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Tina Botwright, Amanda J. Able

Good Practice Guide: threshold learning outcomes for agriculture

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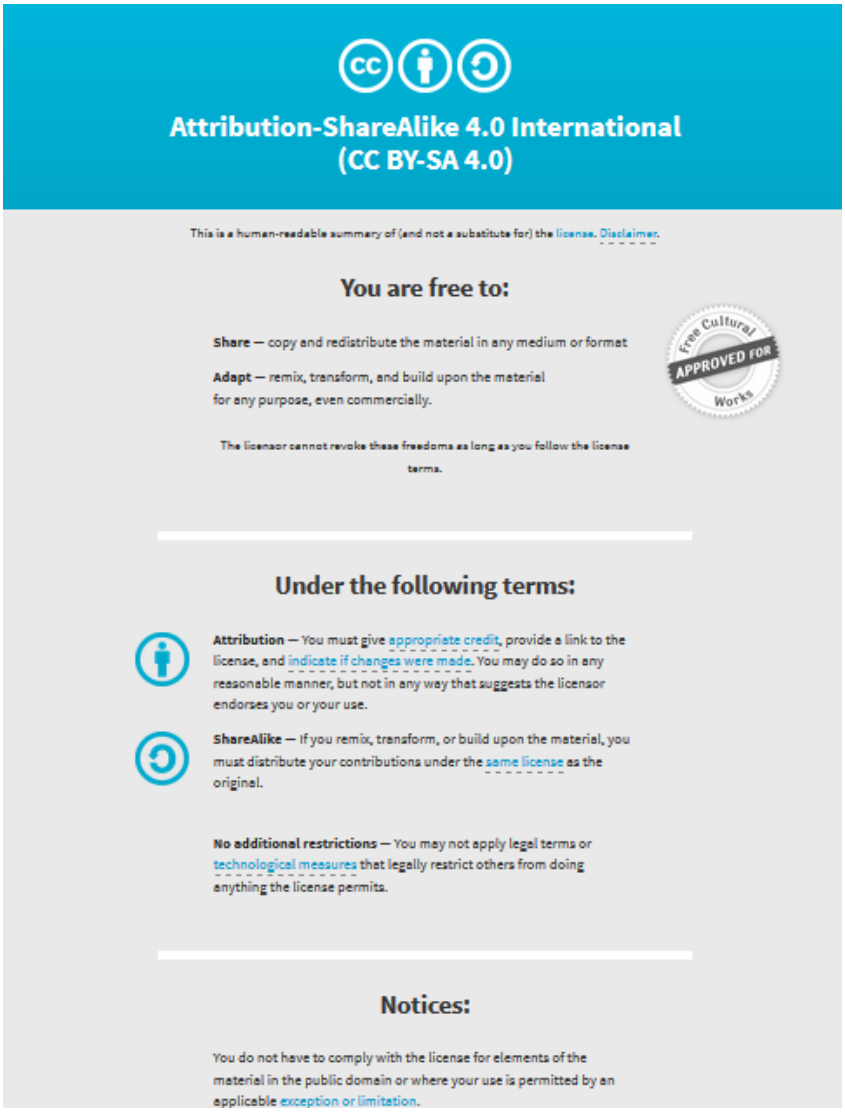

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GOOD PRACTICE GUIDE:

THRESHOLD LEARNING OUTCOMES FOR AGRICULTURE

Australian Government

Office for Learning & Teaching

Ag LTAS

EDITORS TINA BOTWRIGHT ACUÑA
AMANDA J. ABLE

About

The Good Practice Guide: Threshold Learning Outcomes for Agriculture is a project deliverable of **A consensus approach to defining standards for learning outcomes and informing curricula design for Agriculture**.

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Preface

The Good Practice Guide: Threshold Learning Outcomes for Agriculture expands upon the national Learning and Teaching Academic Standards Statement for Agriculture (AgLTAS). The practical information within this Good Practice Guide will be useful when implementing the Threshold Learning Outcomes (TLOs) in curriculum. Each TLO has been individually addressed via a literature review that summarises key issues, identifies opportunities and lists resources; and case studies that address that TLO.

The project team for the development of this Good Practice Guide has worked tirelessly and we have learnt much from them. We are grateful for their efforts and were privileged to engage in such valuable discussions about teaching in agriculture. We would like to also extend special thanks to Emeritus Professor Susan Jones (University of Tasmania) for her guidance.

We acknowledge the support and engagement of those academics, industry representatives and students who participated in the AgLTAS project and contributed case studies to this Guide.

We hope you find that the Good Practice Guide is a useful resource in the design of activities and assessment items for agriculture students.

Tina Botwright Acuña and Amanda J. Able

Summary

Tina Botwright Acuña and Amanda J. Able

Background and context

The Good Practice Guide: Threshold Learning Outcomes for Agriculture (the Good Practice Guide) builds on the national Learning and Teaching Academic Standards Statement for Agriculture (AgLTAS), which was developed through an extensive consultation process among academics, students and industry personnel across Australia.

The AgLTAS facilitates the implementation of academic standards by the agriculture discipline community and informs curriculum design. It describes the nature and extent of agriculture and provides five key Threshold Learning Outcomes (TLOs) that describe what a pass-level graduate will know, understand and be able to do upon graduation from a bachelor-level degree in agriculture or a related discipline. The TLOs are: Understanding agriculture; Knowledge of agriculture; Inquiry and problem-solving; Communication; and Personal and professional responsibility (Botwright Acuña et al. 2014a).

The TLOs for agriculture are aligned with the TLOs for science (Jones et al. 2011) but also capture the contribution of other disciplines such as economics, business and social science to agriculture. Importantly, the TLOs serve as a national reference point for curriculum design, assessment standards and benchmarking among institutions.

