffolding the development of research skills within a plant biology unit in level II (Loveys et al. 2014) through tutorials, mentors and online support resulted in a better learning experience and increased student confidence. This research is discussed in more detail below.

Table 3.1: Potential impacts of inquiry-based learning on current issues in higher education (Adapted from Kahn & O'Rourke 2004).

Current issues in higher education	Potential impacts of Inquiry-based learning
GOALS FOR STUDENT LEARNING	
Career-ready; personal skills development	Allows the development of a wide range of abilities: knowledge-creation; team working; presentation skills; information literacy; information and communications technology (ICT); problem-solving; creativity; project management.
Gaps in knowledge Wide range of student experiences	Develops student abilities to identify and fill knowledge gaps; peer interaction can help fill gaps and share experience.
Disparity between theory and practice	Allows theory to be explored within real-world context.
Fragmented learning across units and disciplines.	Integration of cross-discipline knowledge and skills into the inquiry process.
THE LEARNING PROCESS	
Traditional passive/transmission approaches support surface learning	Students make connections between ideas and foster deeper learning opportunities.
Divergence between teaching and research	Able to utilise staff/institute research interests and programs; students have opportunities to participate in research programs.
Traditionally large classes can result in student social isolation	Working in small groups provides opportunities to foster relationships among students and students/staff.
Poor student motivation	Students are able to select topics and lines of inquiry that allow the experience to be relevant and realistic. Peer interactions support student engagement.
Diverse student needs	Students can set the pace of work and work with peers to meet needs.
Competitive approach to learning is not seen as appropriate in the professional environment.	Promotes teamwork for the main task and individual work on sub tasks.

Process-oriented guided inquiry learning (POGIL)

POGIL was developed in the 1990s for chemistry students (Chase et al. 2013) and is designed to follow the learning cycle (Figure 1). POGIL provides a structured inquiry-learning experience, often using structured worksheets, and can be viewed as the first step in the development of inquiry-based and problem-solving skills. POGIL activities are being used effectively across first year chemistry and biology courses at Curtin University and in first year chemistry courses at the University of Adelaide to introduce students of agriculture and related disciplines to inquiry learning.

Working in small groups within class time, students are guided through a specifically designed set of activities that encourage students to use current knowledge to explore one or more models and to construct understanding around a concept. POGIL activities have four components (Chase et al. 2013; McComas 2014):

1. information and orientation to the question/problem
2. exploration of the concepts using one or more models
3. demonstration of understanding through questions and application exercises; wideas can be represented and connected in a number of different ways
4. communication to peers and reflection on progress and performance.

Working in teams in class time, students use background information together with provided models (e.g. flowcharts, graphs, diagrams and charts) and a series of questions to develop an understanding of the key concept and apply the understanding to a new set of problems (Brown 2010). Within the group, students are assigned roles designed to develop an understanding of working as a team (contributing to TLO 5). Roles should be rotated through the group in subsequent activities enabling an understanding of group dynamics and member responsibility to be developed.

POGIL activities require careful construction but have been shown to significantly improve student performance across a range of disciplines. POGIL is the first step in the development of the independent learner that is associated with active learning. POGIL activities are best implemented when structured to replace the "traditional" lecture (Chase et al. 2013) rather than being seen as an additional activity. Replacing traditional delivery with the POGIL approach for an introductory anatomy and physiology class at King College (Bristol, Tennessee USA) resulted in improved performance of students and significantly decreased failure rates. This was accompanied by an increase in student satisfaction rates (Brown 2010).

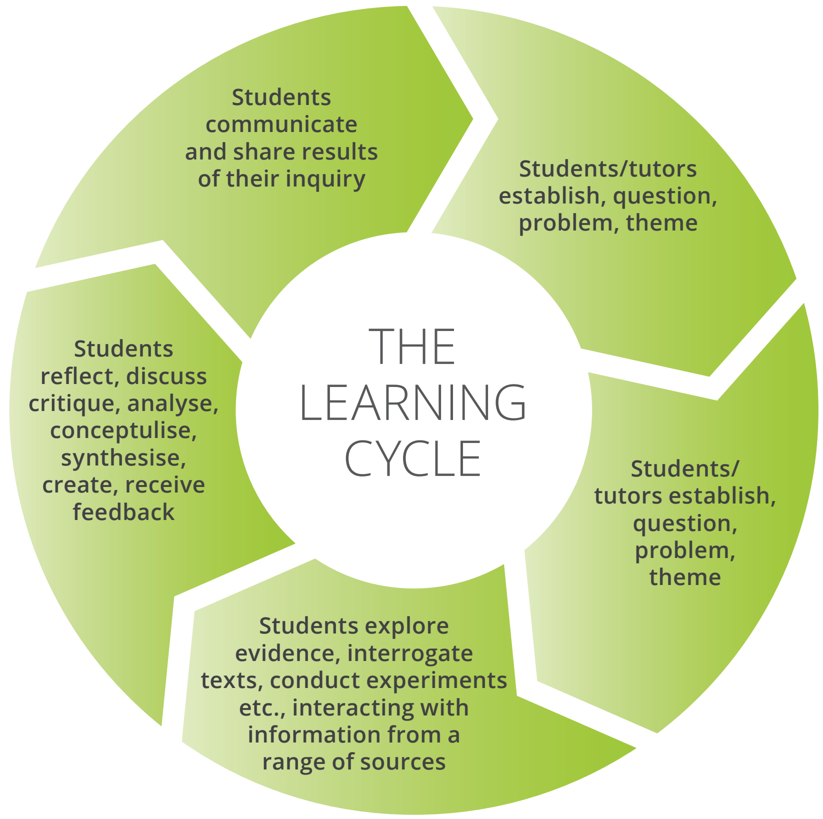


Figure 3.1 The learning cycle (Queens University, 2016)

Problem-based learning

Problem-based learning (PBL) is an extension of POGIL in which the investigation is facilitated by the classroom tutor/teacher but the students are responsible for determining the information that is needed (Savery 2006). PBL differs from POGIL because students are presented with the problem or issue first rather than other resources (Barrett 2005). Having been presented with an ill-structured problem, individuals within the team access and use prior knowledge and, within a collaborative group, use the knowledge to propose a model or a solution (Schmidt et al. 2011). Better learning experiences occur when the problem follows some basic rules (Schmidt et al. 2011) that include that the problem:

- must be authentic (i.e. real world complex problems and issues)
- is adapted to the level of prior knowledge held by the students
- promotes discussion between group members
- leads to the identification of appropriate learning issues
- stimulates self-directed learning
- is of interest to the cohort/group.

The group works together to review and refine the outcomes that include sourcing further knowledge, which is shared among the group members. Integrating the traditional delivery methods of separate theory and practice through PBL provides students with in-context knowledge and allows students to integrate knowledge across the disciplines that contribute to agriculture (including the basic sciences, business, economics and the social sciences).

Group size can influence PBL experience. Small groups provide a platform for social interaction and the development of "belonging", encourage and support discussion, peer motivation and active and closer contacts between students and facilitating staff. Group work is discussed further in TLO 5 (Helle et al. 2006; Schmidt et al. 2011). Although there is some debate about the outcomes of research studies that compare the effectiveness of traditional and PBL approaches to learning, it is widely adopted in learning institutions ranging from primary and high schools through to postgraduate programs and across educational domains in all areas of health education, business, chemical engineering, economics and architecture (Savery 2006). The student's sense of achievement is a valuable outcome of the process.

PBL has been effectively used in units delivered across agriculture degrees both in the class room and as part of online learning. Facilitators can draw on many of the challenges and production issues that face producers to provide authentic questions for their students. Tan et al. (2014) used PBL for first year students in agriculture and veterinary science degrees to transform a traditionally presented unit into PBL using online and face-to-face sessions. Students in this unit used PBL to discover relationships between climate, biophysical and biotic environments and rural production. McAlpine and Dudley (2001) successfully developed an online soil science unit focused on soil sampling and survey techniques using PBL to develop competency in vocational education students. Problem tasks were designed around real-world issues that could be encountered in the field. The online approach challenged students and provided them with confidence in working with farmers; there were some issues with group dynamics.

Examples of PBL assessments are provided in the case studies at the end of this chapter. An example at intermediate level (II) is Case study 3E (Experimental design and statistical analyses using a virtual field experiment). Examples at advanced level (III) include Case study 3J (Agri-environment plan for a UK farm) and Case study 3L (Evaluation of grazing options using GrassGro™).