The Australian Council for Deans of Agriculture has endorsed the TLOs as a high-level statement of bachelor-level Threshold Learning Outcomes for the discipline. As such, they meet the fundamental requirements of the Higher Education Standards Framework (Australian Government 2015) for specific and agreed standards for curriculum design and learning outcomes for each discipline to enable regulation and quality assurance in universities.

The Learning and Teaching Academic Standards Statement for Agriculture is available at **www.agltas.edu.au.**

Development of the Good Practice Guide

As indicated, this Good Practice Guide expands upon the national Learning and Teaching Academic Standards Statement for Agriculture (AgLTAS). Having set the learning outcomes, the next step is to demonstrate that students achieve the TLOs through assessment. This Guide provides academics with strategies for teaching and case studies of aligned assessment for each TLO.

The Good Practice Guide is intended for use by academics who teach into undergraduate degrees (or related areas), including but not limited to: agribusiness, animal science, agricultural economics, horticulture, agriculture and agricultural science, viticulture and oenology, agricultural business management, agrifood systems and wine science.

Overview

A key distinguishing feature of agriculture is its multidisciplinary nature and the contribution of disciplines other than science, such as economics and the social sciences. The integration of these disciplines in the context of agriculture is important for student achievement of the TLOs.

Two common themes appear throughout the Good Practice Guide: 1) the interdisciplinary nature of agriculture; and; 2) the emphasis on transferable and applied skills that will allow graduates to contribute to the successful practice of agriculture in a wide range of roles. The authors have also provided discussion to guide the interpretation of each overarching TLO.

TLO 1: ***Understanding agriculture*** focuses on the required curriculum to address the TLO as well as the complexity of agriculture as a discipline. The complexity lies in the many different sub-disciplines of agriculture; the often inter-related drivers that underpin agricultural practice; different value chains and products; and the different views in the community of agricultural issues, especially sustainability. An understanding of this complexity, in the context of agriculture, is key to the decision-making processes to which graduates will contribute in the future. The case studies presented in the Good Practice Guide for TLO 1 usually demand students address this complexity in their learning.

TLO 2: *Knowledge of agriculture* provides a discussion about the nature of integrative knowledge and the importance of its application to agriculture. The case studies demonstrate that students, particularly in the last year of their degree, tend to be assessed for their ability to transfer or use knowledge to solve dynamic complex problems in agriculture, rather than being explicitly assessed for having that knowledge. The opportunity for students to learn and apply their knowledge during experiential learning, such as Work-integrated learning (WIL), should therefore be considered.

For TLO 3: *Inquiry and problem-solving*, the challenges for implementation and assessment are discussed. However, solving problems is the focus of the majority of case studies presented in the guide. As mentioned previously, graduates with the demonstrated capacity to solve problems are essential to the agriculture industry. The authors have discussed how inquiry-based learning can be developed progressively in the design of assessment tasks from Process–oriented guided inquiry learning (POGIL) to project-based learning, with associated case studies.

TLO 4: *Communication* describes different ways of communicating that could be used in the classroom and how these can be used in different contexts. The agriculture communication TLO is unique in that it requires graduates to understand methods of two-way communication and how these might feed into decision-making processes. The case studies for TLO 4 demonstrate traditional and contemporary modes of communication that graduates need to apply in the work place or during professional practice.

For TLO 5: *Personal and professional responsibility*, a framework for integrative and professional practice has been presented with a discussion of the types of learning activities that address this TLO. WIL and student-led inquiry, both as individuals and in groups, are particularly relevant methods of encouraging development in this TLO. However, even though many of the principles of Workplace Health and Safety (WHS), regulation and ethics are taught, they are often not directly assessed. They are instead implicitly assessed as a component of a decision-making process or within the other TLOs. Some of the case studies for TLO 5 demonstrate explicit assessment of these principles and behaviours in the workplace.

Although each of the TLOs has been addressed independently, they are integrative. Wherever possible, we have highlighted the linkages between TLOs. For example, the understanding of different world views (TLO 1) along with the understanding of the methods used for effective two-way communication (TLO 4) will contribute to the ability of graduates to conduct themselves in an ethical manner (TLO 5). Examples of how curricula are mapped to the various TLOs in two agriculture degrees are presented in Botwright Acuña et al. (2016). The need to assess TLOs many times and progressively during a degree is also discussed.

Given the multidisciplinary nature of agriculture, academics may have considerably different perceptions of what is required to meet a graduate TLO in practice. A combination of external review and curriculum mapping workshops involving the entire teaching team is therefore recommended when mapping degrees to TLOs (Botwright Acuña et al. 2016). The examples given in this guide will be useful in the design of assessment that aligns to particular TLOs at a particular progression level.

A further outcome of the multidisciplinary nature of agriculture and the focus on the application of knowledge is the relatively greater number of case studies for TLOs 2 and 3. Also, while each university offering agriculture and related degrees was contacted to contribute case studies, some chapters, such as those for TLOs 1 and 5, contain relatively more case studies from the home university than others.

How to use this guide

We, the authors, have modelled components of this Good Practice Guide on those used for each of the individual Good Practice Guides for Science (Yucel 2013; Jones 2013; Kirkup and Johnson 2013; Colthorpe et al. 2013; Loughlin 2013) and Law (Steel 2013). However, we have combined all TLOs into a single guide as an acknowledgement of how the TLOs are often addressed in an integrated way.

Each TLO chapter contains the following:

1. a literature review related to the interpretation of the TLO hyperlinked with case studies of assessment practice
2. an annotated list of resources that may be useful in teaching specifically addressing that TLO
3. a summary of the key issues, outcomes synthesised from the literature review and future opportunities identified
4. case studies of assessment practice aligned to the TLO.