Evaluation of the learning experiences have found that students generally find the tasks challenging but have a high sense of achievement in developing existing knowledge to enable them to solve the problem.

Project-based learning

Project-based learning is a further development of POGIL and PBL in which students develop a question in an area of interest and are guided through the process by the teacher/facilitator (Bell 2010). Project-based learning allows a more open-ended approach to inquiry than POGIL and PBL and allows the students to be more independent in the approach. The time allocation for project-based learning is greater than that for other inquiry-based approaches with projects continuing over a number of weeks and the teacher/facilitator acting in an advisory role (Helle et al. 2006).

The redesign of the courses provided by Hawkesbury Agricultural College (NSW) in the 1980s allowed students to identify problems at farm-level and work with peers and farmers across the farm system to propose, test and review solutions (Bawden et al. 1984).

The setting for developing inquiry learning and problem-solving skills can range from the classroom, laboratory, field and workplace. Data collected as part of the process can include social and economic information, data from surveys and questionnaires as well as data collected from laboratory and field experiments and trials (Hofstein & Lunetta 2004). At Curtin University students utilise field sites to pose production questions, to design and implement trials to answer these questions and to analyse, review and report outcomes (Case study 3N: Scaffolded research trial, presentation and report). Students' interest and motivation have been shown to be significantly greater when they are involved in planning, design and implementation (Hanauer et al. 2006; Schoffstall & Gaddis 2007).

The project-based learning process is driven by questioning based on natural curiosity and the motivation to provide a solution. Project-based learning is often linked to the production of an end-product or design, considered to be a more concrete outcome than that achieved in problem-based learning alone (Helle et al. 2006).

In project-based learning, the collaborative group is the controller of the investigation. When students feel that their contributions towards solutions to a problem are valued agricultural students are transformed to "student agriculturalists". This transformation has been used to describe the impact of inquiry learning on science students (Howitt & Wilson 2015). Loveys et al. (2014) used project-based learning with a group of students in the second year of agricultural science and viticulture and oenology degrees. Students were provided with research topic areas early in the semester and worked in groups with mentors to design and undertake a project. Students found the experience challenging, particularly in the areas of design and finding appropriate literature, but responded well to the group environment and, with the addition of more support, were more confident in research and data analysis.

Agriculture provides many opportunities to provide students with authentic, real-world experiences through field tours and work experience placements (Work Integrated Learning or WIL) as well as through questions, problems and projects within the classroom environment. Linking students with producers and researchers during field tours exposes them to unpredictable and complex situations, and provides the opportunity to see firsthand the investigation processes and to interact with producers, business owners, consultants and research scientists. An example of how interaction with industry can be used in project-based learning is given in the case studies in the chapter for TLO 5, in the context of becoming a self-directed and independent learner.

Students can use technology such as virtual labs and remote/local data collection for analysis of real world problems, analysis of data and the development of models and solutions (Edelson et al. 1999; Kim et al. 2007). These technologies include:

- soil sensors (temperature, pH, moisture and electrical conductivity)
- weather data (Bureau of Meteorology (BOM) local weather stations)
- pasture/plant growth using normalised difference vegetation index (NDVI) (e.g. 'Pastures from Space' or hand-held NDVI meters)
- animal grazing patterns using tracking sensors
- development of precision agriculture paddock maps based on grain yields and soil analysis data.

Computer technologies such as modelling and simulations have been described as "intellectual partners" that encourage and support higher order thinking skills (Kim et al. 2007). Examples of agricultural modelling programs used at Curtin University as part of inquiry and problem-solving include, but are not restricted to:

- 'The Island' (The University of Queensland) (Case study 3E).
- 'Risky Business Farm Game' (Case studies 3H and 3K)
- GrassGro™ (Horizon Agriculture) (Case study 3L)
- Agricultural Production Systems sIMulator (APSIM) (Case study 3O)

These technologies provide students with flexible options for collecting data and have the potential to produce a number of possible pathways for solutions (Bell et al. 2010). New tools are being developed with the aid of the Office for Learning and Teaching (OLT) grants to provide students with on-farm experiences from the class room. These include an interactive 4d farm (OLT grant 2012 - The University of Melbourne) and SMART farm (OLT grant 2015 – University of New England). Students develop skills in analysing outputs and providing comparative evaluation of management options often in the form of consultant reports. The value of these may depend on the levels of prior knowledge and motivation (Kim et al. 2007).

Assessment for inquiry-based learning

One of the issues with an inquiry and problem-solving approach to student learning is the selection of assessment options. Assessment of rote learning is much easier, as critical thinking is discouraged (Elby & Hammer 2001). The importance of using different methods of assessment to assess whether the learning outcomes of a unit have been met is discussed in detail in the Good Practice Guide for Science for TLO 3 (Kirkup & Johnson 2013).

Assessment strategies need to be developed to continue the positive gains made from using inquiry-based learning strategies. Multiple choice tests, for example, are unlikely to be an effective assessment for the new learning strategies. Inquiry-based learning strategies are designed to include the learning cycle, resulting in the production of solutions through an iterative process.

Use of formative assessments that include feedback for improvement could be used as part of the assessment process (English & Kitsantas 2013; Kahn & O'Rourke 2005). For example, a two-page scientific report or FarmNote style report allows for rapid marking and feedback to students that can be incorporated into the next assessment task. This guides student learning and ensures that feedback is read, understood and incorporated. Case Studies 3B and 3G provide examples of guided learning within the semester. Implementation of multiple assessment points (milestones) may impact on workloads for facilitators and result in resistance to changing teaching strategies. Ideally, assessment strategies should be included as a natural component of the inquiry rather than as a separate component (Kahn & O'Rourke 2005).

By nature of the approach there may be multiple solutions for the problem, which may result in a challenge when marking. Major and Palmer (2001) suggest that assessment may need to be based on comparisons across class submissions and the evaluation of the resources used as well as an evaluation of inquiry and problem-solving skills such as experimental methodology, research and critical thinking skills. Learning assessments need to use authentic assessment strategies (Hofstein & Lunetta 2004).

Suggestions for assessment include journals, portfolios, videos and media presentations, experiments, self and/or peer assessment and response items (Barron & Darling-Hammond 2008; Major & Palmer 2001). The ability of individual students to assess their own work is an important outcome of inquiry-based learning approaches; self and peer assessments as well as reflective journals or statements allow students to critically assess performance in light of expectations. Technologies within online learning management systems have been developed for the monitoring and assessment of portfolios, potentially reducing the perceived increased workload of academics.

The development of a range of reporting skills that assess the TLO3 learning outcomes in agriculture include the following:

- scientific papers– Case studies 3A and 3G
- essay – Case study 3B
- poster – Case study 3C
- reports – Case studies 3D, 3E, 3H
- consultant reports – Case studies 3J and 3L
- presentations – Case study 3N.

Conclusions: Challenges and opportunities

Many attempts have been made to establish the validity and superiority of inquiry-based learning pedagogies. The outcomes of these reviews are unclear with conflicting issues in defining the pedagogy, approaches to the research, student cohorts studied, assessment of results and, thus, the potential value of inquiry-based pedagogy to student learning (Capon & Kuhn 2004; Hmelo-Silver 2004; Kirschner et al. 2006; Schmidt et al. 2007). Inquiry-based learning must be recognised as the starting point of lifelong learning and, therefore, attainment of TLO 3 contributes substantially to addressing TLO 5. Results and differences in problem-solving abilities may be observed in students but are more likely to be seen after graduation, which has not been reviewed here.

Inquiry-based learning activities must ensure that learners of all abilities are able to gain new information around the selected topic. This can be achieved in two ways: 1) suitable scaffolding within the activity to address ability and prior knowledge levels; and, 2) the peer learning support provided by group collaboration (Bell et al. 2010). Motivation is critical to the success of the implementation of inquiry-based learning strategies. Challenges for the facilitators are to ensure that all students are encouraged and supported to develop these key skills (English & Kitsantas 2013).

Edelson et al. (1999) identified five challenges to implementing inquiry-based learning in the classroom. These identified challenges were:

- **student motivation:** inquiry-learning activities require active participation as individuals and as part of the collaborative team. Motivation is closely linked to interest in the topic and lack of interest may reduce student engagement.
- **accessibility to tools for investigation:** tools are required to fill knowledge gaps, and allow suitable data collection and analysis. The tools available must be able to cater for varied student experiences and abilities.
- **background knowledge:** all inquiry-based learning for science and for agriculture students requires content knowledge. The design of the activity must provide students with the opportunity to develop the content knowledge required for the investigation. Background knowledge may be influenced by cultural values and beliefs within the student cohort (Magee & Meier 2011).
- **management of activities:** students are required to manage individual tasks as well as prepare and participate in collaborative sessions. Time and task management skills are important to the successful completion of these tasks.
- **practical constraints of the learning environment:** the ability to complete the tasks can be constrained by time (in class and out of class)/schedules and availability of tools and resources.

Edelson et al. (1999) demonstrated how these challenges can be addressed by providing the example of the design of tasks using scientific visualisation of climate data under the Learning through Collaborative Visualization Project (CoVis). Four tools were used for this project: Climate Visualizer, Radiation-Budget Visualizer, Greenhouse Effect Visualizer and WorldWatcher.

Kirkup et al. (2010) recognised the difficulty of using inquiry and problem-solving activities with large class sizes and stressed the importance of using professional development opportunities to teach lecturers to be facilitators. The teacher is critical to the selection, development and facilitation of inquiry-learning tasks in the classroom as they have multiple roles in the process with the potential for increased time commitment high. Importantly, commitment to the implementation of inquiry-learning practices in the classroom must be accompanied by opportunities for ongoing professional development.

This will result in activities that are well scaffolded and supported and provide the student with real world experiences (Hofstein & Lunetta 2004). Those involved in the development and delivery of inquiry-learning in agriculture (as for science) must draw on research and agricultural production experiences.

Inquiry-based learning strategies provide a valuable opportunity for teaching staff to integrate their research interests into the class environment. Students can be provided with examples of current research activities or can actively participate in components of a research program. Research-based learning can begin in the first year of an undergraduate program and develop into project-based capstone units in the final years (Katkin 2003). The links between learning and research are strengthened through the implementation of discovery-oriented studies that rely on progressively developed inquiry skills (Spronken & Smith & Walker 2010).

Resources for TLO 3

Agricultural Production Systems Simulator (APSIM)

https://www.apsim.info/

The Agricultural Production Systems Simulator (APSIM) is a farming systems modelling program. It enables a range of simulations of plant, animal, soil, climate and management interactions. The large number of modules developed by researchers are used by modellers worldwide. The software is freely available and allows simple to complex problems to be investigated over a large number of seasons, locations and soil types.

Australian National University Case Studies of Educational Excellence

http://edcasestudies.chelt.anu.edu.au/category/keywords/problem-based-learning

This site provides examples of case studies across a wide range of disciplines. The available case studies have been recognised as examples of excellence having been supported by awards and grants. Case studies relevant to agriculture include genetics education, sustainable farming/carbon impacts and environment management.

Buck Institute for Education – PBL Essentials Webinar

https://www.youtube.com/watch?v=Pou61mRWzlE

This webinar explains the key concepts around effective, rigorous Project-Based Learning, given by John Larmer, Director of Product Development at Buck Institute for Education.

Bureau of Meteorology (BOM)

http://www.bom.gov.au/

This website provides current weather, past climate data and future climate predictions for numerous sites around Australia. Data can be downloaded for analysis to link to current research trials and can be interrogated to investigate climate change and climate variability over time. All data are freely available. Recent additions in the Agriculture Section include a frost prediction map for the next two nights and MetEye™ – Your Eye on the Environment, which provides accurate up-to-date weather and current predictions around Australia. A recent addition in the Water Section is the Australian Landscape Water Balance which provides Australia-wide maps of actual and relative soil moisture, evapotranspiration and precipitation.

CSIRO Pastures from Space

http://www.pasturesfromspace.csiro.au/

The Pastures from Space program provides estimates of pasture production during the growing season using remote sensing. Pasture biomass and food-on-offer (FOO) are accurately estimated using satellite data, and are combined with soil and climate data to estimate pasture growth rates (PGR). PGR and FOO estimates provide temporal and spatial information of feed resources that can be used by producers to help manage enterprises and, subsequently, have the potential to raise the productivity and profitability of their business. It covers the Mediterranean-type and temperate areas of southern Australia. Users are required to register to access the data.

EduWebinar

http://eduwebinar.com.au/web-tools-to-support-inquiry-based-learning

The website links to numerous web tools that can be used by educators to help their delivery around inquiry-based learning. The web tools are listed around the eight-phase framework developed by Kuhlthau et al. (2012) and a brief description of each is provided.

GrassGro™

http://www.hzn.com.au/grassgro.php

GrassGro™ is a decision support tool that can be used by students to investigate and plan sheep and beef enterprises in various locations around Australia to maximise profits, manage risk and investigate the feasibility and impact of changing management practices. It can be used to test management options across a wide range of seasons to obtain more profitable and sustainable utilisation of grazing systems using information provided on weather, soils, pastures and livestock at a location. An example of using GrassGro™ is given in Case study 3L.

GRDC GrowNotes

http://www.grdc.com.au/Resources/GrowNotes

This website provides a series of regional crop management notes providing information on best practice for a range of crops.

Instructor's Guide to Process-Oriented Guided-Inquiry Learning

https://pogil.org/uploads/media_items/pogil-instructor-s-guide-1.original.pdf

This freely available handbook by Hanson (2006) describes POGIL and its application. This has been discussed in detail in the GPG for Science TLO 3. A number of POGIL guides are available through the website (https://pogil.org/post-secondary); some of these may be applicable to units in agricultural degrees.

NSW DPI Pro-Crop Guide

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides

These guides for a range of agricultural crops provide students with information on crop management.

Risky Business – Simulation Farm Business Game

The Risky Business Farm Game has been developed by Abadi (2003) to allow participants to learn about managing a farm business under risky circumstances including climate and markets. It is run as a facilitated workshop where participants work in groups to manage the computer farm, making decisions around crop rotation, fertiliser application, forward selling of their grain and the management of salinity through planting trees or perennials under an unknown climate and market scenario. Key performance indicators, including farm profit, farm equity, percentage of farm in crop and pasture, annual and growing season rainfall, and percentage of salt in the lowest paddock, are generated for each group and are discussed to enhance the learning experience. Examples of using Risky Business Farm Game are given in Case studies 3H and 3K (Abadi 2003)

The University of Queensland, The Islands

https://islands.smp.uq.edu.au/login.php

An example of using The Islands is given in Case study 3E. This program may be accessed by contacting The University of Queensland and requesting a new login. The login request is generated when this link is accessed and a login ID is requested.

University of Manchester, Centre for Excellence in Enquiry-based Learning

http://www.ceebl.manchester.ac.uk/

The Centre for Excellence in Enquiry-based Learning (EBL) has developed a range of resources including case studies around enquiry-based learning and problem- based learning. Academic papers defining the process of EBL, technical guides and a range of information guides to help develop and implement activities are available.

University of Wollongong

http://www.learningdesigns.uow.edu.au/index.html

The Learning Designs website has been designed to provide teachers and instructors in higher education with information on communication technologies and their role in flexible learning. A large set of resources are available that support the development of flexible high-quality learning experiences for the student focused around exemplars of proven learning designs, guides on their implementation in your knowledge area and tools that are available to support the students.

Knowledge and skills in agricultural economics and business management have been acknowledged as essential in agriculture graduates.

Case study 3A: How does planting density affect crop growth and development?

Unit: Introduction to Agricultural Systems

University: Curtin University

Coordinator/Teacher: Dr Susan Low

Year: Level I (Introductory)

Unit context: This is a core first year unit in the Bachelor of Agribusiness. This unit provides students with an overview of the importance and scale of agricultural industries in relation to Western Australian, national and global contexts. This unit provides students with an understanding of agricultural value chains within the production system, and recognition of the constraints to production in current and future farming systems.

Description of task: Students work in pairs to plan and carry out an experiment to investigate the effects of planting density on growth and development of one monocot and one dicot crop species, such as wheat, barley, oats, canola and lupins. Class data is collated and analysed for the final report. Students are provided with a broad outline of the experiment and references for background reading that are used to decide the density treatments and planting depths for each species.

The experiment is designed by the class with students drawing on experimental design knowledge (TLO 1) and reaching a consensus on the treatments i.e. plant numbers (optimum, high and low density). Students randomise the pots before setting up the experiment in a glasshouse. A consensus is reached on the techniques to be used and the collation of data, which includes stage of growth, plant dry weights per pot and root and above-ground dry weights.