References are collated at the end of the Good Practice Guide.

Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACDA	Australian Council of Deans of Agriculture
AgLTAS	Agriculture Learning and Teaching Academic Standards
ALTC	Australian Learning and Teaching Council
ASA	Australian Society of Agronomy
BOM	Bureau of Meteorology
CSIRO	Commonwealth Science and Industrial Research Organisation
DEEWR	Australian Government Department of Education, Employment and Workplace Relations
EBL	Enquiry-based learning
FOO	Food on offer
GPG	Good Practice Guide
ICT	Information Computing and Technology
KPI	Key Performance Indicator
LTAS	Learning and Teaching Academic Standards
OLT	Australian Government Office for Learning and Teaching
PAR	Participatory action research
PBL	Problem-based learning
PGR	Pasture growth rate
POGIL	Process–oriented guided inquiry learning
RA	Risk assessment
RDC	Rural Research and Development Corporations
SBA	Single-best answer
SLM	Sustainable land management
STEM	Science, Technology, Engineering and Mathematics
SWP	Safe Work Procedure
TBL	Team-based Learning
TLO	Threshold Learning Outcome
WIL	Work-integrated Learning
WHS	Workplace Health and Safety


A key distinguishing feature of
agriculture is its multidisciplinary
nature and the contribution of
disciplines other than science,
such as economics and the
social sciences. The integration
of these disciplines in the context of
agriculture is important for
student achievement of the TLOs.

Threshold Learning Outcome 1: Understanding of Agriculture

Yann Guisard and Natasha Hard

This chapter of the Good Practice Guide (GPG) will assist teachers in understanding and implementing TLO 1. In particular, the chapter aims to:

1. explain TLO 1 *Understanding of Agriculture* and its sub-elements
2. provide a list of key resources across a range of mediums
3. present six case studies which illustrate good practice in assessment
4. identify future research opportunities for curriculum design and evaluation.

The agriculture industry has broadly been defined as "the land-based production of food, fibre and fuel as quality products that may be used unchanged or be transformed into other products for the good of society" (Botwright Acuña et al. 2014). Graduates need to be able to connect and integrate their learning regarding the industry in order to form a consolidated understanding of agriculture as it relates to their specialisation.

When considering TLO 1 in the context of the curriculum design of an agricultural program, it is critical that the integration of each TLO sub-element be considered the primary objective of the curriculum, rather than addressing TLO sub-elements sequentially. The purpose of this integration is to scaffold students' understanding of agriculture, over the duration of their degree, from "uni-structural" to "integrated" (using the Structure of Observed Learning Outcomes or SOLO taxonomy) (Biggs and Collis 1982). A scaffolded approach aims to direct student learning whilst supporting the development of cognitive skills that become part of their educational skill-set (Naidu 2004).

This TLO and its subsequent implementation into the curriculum differ from its equivalent TLO 1: *Understanding Science* in the Science LTAS (Jones et al. 2011) in that it broadly grounds graduates in both agricultural supply and value chains, the drivers of practice change and methods of information adoption. By including disciplines complementary to the traditional sciences such as business, human management and other social sciences, this TLO acknowledges science as one of a number of factors necessary to finding solutions to diverse agricultural challenges. In view of the sometimes contradictory philosophies underpinning these disciplines, graduates need to develop a broad yet integrated understanding of agriculture. TLO 1 is, therefore, contextual to the agriculture TLOs 2 through 5. Each component of TLO 1 is discussed in greater detail in the following sections.

Threshold Learning Outcome (TLO) 1 on Understanding of Agriculture states that, upon completion of a bachelor-level degree in agriculture or a related sub-discipline, graduates can demonstrate an integrative understanding of agriculture by:

1.1 Explaining the role and relevance of agriculture and its related sciences, and agribusiness in society.

1.2 Understanding the major biophysical, economic, social and policy drivers that underpin agricultural practice and how they contribute to practice change.

1.3 Understanding how information is adopted and the context within which producers, processors and consumers make decisions.

(Botwright Acuña et al. 2014a)

TLO 1.1: Explaining the role and relevance of agriculture and its related sciences, and agribusiness in society

This component of TLO 1 requires that students are able to explain "the role and relevance of agriculture" in society. Agriculture plays a critical role in the provision of raw commodity foods, fibres and, more recently, fuels. Students need an integrated understanding of agriculture, including how it relates to the environment, economics and society. This ability is particularly critical with society's understanding of the role and relevance of agriculture in Australia described as 'confused' (Pratley & Hay 2010). A lack of leadership within the industry regarding environmental action has complicated the relationship between the agricultural sector and society (Pratley and Hay 2010).

In Australia the agricultural industry comprises 136,000 businesses; covers 405 million hectares of land; grosses $46.7 billion and uses 8,174 gigalitres of water annually (Australian Bureau of Statistics (ABS) 2013). This equates to the greatest use of land (~53% of the total land mass) and water (~52% of total national water consumption) (ABS 2012). This heavy reliance on natural resources highlights the responsibility of the agricultural sector in the stewardship and sustainable use of land and water (Commonwealth of Australia 2015).

Understanding and regulating the use of these key assets will be critical in ensuring the Australian agricultural sector remains competitive with other parts of the economy, and with other nations (Commonwealth of Australia 2015). This "big picture" approach to introducing agriculture is particularly appropriate for first year students. The concept of producing while simultaneously protecting the land generates a range of activities and assessments such as debates, group work and reflective tasks. As students develop, the introduction of higher level concepts such as economics or labour availability makes for more complex debates.

The ratio of the Australian population to the number of farms has grown from 50:1 in 1960 to 230:1 in 2014 (Ag Institute Australia 2014). This reduction in Australian engagement with farming has led to a disconnect between the city and country with most city dwellers having very little understanding of the challenges of rural life or of agricultural practices (Ag Institute Australia 2014). This disconnect between food consumers and food producers complicates discussions relating to resource use, production and purchasing decisions. The farming sector has not maintained its share of the domestic economy, representing 4.6% of the economy in 1989–1990 but only 2.4% in 2012–2013 (Australian Government Productivity Commission 2014). Learning activities centred on the role and relevance of agriculture to society, therefore, tend to integrate multidisciplinary concepts and are typically grounded in issues regularly raised in the popular press such as land ownership or climate change.

Agriculture influences our lifestyles and employment opportunities, especially in rural communities. Rural areas are facing competing demands for land use from interests and forces such as mining, conservation and urbanisation. Rural youth are moving to larger urban centres as rural centres are unable to offer the same educational and health services (Hugo et al. 2013). However, a strong agricultural sector has the potential to translate into more robust and resilient regional economies that offer greater employment opportunities (ABS 2014). Ensuring such development requires large-scale infrastructure projects, in particular with regard to transport and water (Australian Government 2015). Learning activities such as capstone projects are particularly suited to agricultural economics programs and units grounded in regional and national policy analyses. They typically include desktop-based research activities that aim to assess the impact of policy implementation on different communities and at different scales.

In supporting agriculture's contribution to regional areas and regional communities, different views and cultural understandings must be considered. In particular, for Australia, "Indigenous engagement and leadership as well as indigenous training and employment, are key issues for agricultural development in these regions" (Commonwealth of Australia 2015). Offering opportunities for Indigenous Australians to invest and engage in agricultural practices, the sector can hope to increase investment and jobs growth for Indigenous and regional communities alike (Charles Sturt University 2014). Most universities now include graduate outcomes that integrate a range of indigenous cultural competency standards. Land management based on a range of perspectives lends itself to a variety of oral, visual and written assessment tasks at a number of levels.

Many educators seem to reflect an attempt to broaden cultural diversity and reconciliation in programs but few seek to deliver profitable solutions to indigenous communities. Nevertheless, opportunities are provided for students to develop their professional identity in a complex society, using contemporary issues.

The capacity to facilitate different societal or world views of agriculture is critical for our graduates if they are to actively contribute to sustainable changes in agricultural practice (Jordan et al. 2008). Attainment of TLO 1.1 increases the student's capacity to understand the social drivers that affect practice change and adoption in TLOs 1.2 and 1.3. Furthermore, an understanding of different world views also contributes to TLO 4: Communication.

Australian agricultural graduates will also have a role to play as global ambassadors and in supporting global food security, particularly through the sharing of technology and education (Commonwealth of Australia 2014).

The agricultural community faces a communication and education challenge in Australia. For example, as a complete supply and value chain, agriculture contributes towards anthropogenic climate change, yet also has a role in remediation through innovative practices. These new practices are grounded in the fundamental sciences such as chemistry, biochemistry, botany and physiology; however, their uptake rests upon an understanding of the associated benefits explained in terms of economics, marketing and management of resources, including human resources. Modern agriculturalists are multi-disciplinary individuals who contribute to society along a complex supply chain, often unrelated to the "production" of food, and often in urban areas. By contrast, society associates agriculture with "farming" and, in particular, as being applied or "hands-on" with a primary focus on production. Learning activities associated with high-level concepts such as world view, particularly when used in the context of change in practice tend to be grounded in "experiential learning" (Kolb 1984). For example, Jordan et al. (2008) describe a pedagogical approach to developing a world view of agriculture in a US program using a combination of "scenario planning" and "critical learning systems".

In this chapter, Case Study 1B (a scaffolded learning task in Agribusiness Systems) details an example of how students can develop their ability to formally describe a supply and value chain in a graphical and written format and to discuss it with a specified audience. In Case Study 1C (Diverse views in agricultural land use blog) students articulate their reflections on societal tensions arising from modern food production, using a range of sources and their prior experiences. These approaches align with transformative learning principles by aiming to develop the ways students interpret and assign meaning to experiences (Mezirow 1991). The first case study focuses on the instrumental learning component of transformative learning by supporting students to develop understandings of relationships through an applied task. Case Study 1C, however, focuses more strongly on the communicative learning component where students engage in critical reflection – articulating their thoughts, feelings and views.

TLO 1.2: Understanding the major biophysical, economic, social and policy drivers that underpin agricultural practice and how they contribute to practical change

This sub-element of TLO 1 requires graduates to have a general understanding of the drivers influencing the primary production of food, fibre or fuel, consistent with the sustainable use of natural resources. This is particularly important as the industry directly impacts upon the environment and can create a range of environmental problems such as erosion, biodiversity loss, issues in the use and disposal of chemicals, and high greenhouse gas emissions (Stoutjesdijk & ten Have 2013). This degree of environmental influence does, however, position the agricultural industry to take direct action to improve environmental outcomes.

Students need to understand that agriculture in Australia and internationally will face a range of complex challenges over the coming decades (Ritman et al. 2011). These challenges include biophysical factors such as water availability, disruptions to systems and yields as a result of climate change, and a yield plateau for major crops. Economic and policy challenges include: rising energy costs, remaining competitive, market changes, managing greenhouse gas emissions and the need to balance production and natural resource use. Consumers are demanding more information and the emphasis on sustainable practices and food security is greater. Additionally, middle-sized farms are predicted to further disappear with aggregation into larger scale farms or division into smaller lifestyle properties (Ag Institute Australia 2014). These changes have led to a range of new models such as co-ops that enable farmers to pool resources and improve scales of production and market positions (see for example the CBH group, Dairy Farmers Milk Cooperative Ltd or the Batlow Fruit Co-operative Ltd).