Students learn how to determine stage of growth through a practical session prior to the first data collection using decimal keys, such as Zadoks et al. (1974) data management, use Excel for data analysis and then write a scientific report. The experiment runs for eight weeks through the semester with data collected every two weeks. Students write a mini-scientific paper that includes the relevance of the results to crop management.

Educational aims: This assessment task aims to encourage students to:

1. find information relevant to current accepted crop management practices from relevant industry information sources (TLO 3.1)
2. use relevant information to plan and undertake an experiment in a glasshouse (TLO 3.3)
3. develop skills in accurately describing stage of growth of monocot and dicot crop species (TLO 3.3)
4. collect, collate and statistically analyse data from the experiment (TLO 3.4)
5. Produce a scientific report that identifies the relevance of the information to farming systems (TLO 3.4)
6. work effectively and responsibly together with class members (TLO 5.2).

Assessment details: The assessment is worth 30% of the final grade. In Part 1 (10%), students submit a literature review and methods in Week 4 of the experimental period. This is marked and feedback is provided on areas that need improvement for the final report. In Part 2 (20%), tutorials are provided to guide students through data analysis and the writing of the final submitted paper.

Other relevant comments or advice: Consider the size of the data sets to be analysed. Large data sets (due to large class size) become overwhelming for first year students. However, it is important that students work together in groups to collate replicate data, which allows for discussion around source of variation and ensures that all students are involved in planning and data collection.

Case study 3B: Scaffolded essay on sustainable management

Unit: Sustaining Our Rural Environment I

University: University of New England

Coordinator/Teacher: Dr Janelle Wilkes, Mrs Lisa Gurney, Ms Julie Godwin

Year: Level I (Introductory)

Unit context: This is a core unit in the Bachelors of Agriculture, Agribusiness, Agrifood Systems, Animal Science and Rural Science. This unit introduces students to the underlying principles of natural resource allocation and sustainable use. The global impact of the human population on land, food and energy resources is investigated.

Description of task: The unit is taught in a blended mode to both on-campus and distance students and includes practical sessions on campus for both cohorts.

Students complete a connected four-part assessment worth 40% of the total grade that considers the importance of structure, style and content in effective written communication (thereby addressing TLO 3.2).

Student confidence and engagement are promoted through early success and skill development in the low-weight early tasks undertaken prior to the major written task.

Educational aims: This assessment task aims to:

1. find information from a variety of sources
2. evaluate the reliability and relevance of sources of information
3. synthesise information to produce a coherent written document.

Assessment details: All parts of the assessment are relevant to the theme of the major written task, as follows:

Part 1 (library quiz 5%, Week 2): This quiz consists of 15 questions on the library website, search functions, evaluation of appropriate and relevant academic information and basic referencing.

Part 2 (synthesis 5%, Week 4): Students are provided with extracts from four sources with full bibliographical details, including one unreliable source. Students write a paragraph that synthesises information from the extracts provided. Student work is peer-assessed in class over 1.5 hours, where they discuss critical reading and evaluation skills, the development of their synthesis and scientific writing skills for the major written task.

Part 3 (essay 25% Week 8): A written task of 1500 words where students demonstrate their scientific writing skills and in-depth exploration of the topic.

Part 4 (self-evaluation 5% Week 8): Students engage in a reflective task to evaluate their learning and new capabilities in scientific writing.

Other relevant comments or advice: This assessment has been refined using reflective practice by students and staff. The topic is used to weave the unit together and ensure students are developing a deep understanding. Choosing a topic with which the student will engage is essential. The most successful topics used have been food miles, food security and coal seam gas.

The unit coordinator works collaboratively with the librarian and the first year academic science advisor to ensure the assessment has clear instructions, the topic can be successfully researched using the university library facilities and clear marking rubrics are included.

To date, the major writing task has been an academic essay. We are now moving to more authentic assessment tasks, e.g. preparation of a two-page background document in scientific style as a briefing note for a minister. Further information is provided in Wilkes et al. (2015).

Case study 3C: Project – identification and metabolic activity of spoilage microorganisms

Unit: Microbiology and Invertebrate Biology II

University: The University of Adelaide

Coordinator/Teacher: Professor Eileen Scott, Dr Karina Riggs

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelor of Agricultural Sciences. This unit provides an introduction to the biology of microorganisms and invertebrates of importance in agriculture, food, wine and natural ecosystems.

Description of task: The project addresses three questions:

1. What is the predominant organism present?
2. What other types of microorganisms are common in the specimen?
3. What substrates are the predominant organism(s) likely to use?

Students provide a spoilage organism (by approval of the course coordinator) or choose from a range of specimens provided such as fruit, vegetables or plants. Students work in teams of three or four and can choose their team members. Over a period of three weeks students are provided with culture media, materials and equipment to identify the spoilage organisms for their specimen based on characteristics (colour, texture, consistency, smell, pH, dry weight); direct microscopic examination; sampling and enumeration-direct plating/serial dilution; and; metabolic activities.

Students first plan, using a flow chart, how they will isolate their spoilage organism based on simple observations and the knowledge and skills learnt in the first four weeks of the course. They determine if their sample is likely to contain fungi, bacteria or yeast. This flow chart is checked by academic staff in the practical session before any experimental work can be conducted.

Students complete an individual journal online using the Learning Management System. Students complete four entries that focus on their contribution to planning and experimental work, the interpretation of results and to the poster. Students can incorporate photos taken throughout the study.

Students are guided through designing the poster in a series of structured tutorials. Guidelines and a marking rubric are supplied for the poster, journal and peer assessment. Project groups evaluate exemplars of posters across the grades P, C, D, HD that were submitted by past students and mark them using the rubric provided. Past posters are carefully chosen so that they do not include the same spoilage organisms of current students. The posters are assessed independently by two staff and both rubrics returned to the students.

The journal is assessed in conjunction with the poster and peer assessment to determine the contribution of each group member and the functionality of the group.

This project involves mentors from the South Australian Research and Development Institute (SARDI). The mentors attend practical sessions when students are working on their projects to provide guidance and support to students. A mini-conference is held upon submission of the posters that academic staff, mentors and the program coordinator attend and ask students questions about the project work and posters over morning tea. Students are able to interact with researchers in the field of microbiology and also become aware of the types of careers their degree can offer and obtain an insight into the benefits of postgraduate studies.

Educational aims: This assessment task aims to encourage students to:

1. explain the role and importance of microorganisms and invertebrates
2. discuss beneficial and deleterious activities of microorganisms in agriculture, food and wine
3. demonstrate an understanding of the processes involved in the recognition and manipulation of key groups of microorganisms and invertebrates
4. demonstrate effective information handling and communication skills
5. demonstrate the ability to work in a team.

Assessment details: The microbiology project work (poster and journal) contributes 15% to the total grade. The poster and peer assessment contributes 10% while the individual journal contributes 5%.

Other relevant comments or advice: Students generally enjoy this assessment task as they are given creative freedom to conduct their own microbiological investigation. Groups of 3–4 students are recommended to ensure the workload is divided equally. Having checkpoints throughout the projects ensures students remain on task and also allows academic staff to identify any issues with experimental results or within groups.

Case study 3D: Analysis of crop growth and development

Unit: Crop & Pasture Production II

University: The University of Adelaide

Coordinator/Teacher: Associate Professor Gurjeet Gill

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelor of Agricultural Sciences. This unit delivers an overview of agronomic production systems from a diverse array of dryland pastures and crops. In particular, the unit provides a practical understanding of selection, establishment, management and utilisation of crops and pastures in the main rainfall and soil environments encountered in southern Australia.

Description of task: Students work in groups of four to measure the crop development stage and shoot dry matter (biomass) of wheat, barley, canola and faba bean crops over the semester. Each group is responsible for recording, collating and analysing their own data; this information is used to prepare an individual final report.

Seeds are sown in 80m long strips at the teaching farm (Roseworthy Campus) with three samples taken over the entire length of each crop at each of three sampling times across the semester. Students determine the crop development stage using the decimal code appropriate to the crop.

Students record plant biomass and use it to determine crop growth rate and relative growth rate. The activity is supported by lectures on development patterns and crop growth analysis.

Educational aims: This assessment tasks aims to assist students:

1. to learn skills in measuring plant density, and biomass of field crops
2. to gain the ability to describe stages of development of field crops
3. to develop skills in interpreting and presenting information on crop growth and development
4. to undertake the comparative assessment of differences in crop growth and development pattern of four major crop species grown in South Australia (wheat, barley, canola and faba bean). Students also gain an appreciation of the differences in the development pattern of determinate (wheat and barley) and indeterminate (faba bean and canola) crops.