To meet these challenges production will need to be more efficient, adaptable and resilient (Ritman et al. 2011). To optimise yields a greater focus on pest-, disease- and weed-control strategies will need to occur, especially with the threat from the global movement of people, products and produce (Commonwealth of Australia 2015). Whilst Australian productivity in agriculture is high, it remains behind that of the United States and Canada (Sheng et al. 2013). In conjunction with slowing productivity gains in Australia, there have been calls for greater investment in research and development to advance agricultural technology (Nossal & Sheng 2010). Ensuring graduates are prepared to help to address these challenges is critical. In Case Study 1E (Analysis and field tour of agricultural commodities) students review the history of a key commodity to understand the how and why of practice changes before providing a succinct prediction for the future of the given commodity while accounting for macro- and micro-economic factors and influences from a range of disciplines.

Graduates also need to understand the government's role in managing the diverse interests of stakeholders, supporting research and innovation, and encouraging productivity. They must be aware of new technologies and developments in biotechnology and nanotechnology to ensure appropriate regulatory practices are in place when needed (Stoutjesdijk & ten Have 2013). TLO 5 builds upon this awareness by requiring that graduates can demonstrate knowledge of appropriate regulatory frameworks. While governments impose regulatory conditions, they are also able to alter land management practices through the manipulation of market conditions. This can be achieved by influencing societal norms through education, incentives, property rights, investing in social capital, and altering taxes and fees as well as direct regulation (Mallawaarachchi & Green 2013).

The increasing focus on sustainable land management is indicative of changing government and community priorities towards longer-term and more holistic understandings of returns (Mallawaarachchi & Green 2013). To illustrate these concepts, in Case study 1D (Researching and communicating contemporary issues in an agriculture essay), students examine the interrelation between underlying biophysical and socioeconomic factors for a contemporary issue in Australian agriculture. This approach to developing understandings of sustainable practices within the context of a student's profession has been favoured as the student will likely have the potential to influence actions and decisions within that context into the future (Parkin et al. 2004).

TLO 1.2 specifically illustrates the drivers underpinning change (see Case study 1A: Group problem-based learning task), but the reader is also directed to TLOs 2, 3 and 4 as integral to developing "innovative" graduates. As those who will be required to resolve these future challenges, graduates need to understand the role that technology and innovation can play in agriculture.

Developing innovative behavioural traits in undergraduate students is a challenging task. Broadly, the literature associates "innovation" with major qualities such as "creativity" and "critical thinking" (Macquarie University 2015), but also "entrepreneurship" and related sub-components (Alcaraz-Rodriguez et al. 2014). These traits are typically demonstrated at the highest levels of traditional educational taxonomies such as Bloom or SOLO, but are grounded in more traditional low-level knowledge and skills. Educational activities supporting these outcomes focus strongly on student-centred activities, experiential learning (in and out of the classroom) and group work (Mayhew et al. 2012).

TLO 1.3: Understanding how information is adopted and the context within which producers, processors and consumers make decisions

Decision-making processes along the value chain are complex and influenced by a range of factors, including some of the economic, social and policy drivers previously discussed. In order to make informed decisions, graduates need to understand how different stakeholders access information and make decisions in different contexts.

Whilst research and development (R&D) has the potential to improve productivity, adoption and adaptation, the integration of such innovations into farming practice remains critical (Nossal 2012) and is fundamental to the professional practice of communication (explored in TLO 4). In TLO 1.3, students communicate information for the purpose of decision-making, particularly when exploring innovative solutions. This nexus between the creation of knowledge and its uptake for the purpose of increasing the efficiency of agriculture is documented in the literature. For example, Pretty et al. (2010) formulated a list of 100 questions of importance to global agriculture. These questions may be used by educators to inform the development of curricula. A contemporary teaching pedagogy termed "Research Led Teaching" (Brew 2006), aims to introduce students to the process of knowledge creation (a concept explored in depth in TLOs 2 and 3).

In modern Australia, agriculturalists no longer carry out their practice in isolation from the rest of the society. The concept of a "social licence" increasingly influences domestic and global decisions from consumers. Although price remains a primary driver for consumers of commodity and small agricultural goods (Bradbear & Friel 2013), developed economies observe a consumer interest in other aspects of food and its sourcing, such as the risk perceived with country of origin (Lim et al. 2014) or a preference for organic products (Schleenbecker & Hamm 2013).

A range of suitable educational approaches to investigate complex and multi-faceted problems are available to teachers and include constructivist instructional models such as Problem Based Learning (PBL) (Barrows 1996), Case Based Learning and/or Inquiry Based Learning (Bell et al. 2010). In Case Study 1A (Group-problem-based learning task), groups of distance education students use a PBL approach to investigate a key concept (or "trigger"). The use of PBL in this instance aims to provide "an instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery 2006). Such an approach requires students to recognise the perspectives of diverse stakeholders and apply their integrated understandings of agriculture to develop informed solutions.

Three key components have been identified to determine the extent to which innovation is adopted. These include, the supply of innovative practices and solutions, the farmer's willingness or desire to innovate and the farmer's capacity to innovate (Nossal 2012). Psychological and sociological characteristics such as risk aversion, attitudes to learning, awareness of innovative practices, individual goals and values and past experiences also have the ability to influence decisions regarding the adoption of innovation (Nossal 2012). Understanding and experiencing the stages of information flow, decision processes and development of innovations commonly reported in the literature (Ritman et al. 2011) will, therefore, provide benefit to students.

New technologies afford a myriad of opportunities for the agricultural sector. In particular, new technologies assist in the collection of "just in time" data and facilitate the sharing of information among all stakeholders along the value chain. The provision of timely and reliable information (such as early weather warnings, pest outbreak predictions, commodity trends and transport availability) is important for professionals to optimise productivity by reducing inputs (in particular, labour) and maximising outputs.