Assessment details: The report is worth 10% of the overall grade. The field experiment runs though the semester. Students are required to discuss and present their data using appropriate analysis and describe the relationship between crop dry matter, days after sowing, and crop growth stages across crop species over time.

Other relevant comments or advice: This activity provides the student with an opportunity to perform a task in real-time in the field at a scale representative of an on-farm experience.

Although students are guided through the measurement and calculation of the parameters, they must collect, analyse, interpret and then report the data in the context of their expectations (from the literature) thus contributing to TLOs 3.2 and 3.4. Considering the different measures and which ones are most applicable to a particular crop species will enable students to know which tool to select in future investigations (therefore contributing to TLO 3.3).

Working in groups during the data collection also allows students to learn from each other during that process and to work effectively (TLO 5). Resources may include the Zadoks decimal code for cereals (Zadoks 1974) and the BBCH scale (BBCH 2016).

Case study 3E: Experimental design and statistical analyses using a virtual field experiment

Unit: Quantitative Biology

University: Curtin University

Coordinator/Teacher: Dr Nicola Browne

Year: Level II (Intermediate)

Unit context: This is a core second year unit in Bachelor of Agribusiness. This unit provides an introduction to a range of statistical procedures which are frequently used in the biological sciences.

Description of task: The assessment is designed to allow students to design, set up and run a field experiment on a virtual experimental station. The assessment utilises a program developed by The University of Queensland called 'The Islands'. The program was developed for use as a tool to support teaching and learning in experimental design and statistical analysis. The current version of the program has three islands with different climates and soil types that are populated by small communities; each island has a field station with 36 plots (6 x 6) available.

Students must design a balanced field experiment to determine the optimum levels of nitrogen (N) and phosphorus (P) required by the crop on each island by varying the levels (five options available) of N and P applied to the crop. Students must decide on the parameters that are to be measured and recorded in the experiment. Data are collected through the experiment. Students must select appropriate statistical analysis methods and analyse the data for treatment effects and interactions within and across the islands.

Educational aims: Students learn to:

1. describe, summarise and appropriately present data
2. screen and appropriately transform data
3. select appropriate methods of statistical analysis for data sets and perform these procedures using statistical software.

Because students interpret and describe the output from their chosen statistical analysis in a manner appropriate for a scientific report, this task specifically meets TLO 3.3 and TLO 3.4.

Assessment details: The experiment is written as a short paper that includes an introduction, detailed methods section, results section, discussion and conclusion. Students are expected to have reviewed the impacts of nitrogen and phosphorus on crop production and to use this information in the papers. The assessment is worth 20% of the final grade for the unit.

Other relevant comments or advice: This assessment requires students to have some experience in data handling, univariate analysis and data organisation.

It is recommended that students are provided with a tutorial on field experimental design that includes a thorough discussion of block designs and confounding factors. This information is essential to ensure that students can devise an appropriate experimental layout and sampling design that will provide meaningful data.

If students are unfamiliar with The Islands, a 30-minute introductory session to The Islands by the facilitator will be necessary. A link to The Islands is provided in "Resources"; contact must be made with The University of Queensland through the link to obtain access.

Case study 3F: Team-based learning in biochemistry

Unit: Animal and Plant Biochemistry II

University: The University of Adelaide

Coordinator/Teacher: Associate Professor Christopher Ford, Dr Beth Loveys

Year: Level II (Intermediate)

Unit context: This is a second year core unit contributing to the Bachelors of Agricultural Sciences, Applied Biology, Viticulture and Oenology, Food and Nutrition Science, Animal Science, and the Science (Veterinary Bioscience). This unit provides an advanced introduction to the fundamental processes of plant, animal and microbial metabolism.

Description of task: Students have two whole-class Team Based Learning (TBL) exercises during the semester where they are provided with some learning materials prior to the class on the topic.

The TBL class begins with a series of 'single-best-answer' (SBA) questions based on the pre-class learning material, which are answered individually. Students then work with their team members to answer the same SBA questions. The answers are then revealed by the academic followed by discussion and clarification of any areas of confusion.

Subsequently, still working in their teams, students are presented with an additional series of SBA questions based on one or more scenarios developed from the topics under study. Answers are discussed within a class-based setting.

Educational aims: The topics chosen will allow students to learn to:

1. explain how protein structure and function are derived from the constituent amino acids, and compare the features of structural and globular proteins
2. describe the basic principles governing the rate of enzyme-catalysed reactions and the forms of inhibition of enzyme-catalysed reactions
3. describe the major pathways of carbohydrate and lipid metabolism and demonstrate how energy is stored and released through them.

The assessment task also contributes towards the unit learning outcome that students will have demonstrated the ability to undertake the research, preparation and delivery of presentations of biochemical topics selected to reinforce and augment the material presented in lectures.

Assessment details: The assessment comprises an individual and a team component. For the 10 SBA questions, the class votes on how to allocate the marks available (5% over two team-based learning activities) between the individual and team tests, e.g. 20% individual, 80% team. Students may dispute the academic's answer and provide a reasoned argument defending another possible answer. Points may then be awarded to the team.

Other relevant comments or advice: Interesting, controversial case studies or applications exercises provide good topics. It is important to have some mini-lectures prepared to be able to quickly address any areas of confusion.

Case study 3G: Scaffolded research skill development in the plant sciences

Unit: Foundations in Plant Science II

University: The University of Adelaide

Coordinator/Teacher: Dr Beth Loveys, Professor Amanda Able

Year: Level II (Intermediate)

Unit context: This is a second year core unit in the Bachelors of Agricultural Sciences, Applied Biology, and Viticulture and Oenology. This unit introduces the structure and function of plants with an agricultural and horticultural importance.

Description: The group research project provides the students with experience in the development and implementation of research to study factors affecting plant growth. These include: water stress, hormones, mineral status and biotic interactions and their impact on the plant at a physiological, anatomical, molecular and/or phenological level.

Online and face-to-face tutorials are used to guide students through developing a hypothesis, deciding on the data to collect, identifying appropriate statistical analysis methods and the interpretation of data. Students develop a research proposal as a group with some input from a mentor; they run the experiments and analyse the data as a group. Mentors are usually early career researchers in the plant sciences and the projects identify with a contemporary issue in agriculture (TLO 3.1) (e.g. phosphate uptake, salinity or drought).

The groups present their project outcomes as an oral presentation to the class. Students are also required to undertake peer assessment and provide a reflection about how they performed as a group.

Educational aims: The project will allow students to learn to:

1. design an experiment to help answer a research question
2. present data in a meaningful way via written and oral means
3. analyse data correctly and interpret outcomes accordingly
4. use the scientific literature appropriately in research development and interpretation of results
5. contribute to the team/group in a meaningful manner.

Assessment details: The assessment for the research project is worth 20% of the final grade for the unit.

Group Research Proposal (5%): Students work with a mentor and are supported by tutorials to develop their research proposal by Week 4. The proposal (~three pages) contains a literature review, research question/hypothesis, the experimental design and methodology and references. A rubric, used to mark the proposal, is provided to the students to assess whether the proposal has met the requirements for the planning, design and analysis and has the elements regarded essential in the sciences (such as controls and replication).

TLOs 3.1, 3.2 and 3.3 are met through this component of the assessment task. Using the feedback comments students refine their project proposal and change their list of requirements for the experiment.