Innovation is, however, not solely related to production. Consumers also make decisions on the basis of innovative information strategies such as mandatory or voluntary labelling (Australian Government 2015). Similarly, processors demonstrate the quality of a product using novel traceability technologies. However, transformational technologies will only be effective when they have social licence and acceptance in society (Australian Council of Deans of Agriculture 2014). These concepts are illustrated in Case Study 1F (Introduction to agricultural systems) where students access, summarise and interpret long-term climatic data to assess the suitability of a site to agricultural production as well as business risk and resilience.

Conclusions

Agriculture is a complex industry. It requires a broad supply and value chain and is located in both urban and rural areas. Overall, it faces a range of diverse biophysical, economic and social challenges that will need addressing by the graduates of various agricultural degrees ranging from agricultural economics to horticulture. When addressing TLO 1, curriculum designers should focus on the broad and integrative nature of this industry for the purpose of decision making before addressing issues aligned more precisely with the nature of the degree, as described for TLOs 2–5.

TLO 1 ***Understanding Agriculture*** is a degree-long process. It is iterative as new technical knowledge and skills (described in TLOs 2-5) in turn inform a deeper understanding of the major factors influencing efficiency in agriculture. Its integration is scaffolded in the degrees and concepts can be revisited at various stages of the student's progression, with increasing levels of sophistication and depth.

Graduates will be agents for change, educating the public on the modern role and relevance of agriculture in society. This capacity to induce change is strongly related to their own understanding of agriculture. Evidence-based research into the capacity for students to demonstrate an understanding of the integrative nature of agriculture is, therefore, necessary to effectively support the development of high quality curriculum. Educators are faced with the challenge of educating students about the "breadth" of agriculture (as described in this TLO) as well as the depth (see TLOs 2–5). An array of educational tools is available to complement the traditional approach to tertiary education. In particular, group work, problem-based approaches and research-led teaching have provided evidence of developing innovative behavioural traits.

Resources for TLO 1

The resources suggested here should be used in combination with the list of references cited in the text.

Print resources

These print resources are commonly used to introduce agriculture to beginning students.

Henzell, T. (2007). *Australian agriculture: Its history and challenges*. Melbourne: CSIRO Publishing.

Malcolm, B, Sale, P, Leury, B & Barlow, S (2010). *Agriculture in Australia - An Introduction*. 2nd edn. Oxford University Press.

Video resources

Video resources are useful to 'trigger' collaborative activities as well as illustrate and support concepts taught in a more traditional manner.

https://youtu.be/PrMF3DX8erU
Investing in agribusiness, Andrew Forrest, Minderoo Foundation (Outlook 2015)

https://youtu.be/EE5A2CN_Pcw
Cutting red tape in agriculture. Lisa Elliston, ABARES (Outlook 2015)

https://youtu.be/BKjfjQL1VF4?list=PLqIYfafT5kucSXKnZbZPeaFEUzqyzjytm
Future technologies for future profitability, Tim Neale, PrecisionAgriculture.com.au (Outlook 2015)

Blogs

This genre requires students to seek reliable information, summarise it in a concise manner and express a personal opinion in a context where the reader may be able to submit a comment or a reply to the post to argue for or against the author's conclusions.

http://www.agriculture.org.au/blogpost/1195476/The-Agribusiness-Blog
(The) Agribusiness Blog

http://agriculturalmc.com/blog/
Dirt & Dollars AMC

http://www.cultivate.org.au/blog
Cultivate Agribusiness

Websites

The websites suggested here support the broad nature of TLO 1 but should be considered on the basis of the nature of specific programs.

http://www.aginstitute.com.au/
AG Institute Australia

http://aciar.gov.au/
Australian Centre for International Agricultural Research

http://www.agriculture.gov.au/abares
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

http://www.agriculture.gov.au/
Australian Government Department of Agriculture and Water Resources

http://www.farminstitute.org.au/
Australian Farm Institute

http://www.bom.gov.au/
Australian Bureau of Meteorology

http://www.batlowapples.com.au/index.php
Bartlow Fruit Co-operative

https://www.cbh.com.au/
CBH Group

http://www.dfmc.org.au/
Dairy Farmers Milk Co-operative Ltd

http://www.nff.org.au/
National Farmers' Federation


Graduates will be agents for
change, educating the public on
the modern role and relevance
of agriculture in society.

Case study 1A: Group problem-based learning task

Unit: Professional Skills in Agriculture and Horticulture

University: Charles Sturt University

Coordinator/Teacher: Mr Peter Mills

Year: Level I (Introductory)

Unit context: The unit is designed to provide a broad understanding of agriculture and horticulture focusing on production, environmental, economic and social elements. Students are expected to search for information to develop an evidence-based approach to investigating problems in agriculture. This aligns with TLO 1's focus on ensuring students have an integrated understanding of agriculture. The unit is typically undertaken by students completing a Bachelor degree in Agricultural Business Management, Wine Science, Agriculture, Eco-Agriculture or Horticulture.

Description of assessment task: Conducted over three weeks, the group assessment task engages students in a real-life scenario in a Problem Based Learning (PBL) approach. Each group is given a simple scenario to discuss and research. Students need to understand, at an introductory level, factors that underpin agricultural practice and how they contribute to practice change (addressing TLO 1.2) in order to provide valid strategies for improvement. An understanding of the different ways stakeholders make decisions (addressing TLO 1.3) and, therefore, act to ensure their strategies are successful also enables this outcome. Students are normally allocated into groups of 8–10 based on gender, the degree in which they are enrolled, and learning style. They use an online meeting platform. At the conclusion of week three, students are required to draw upon Driscoll's cycle of reflection (Driscoll 1994; 2000; 2007).