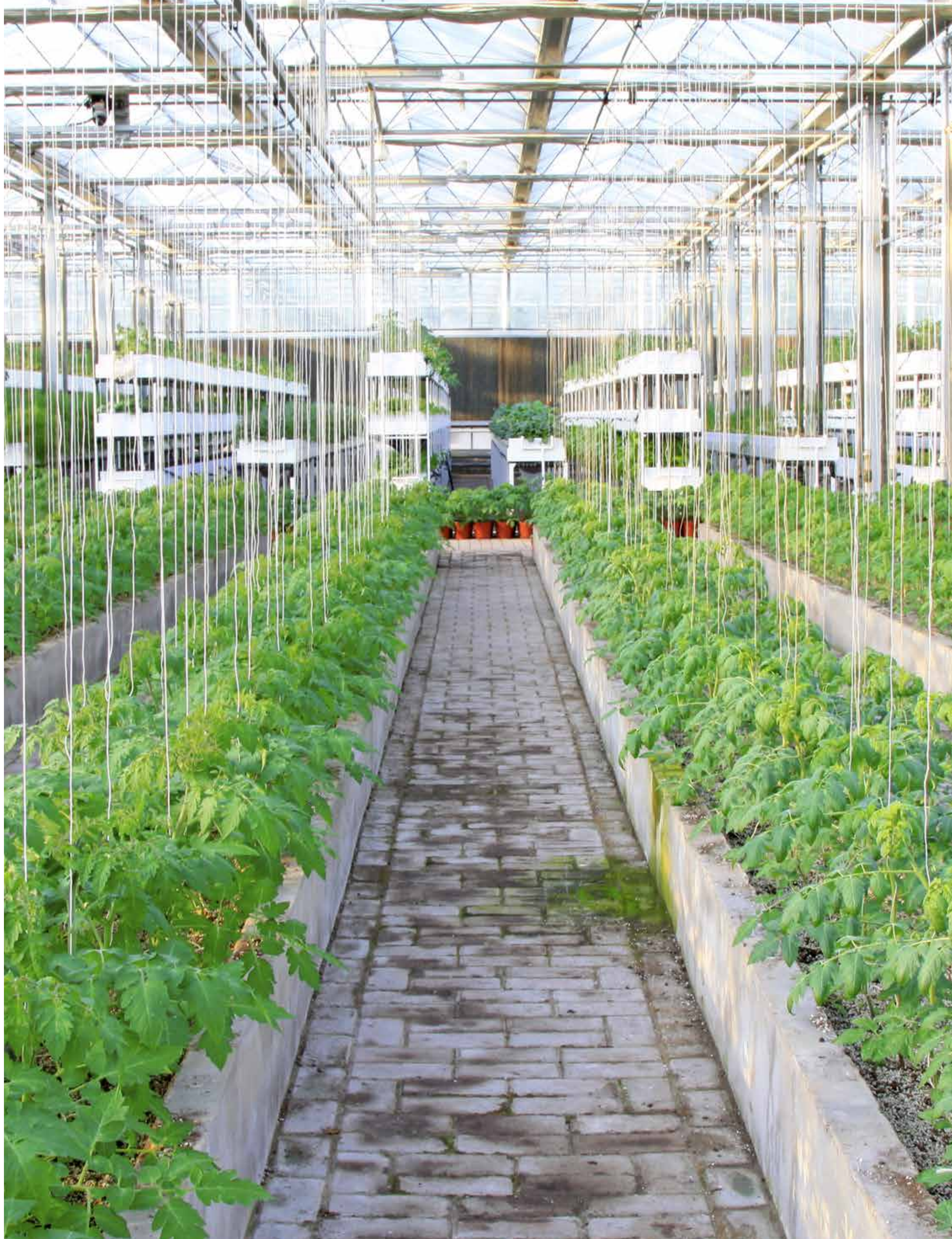
Group oral presentations (10%): are presented in the final week of the semester (week 12). The group oral presentations are 7–8 minutes long with each group member contributing to the presentation. The PowerPoint files are also submitted via the Learning Management System. Mentors guide students in the development of the presentation in a tutorial prior to the session. Students must include the relevance of the research to the broader scientific literature and can gain points as an individual for questions asked during presentations (to encourage interaction). The final mark for the oral presentation comprises an individual mark for performance in the oral presentation (30%) and a group mark based on the seminar and the submitted PowerPoint presentation (70%). The rubrics are given to students at the start of the semester.

Peer assessment and reflection (5%): Students submit a peer assessment and reflection activity at the end of the semester. Students are asked to rate themselves and their team members for their contribution to the group research project. The average contributes 30% of the mark given for peer assessment. Students receive zero marks if they do not submit a peer assessment. Criteria include regular group meeting attendance, communicating well in the group, determination to achieve high results, cooperation with other group members, and demonstration of leadership qualities, proactive contribution and willingness to share the workload. The remaining 70% of the peer assessment mark is a reflection written by each individual on the research process and how and why they would manage at least one aspect differently. Students will usually take this opportunity to reflect upon the 'group charter' that they prepared in the Week 1 tutorial.

Other relevant comments or advice: This is great experience for students and often their first attempt at independent research. The students really enjoy this assessment and often comment on how valuable it was.

Organising the mentors is the biggest task for academics and communication with the mentors before and during the research project is critical to its success.

Groups of five students work best; otherwise some students are tempted not to contribute to the group activities. The perceptions of students with regards to their research skills, both before and after undertaking this activity, has also been examined (Loveys et al. 2014).



Case study 3H: Managing on-farm risk to maximise profitability

Unit: Agribusiness Risk Management

University: Curtin University

Coordinator/Teacher: Dr Amir Abadi, Dr Sarita Bennett

Year: Level II (Intermediate)

Unit context: This unit examines strategies for managing production, price and financial, legal, human and technological risk. Methods are taught that assess and control risk in agribusiness.

Description of task: This forms Part 1 of a scaffolded Inquiry Learning assessment across years and units, with Part 2 occurring in second year. The second part occurs in third year and is provided in Case Study 3K.

Working in pairs, students run a farm using the computer-based simulation model, Risky Business Farm Game. The farm consists of nine paddocks with those at the lowest elevation at risk of becoming increasingly saline unless perennials or trees are planted. Information on soil types, previous rotations and crop prices are provided for each year, together with information about years with similar rainfall patterns.

Information on climate forecasts and weather outlooks are given to the students, who do not have complete knowledge of the coming season. Students make decisions on the crop or pasture species to sow in each paddock and the fertiliser applications to be used. As they progress through each year, decisions need to be made on forward selling any or all of their grain. Information about the season is provided as the game progresses. Students also have the option to include tree belts, saltbush, perennial pastures and fallow in their paddocks.

The class moves through the game at the same rate so that everyone is concurrently working on the same year and part of that year. The aim of the game is to manage a profitable but sustainable farm over a number of years (typically 6+ years over a 3–5 hour workshop.)

Educational aims: The task will allow students to learn to:

1. identify contemporary issues and opportunities in agriculture (TLO 3.1)
2. analyse the advantages and disadvantages of enterprise diversity within a farming system to reduce risk in future sustainable farming systems
3. collect, accurately record, analyse, interpret and report data (TLO 3.3)
4. make meaningful decisions about risk and uncertainty including the adoption of innovations and sustainable natural resource management (TLO 3.4).

Assessment: The assessment is worth 30% of the final grade. Students write and submit an individual report on their own results over the management period of the game and compare their results with those of their fellow students. In particular, they are required to discuss:

- the key performance indicators of their farm compared with their fellow students at the end of the game including profit after tax, gross margin and commodity prices of the different crops over time and rainfall and its variation over time
- the salinity level in the bottom paddock and how it changed with management
- the choices made by the different groups and how these choices affected profit after tax, equity and salinity levels.

Students are provided with a rubric that focuses on the clarity of information presented, the depth of analysis and the ability to relate information to sustainable agriculture.

Other relevant comments or advice: Ensure that students are moving through the game at the same rate using the passwords required for each year. This ensures that lagging students do not gain access to information made available to students who move at a faster pace, including decisions on forward selling grain in relation to price and weather.

It is useful to discuss the results of the different groups – profit, equity, % crop and salinity at the end of each year and why the differences in the farms is developing. This ensures that students who are not from farming backgrounds understand some of the different decisions that are being made in relation to weather, fertiliser application, crop rotations and salinity management.

Make sure that all students have downloaded and retained a complete copy of their farm and decisions made over the management period, as well as the summary of the other groups when the workshop finishes.

The software has a dedicated component to ensure that the KPIs are captured by students for forwarding to facilitators and tutors.

Case study 3I: Plant nutrient analysis project

Unit: Soil and Plant Nutrition III

University: The University of Adelaide

Coordinator/Teacher: Associate Professor Glenn McDonald

Year: Level III (Advanced)

Unit context: This is a third year elective unit in the Bachelors of Agricultural Sciences, and Viticulture and Oenology. This unit examines the factors that determine the availability of mineral nutrients in soil, their uptake and their use by plants.

Description of task: Working in small groups, students identify a question or a problem in plant nutrition from one of the following topics:

1. diagnosis of poor or uneven growth in plants, crops, pastures or perennials that may be related to a nutritional problem
2. spatial variation in nutrient concentrations and growth or quality
3. characterising the nutrient content of grain, fruits or vegetables produced under different production systems
4. variation in mineral levels of wine
5. variety or species differences in nutrient concentrations
6. effects of management practices on nutrient uptake and concentrations.

Each group has a nominal budget (to restrict the number of samples they need to take) and must develop a sampling strategy that allows them to 'solve' the identified problem. They collect samples for analysis and additional data (e.g. production practices, soil types, soil pH/EC) to assist them in interpreting their nutrient analysis data. Students write an individual report that summarises and interprets the data collected. This learning activity is supported by the provision of guidelines on developing a clear question, sampling size and technique, and the types of additional information students might consider. Two tutorials on reading the outputs from analyses and interpreting soil and plant analysis data using hypothetical problems help students learn how to interpret their own results. A key for diagnosing nutrient deficiencies in wheat and grapevine has also been developed for use as a tutorial exercise if the project involved diagnosis of nutrient deficiency.

Educational aims: The project will allow students to learn to:

1. develop an appropriate sampling strategy to diagnose a problem or test a hypothesis within the limits of their budget
2. interpret data on nutrient concentrations
3. present this information to a general audience.

These aims specifically address the intended learning outcomes for the unit that students will have be able to have skills in sampling soil and plant tissues for routine analysis and diagnosis of nutrient status; interpret results of soil and plant analyses; critically analyse and interpret data; and work cooperatively as a member of a group.

Assessment details: This activity is assessed by a project report of 1500 words and contributes 15% to the overall grade. The report is written in the standard scientific paper format; students are given a rubric for the introduction, materials and methods, results and discussion with particular reference to a set of interpretations. The importance of articulating an appropriate research question and determining a sampling method that accounts for variability is emphasised. Students are also assessed on their ability to describe results accurately and to use appropriate graphical means and interpretation in the context of the broader literature.

Other relevant comments or advice: Tutorials help students to interpret their data. However, in some cases they do not attend or engage with these tutorials.

Some groups give the project a good deal of thought while others leave their decision on a topic to the last moment. The inclusion of a number of formal discussion sessions with each group on aspects of the project process may help to address this.

Analytical costs may restrict the participation of students in the project and reduce interactions between students. This tends to be the case when a student takes samples from their own farm and the other students 'go along for the ride'. This task works better with smaller class sizes.

Case study 3J: Agri-environment plan for a UK farm

Unit: Sustainable Agricultural Systems and Food Security

University: Curtin University

Coordinator/Teacher: Dr Sarita Bennett

Year: Level III (Advanced)

Unit context: This is a core third year unit in the Bachelor of Agribusiness. This unit develops students' knowledge of agricultural systems in terms of social, economic and environmental sustainability.

Description of task: Students work in pairs to develop an agri-environment plan for a farm in the UK using the Countryside Stewardship Scheme and associated websites that provide financial incentives for the environmental management of farmland. Students write an individual report on their Farm Environment Plan providing:

1. a map of the farm showing the location of the options to be implemented
2. specification of the points allocated for the various components
3. justification of their decisions on which management options they will be implementing
4. prioritisation of each option to the region.

The report includes a section on the suitability of the UK Agri-environment Scheme to the Australia environment and ways it could be modified to suit the Australian farming environment.

Educational aims: The task allows students to learn how to:

1. analyse the advantages and disadvantages of enterprise diversity within a farming system to predict and develop future sustainable farming systems
2. access and evaluate a range of relevant international and national information to support an argument in professional written and oral formats
3. work constructively within a team to achieve project outcomes.

Assessment details: Students write a consultant report. An outline of the UK Countryside Stewardship Scheme is provided in class along with the relevant websites. The students develop the majority of the plan in class. Detailed information is provided to the students on the suggested structure of the report including the word limit. The assessment is worth 15% of the final grade.

Other relevant comments or advice: The Countryside Stewardship Scheme details can be found at https://www.gov.uk/government/collections/countryside-stewardship-get-paid-for-environmental-land-management. The activity works best when 1–2 farms are selected prior to the class workshop, rather than letting students choose a farm. A tutorial on accessing all the material and detailing the main points of the Countryside Stewardship Scheme is beneficial in directing students to the relevant material as well as the priority options for the chosen farm/s. Use of the Geographic Information Software MAGIC (www.magic.gov.au) is also highly beneficial in providing the students with detailed geographic information about the natural environment in which the farm sits. Familiarity with the farming system of the area is also useful in directing students to suitable options when developing their plan.

Case study 3K: Optimising productivity and sustainability on-farm with changing climates and markets

Unit: Sustainable Agricultural Systems and Food Security

University: Curtin University

Coordinator/Teacher: Dr Sarita Bennett, Dr Amir Abadi

Year: Level III (Advanced)

Unit context: This is a core third year unit in the Bachelor of Agribusiness. This unit develops students' knowledge of agricultural systems in terms of social, economic and environmental sustainability.

Description of task: This assessment is the second part of a scaffolded Inquiry Learning assessment across years and units, and builds on knowledge and results gained of the Risky Business simulation farm game in Case study 3H.

Students work in pairs and run their own farm of nine paddocks. As in Case study 3H, the bottom paddock is in danger of becoming saline. Students are required to run the farm for three scenarios, each over ten years, with the following outcomes:

1. manage the farm to account for unknown variable climates and markets to reduce risk, maximise equity gain and manage rising salinity
2. maximise equity-gain with known climate and markets
3. optimise equity gain and manage natural resource management value with a known climate and markets.

For the first scenario groups discuss finances, salinity, depth to watertable and management decisions and relate these to climate and markets. For the second two scenarios students work in pairs, independent of the other groups.

At the end of each scenario, students are required to save the KPIs of the farm, and to ensure that they have recorded natural resource management information including percentage salinity and depth to water table of the bottom two paddocks and percentage of farm sown to trees, saltbush and perennial pastures.

Educational aims: The assessment aims to teach students to:

1. analyse the relationships between social, economic, environmental and cultural factors on agricultural systems and implications for structure of agricultural businesses
2. assess the advantages and disadvantages of enterprise diversity within a farming system and explain the importance of biodiversity
3. evaluate the potential impact of modified farm practices and new technology on sustainability of farm businesses and rural communities and landscapes
4. demonstrate skills in succinct report writing, good organisation, logical argument and presentation skills in debate
5. work constructively within a team to achieve project outcomes.

Assessment: Students are required to write an individual report (15% of the final grade, unspecified word limit) on their results over the three scenarios of ten years that they have managed the Risky Business Farm. In particular, they are required to discuss:

1. the key performance indicators of their farm across the three scenarios including profit after tax, farm equity, markets, paddock gross margins, and rainfall and its variation over time
2. the salinity and water table levels in the bottom two paddocks and how they changed with management and weather across the three scenarios
3. the choices made in each scenario and how they affected profit after tax, equity and salinity and water table levels.

Marking criteria include clarity of information written and presented, depth of analysis and ability to relate information to sustainable agriculture.

Other relevant comments or advice: The scenarios have been set at ten years to allow students who plant mallees in the first year to obtain two harvests from the trees – at Year 6 and Year 10.

Ensure that students are moving through the game at the same rate using the passwords required for each year for the first scenario of ten years. This ensures that lagging students do not gain access to information made available to students who move through the simulations at a faster pace

Where possible, pair students so that one student is from a farming background and/or has used the game before.

It is useful to discuss the results of the different groups – profit, equity, % crop and salinity at the end of each year during the first scenario and why the differences in the farms is developing. This ensures that students who are not from farming backgrounds understand some of the different decisions that are being made in relation to weather, fertiliser application, crop rotations and salinity management that will help in their decision-making and critical thinking skills for subsequent scenarios.

Make sure that all students have downloaded and retained a complete copy of their farm and decisions made over the management period for their three scenarios when the workshop finishes.

The software has a dedicated component to ensure that the KPIs are captured by students for forwarding to facilitators and tutors.

Case study 3L: Evaluation of grazing options using GrassGro™

Unit: Pasture and Rangeland Management

University: Curtin University

Coordinator/Teacher: Dr Susan Low, Dr Sarita Bennett

Year: Level III (Advanced)

Unit context: This unit explores the role and types of pasture systems, including the use of fodder shrubs in cropping and animal production enterprises.

Description of task: Students use GrassGro™, a decision support software program, to compare and evaluate grazing management options for a sheep breeding enterprise. In preparation, students review the advantages and disadvantages of set stocking, rotational and cell grazing in terms of animal and pasture productivity, and potential impacts on farm sustainability.