Educational aims:

1. to develop reflective skills including the ability to provide illustrative examples; evaluate individual and group efforts; and consider multiple contexts and understandings
2. to enable the student to integrate and apply prior learning to understand, discuss and develop strategies to resolve or overcome issues related to a specific ag-based scenario.

Other relevant comments or advice: Based on student feedback, a weighting of 20% is recommended for this activity. The students found the PBL approach rewarding: "I think there is no doubt that by solving the problem, I will retain a lot more information than through regular lectures etc. and I found it really interesting."

The students made a range of suggestions including:

- having specified roles and adhering to them
- having the first group meeting as a synchronous one with a staff facilitator
- meeting twice per week for one hour each time
- providing clear notice of when the PBL period is in the unit outline.

Case study 1B: Scaffolded learning task

Unit: Agribusiness Systems

University: Charles Sturt University

Coordinator/Teacher: Professor David Falepau

Year: Level I (Introductory)

Unit context: This case study is part of a Bachelor in Agricultural Business Management and focuses on a three-fold assessment task in a first year unit introducing students to the holistic nature of agricultural industries. This unit considers agri-food and fibre industries as a collection of 'agribusinesses' contributing either directly or indirectly to a chain of activities that extend from the paddock to the consumer.

Description of assessment task: The combined weighting of this three-part assessment item is 70% of the total grade. The first component requires students to develop a value chain diagram and description for their product (10% of all marks - up to 1000 words). Students then provide a short presentation (5 min) and a written report (1000 words; combined value for the presentation and report = 30% of all marks) focusing on the physical transformations from a raw product to a consumable product. Lastly, they analyse how effective, efficient and sustainable their chosen value chain is and identify opportunities for improvement in a report (30% of all marks – 3000 words).

The assessment supports students' agricultural understandings by using one value chain as a framework. Firstly, students must understand the agribusinesses that comprise agri-food and fibre value chains. Students then explore the factors that affect value chains and how the agribusinesses are associated with change practice (TLO 1.2) or made decisions (TLO 1.3). This approach is taken to study the components of and the interrelationships among resources, functions, processes and consumer products of agribusiness systems (and therefore may also fit with TLO 2). Emphasis is placed on identifying issues affecting the sustainability of agribusiness systems in a dynamic global environment.

Educational aims:

1. to develop knowledge and understanding of agribusiness systems and value chains
2. to encourage a detailed understanding of the post-farm gate value-adding and associated product flows and transformations throughout the system
3. to enable the student to critically analyse the performance of systems to identify strengths, weaknesses, future implications and potential for improvement (productivity and efficiency).

Other relevant comments or advice: The lectures and tutorials in this subject must be ordered in line with the required stages of the assessments. The academic needs to approve the choice of product early in the assessment so that students do not choose very short value chains. When the value chain is short, the academic needs to ensure that it is increased in order to enable consideration during the entire unit. As a result, students are discouraged from studying fresh vegetables for which there is no value adding. This assessment task requires significant marking time in order to provide appropriate feedback. This unit is well received by the students as it helps them to conceptualise products that are of interest to them.

Case study 1C: Diverse views in agricultural land use blog

Unit: Food Environment and Culture

University: Charles Sturt University

Coordinator/Teacher: Ms Caroline Love

Year: Level II (Intermediate)

Unit context: This unit covers ethics and ethical frameworks, environmental and social sustainability linked to economics, the major challenges facing agricultural production and food security, and how Indigenous Australian culture and values intersect with and can inform land use and management. Students undertaking this unit come from a range of degrees including the Bachelors of Viticulture, Wine Science, Wine Business, Agricultural Business Management, Agriculture, Eco-Agricultural Systems or Horticulture.

Description of assessment task: This assessment item is worth 25% of the total grade. Students post six blog posts of 300– 400 words over the semester. Students draw upon peer-reviewed literature and material covered in the unit to present informed views and justify their responses.

Examples of questions include: "Discuss: What place is there for Indigenous land management within commercial farming systems in Australia? Provide a balanced answer to the benefits and challenges faced." or "Using the climate projections for the year 2050 examine the vulnerability and adaptation responses of an industry and location of your choice using the Vulnerability Assessment Tool. Discuss your overall summary of adaptation required, listing any assumptions you have made and any additional concerns you have."

Students need to be able to understand, articulate and discuss the core concepts and how they relate to society (thereby addressing TLO 1.1). Because of the focus on issues relating to agricultural production, the blog increases student understanding of key factors that influence agricultural practices (TLO 1.2) and how these influences impact decision-making processes (TLO 1.3).

Educational aims:

1. to develop a deep understanding of the breadth and depth of literature relating to environmental and social sustainability
2. to develop an understanding of the major challenges facing agricultural production including social and environmental sustainability and Indigenous culture and values
3. to enable the student to understand and integrate core concepts into discussions and analyses
4. to enable the student to be aware of how one's own understandings and thinking can change through exploring different ideas, views and/or literature.

Other relevant comments or advice: This task focuses on the research and presentation of information, not necessarily critical analysis. Depending on the blog tool used, it can get 'messy', so the tool needs to be as simple as possible and the topics need to link to the weekly study material.

The task needs to be kept to a reasonable length and could be improved by linking the blog topics, so that they scaffold as a whole-of-task. Another possible improvement could be to share the blogs of a specific week among students in order to shift the focus of the task to peer critic of the information presented. Students reported that they enjoyed the short "snapshot" reviews to feed into the class discussions. They also reported that, over time, they saw the value of the task design.