Students work individually as a consultant who has been asked to review grazing management options for the sheep breeding enterprise. The students must frame a question from the client to be addressed, identify the grazing options that they intend to evaluate and identify possible output data that could be used to evaluate productivity, profitability and sustainability of the enterprise. Students develop grazing options through manipulation of management decisions such as grazing times, stocking rates, number of paddocks, pasture type and having the option of adding a silage or hay operation depending on location.

Simulations may be run a number of times depending on the outcomes to allow students to refine their strategies. The final report is written as a consultant report addressing the client's questions and providing options for consideration supported by evidence from both the simulations and literature.

Educational aims: The task will encourage students to learn to:

1. identify issues associated with grazing management and identify grazing options that may provide opportunities for improved productivity and sustainability (TLO 3.1, 3.2.)
2. use GrassGro™ to simulate a range of production strategy options for a breeding enterprise (TLO 3.3)
3. show an understanding of the relationships between productivity, profitability and sustainability (TLO 3.2)
4. interpret data from the simulations and evaluate the advantages and disadvantages of selected options (TLO 3.3)
5. produce a report that demonstrates an understanding of consultant/client relationships and that is written in language and format suitable for the client (TLO 3.4).

Assessment: The assessment makes up 20% of the final mark. Students are provided with a rubric before the sessions. The rubric places importance on the options selected for evaluation, the indicators that have been selected to evaluate to answer the client's questions, and the provision of a report written in language suitable for the client that would allow the client to make an informed decision. The information provided must include both advantages and disadvantages of the options.

Other relevant comments or advice: Students need a working knowledge of GrassGro™. The identification of possible management options and the introduction of additional enterprises are supported by tutorials around grazing principles and animal-plant interactions.

Case study 3M: Insect ecology and behaviour project

Unit: Insect ecology and behaviour

University: University of Tasmania

Coordinator/Teacher: Dr Geoff Allen

Year: Level III (Advanced)

Unit context: This is an advanced elective in the Bachelor of Agriculture and a core unit in the Bachelor of Agricultural Science. This unit provides an overview of insect ecology and examines life-history strategies, behavioural ecology, mating systems, insect-plant interactions and natural enemies. It explores the application of this theory to pest management and briefly overviews specialist areas such as medical and forensic entomology.

Description of task: This term project includes experiments on the commercial biocontrol agents, the egg parasitoids *Trichogramma carverae* and *Trichogramma pretiosumiae*. These parasitoids are mass reared for the biocontrol of caterpillars (see http://bugsforbugs.com.au/product/trichogramma/)

Students work in small groups to undertake hands-on activities over a six-week period. All results within a group are owned collectively for write up. The group is responsible for the wellbeing of the wasps during their experiments. Depending on the nature of the experiment, at least one person in each group may need to check the wasps daily to count and feed them if necessary.

A selection of possible topics includes:

1. host egg age and parasitoid oviposition success
2. female adult parasitoid fecundity in relation to age and host deprivation
3. intraspecific competition between conspecific ovipositing females and parasitism success
4. adult parasitoid nutrition, longevity and lifetime fitness
5. development age of wasp larvae inside eggs and the effect of storage at low temperature.

Educational aims: The project will allow students to:

1. be able to apply theoretical and practical knowledge of entomology to new problems and situations
2. demonstrate academic skills in research, analysis and synthesis of information
3. develop a broad understanding of the standard scientific method and its application in practice
4. identify and critically evaluate central issues in entomology
5. demonstrate information literacy (accessing information, academic integrity, scientific presentation) and oral presentation skills
6. implement time management skills for an extended project.

Assessment details: Students write a laboratory report. Detailed notes are provided to students on the structure and key attributes of the report, including page length. Marks are allocated for each section of the report in relation to the unit intended learning outcomes. The task is worth 25% of the final grade.

Other relevant comments or advice: Working directly with a biocontrol company can enable iterative feedback on the parasitoid quality of their rearings and engage the students in the practical outcomes of their findings. This task requires much one-on-one discussion with groups on experimental designs. Running a small initial pilot experiment with the groups which enables students to "get a feel" for wasp handing, rearing and development times leads to better outcomes.

Case study 3N: Scaffolded research trial, presentation and report

Unit: Advanced Cropping Systems and Precision Agriculture

University: Curtin University

Coordinator/Teacher: Dr Sarita Bennett

Year: Level III (Advanced)

Unit context: This unit is offered in the Bachelor of Agribusiness and provides students with practical and theoretical knowledge of new technologies associated with broad acre cropping and pastures and their role in mixed farming systems.

Description of task: Students collect experimental data on one crop sown in two blocks at the field trials area. The aim is not to complete a field trial, but to investigate ways in which management of a crop species can be modified within the farming system to raise the productivity barrier, either in that crop or in the subsequent crop. Students work in pairs and choose both the crop to work with and the productivity issue they wish to address.

Over the semester, students visit the field trials area four to five times to collect data, with some experimental work also being required in the laboratory or field outside of these times. Time for analysis of the collected data is provided in the last practical session.

Students discuss their choice of crop and their experimental design, feasibility, treatments and measurements with the lecturer before commencing their experiment, which enhances the learning outcomes for the students.

Educational aims: The task allows students to learn to:

1. analyse modern approaches to crop improvement through genetic technologies and develop balanced arguments on the merits and ethics of these technologies
2. describe advanced agronomic systems, and understand the relationships between genotype, management and environment; new crop management techniques; precision agriculture approaches and technologies; crop biodynamic models and their application, and decision support systems
3. discuss the impacts of possible changes in CO2, temperature and rainfall distribution on crop growth and yield at farm and regional scales
4. design options for future farming systems which integrate knowledge on crop, pasture and livestock improvement and advanced agronomy with likely scenarios for climate variability and change.

Assessment details: Students working in pairs use PowerPoint to present their findings to the class. The talk is 30 minutes and includes questions. Each team member presents equal components of the presentation, and all class members are expected to ask questions.

An individually written 4–page summary of the results with is made available to all class members before the presentation. Class members are expected to think about potential questions for each talk and student contribution is assessed. The assessment is worth 30% of the final grade.

Other relevant comments or advice: The timing of the semester means that field trials have to be planted before the start of semester, and experiments chosen that can be conducted and completed within the semester. The first practical class is spent in the classroom, where the students chose their research projects from the crops available for study.

Case study 30: Evaluation of land for agricultural production

Unit: Agricultural Landscape Systems

University: University of Tasmania

Coordinator/Teacher: Dr Richard Doyle

Year: Level III (Advanced)

Unit context: This unit is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit involves assessing land and its sustainable production potential for a range of uses using desktop, field and minor laboratory-based assessment of the soils, landforms, climate, hydrology, vegetation and geology. This information will be used to assess land capability and suitability.

Description of task: The task has three integrated components. In Part 1, students produce desktop study that details the climatic, topographic, vegetation and geological information pertinent to land use in a mapping area.

Part 2 is an oral defense, not described here.

Part 3 is a final written report on the land evaluations undertaken on a combined class mapped area. It covers the soil description, classification and analysis along with a Land Capability assessment and Land Suitability assessments to Class and Sub Class levels. Crops and their requirements are required to be matched to the landscape. There is a need to clearly outline the limitations of the land when considering the uses proposed. Five soils in the simulation model, APSIM, have been parameterised for soil physical characteristics. Scenarios that test the impact of these soil characteristics can be configured in APSIM for contrasting climatic conditions and crops, with the output used to support the proposed land use decisions.

Educational aims: This task requires students to:

1. describe soil profiles in the field and map and classify them using the Australian standard systems
2. collect, interpret and integrate soil, land, climate and crop information so as to make sustainable and productive land use assessments and evaluations
3. communicate and justify their land assessments via clear written and oral reporting.

Assessment details: Part 1 is worth 15% of the total grade. For Part 3, students jointly write up the work and receive a single (combined) mark for the final report which is worth 15% of the final grade.

Other relevant comments or advice: Five soil types were parameterised for soil physical characteristics including runoff, depth to the water table and permeability. It is necessary to have access to a demonstrator experienced in the use of APSIM to run this part of the practical class. Students who could integrate APSIM output with the land use decisions tended to do very well in this assessment task.

The practical work is undertaken and reported in pairs and advice on how to work in pairs is explicitly described at the start of the unit. Students can be awarded extra marks for assisting their partner or, alternatively, have marks deducted if they are not contributing equally to the workload. In a few instances it has been necessary for a pair of students to be separated and to submit their assignments individually.