Case study 1D: Essay on researching and communicating contemporary issues in agriculture

Unit: Agricultural Systems 1A

University: The University of Adelaide

Coordinator/Teacher: Associate Professor Glenn MacDonald

Year: Level I (Introductory)

Unit context: The unit provides a general introduction to Australian agricultural systems within a global context. Topics vary each year and examples include the use of hormones in beef cattle production and the development of agriculture in northern Australia. Agricultural Systems 1A is a core course in the Bachelor of Agricultural Sciences.

Description of assessment task: The 1500-word essay is worth 15% of the total grade and is submitted in week 6 of 12 weeks. This task introduces a range of terminology used in agriculture and this benefits students who have no agricultural background. It also serves as a broad introduction to Agriculture. The essay is submitted to the tutor and after marking the students have the option to respond to the marker's feedback and resubmit the essay.

The essay topic changes annually, focusing on contemporary agricultural issues and improving students' understandings of sustainable production systems explicitly addressing TLO 1.2. Furthermore, the need for students to identify, locate and evaluate key information, while contributing to TLO 3, enables students to better understand the context in which stakeholders make decisions (TLO 1.3).

Educational aims:

1. to develop an understanding of the biophysical and socioeconomic factors underpinning the major agricultural industries in southern Australia and how they interrelate with one another
2. to develop an understanding of the essential features of sustainable agricultural systems
3. to develop an understanding of the importance of physical and biological resource base as the foundation of sustainable production systems
4. to enable the student to find, collate and critically evaluate information from different sources.

Other relevant comments or advice: Because this is a first year class, the assessment task needs to cater for students with different knowledge and experiences. The choice of the essay topic each year is therefore critical and challenging. Topics should be current, but need to be easy to research. For example, in a previous year, students investigated the issue of "permeate in milk." Finding published data on this topic was difficult, which is counter to the essence of the assessment task where students are required to identify two primary sources. Some students have not written essays previously, hence good teaching support is necessary. We use internal supportive material (a handbook) and provide an internal tutorial.

Case study 1E: Analysis and field tour of agricultural commodities

Unit: Food and Fibre Production in a Global Market

University: University of Tasmania

Coordinator/Teacher: Dr Alistair Gracie

Year: Level I (Introductory)

Unit context: This unit provides an understanding of historical developments, current status and future opportunities and challenges of the dominant agricultural and horticultural industries in Tasmania and Australia. Key factors involved in establishing new industries and the importance of comparative and competitive advantages to the ongoing success of existing industries in a competitive global market are considered. The concepts of supply chains, value chains, value-adding and quality assurance, and food and fibre processing are introduced. Practical and tutorial sessions involve guest speakers, group discussions and a 3.5-day field trip to the north-west of Tasmania. The unit is compulsory for students in the Bachelors of Agriculture and Agricultural Science courses.

Description of assessment task: This task has two components.

1. ABARE Conference paper. Working in pairs, students select a recent and historical (10 years previous) paper from the ABARE Outlook Conference on one of the following commodities: wheat, beef, dairy, wool, wine or sugar. Students present a 5-minute seminar on the status, trend and future outlook of their allocated commodity. Assessment criteria linked with TLO 1, and in particular TLO 1.2 include student demonstration of their understanding of the status, trends and future outlook of the commodity. This assessment task is worth 10% of the final grade.
2. Field trip to the north-west coast of Tasmania. Students keep a record of activities and information gathered during the mid-semester field trip. This includes notes taken during presentations, samples collected in the field and photographs. Students are encouraged to use their initiative and powers of observation to interpret, record or present information in the field book. An analysis of each visit or activity is included. This assessment task is worth 15% of the final grade and specifically addresses TLO 1.2 and 1.3.

Educational aims:

1. identify the comparative and competitive advantages of primary industries and encourage an understanding of how these can be applied to promote future growth and sustainability
2. demonstrate an understanding of emerging and established primary industries at the industry and enterprise level.

Assessment details: This case study is composed of two assessment tasks to the value of 25% of the total grade. These tasks align with TLO 1.1 and 1.2.

Other relevant comments or advice: The mid-semester field trip is widely reported by students to be one of their favourite components of the unit. This is because students are provided with an opportunity to meet leaders in industry and to gain a first-hand appreciation of the size, scope and structure of locally and internationally owned agricultural and horticultural companies.

Case study 1F: Climate and agriculture data analysis exercise

Unit: Introduction to Agricultural Systems

University: Curtin University

Coordinator/Teacher: Dr Susan Low

Year: Level I (Introductory)

Unit context: Introduction to Agricultural Systems is a core first year unit in the Bachelor of Agribusiness and is foundational for second and third year agribusiness units. This unit provides students with an overview of the importance and scale of agricultural industries in relation to Western Australian, national and global contexts.

Description of assessment task: This task is designed to develop an understanding of the links between climate and potential agricultural production systems and enterprises. The task is divided into four components:

1. Defining weather and climate terms that are commonly used in agriculture production
2. Exploring and describing the drivers of weather patterns
3. Comparing climates across agricultural production environments
4. Assessing climate variability through application of trend lines to specific data sets.

Each student is provided with a set of weather station identification numbers where each is to provide a range of climates across Australia. Students use the Bureau of Meteorology (BOM) site, Climate Data online, to find the weather stations. Using the data set for each location (usually >20 years of data) students produce graphs for average monthly rainfall and average maximum/minimum temperature. The graphs are then used to describe the annual weather patterns for the area. Students then research the production enterprises common to the area and explain why the enterprises (especially crops) are suitable for the location. Students apply trend lines to the full data set and use the Climate Change and Variability component of the BOM web site. Using the trend lines students assess the changing patterns and present an assessment of possible future challenges to production.

Assessment details: The assessment contributes 15% to the total grade. The focus on weather and climate patterns provides students with an understanding of some of the biophysical factors associated with agricultural production thereby addressing TLO 1.2. TLO 1.3 is also addressed because students gain an understanding of how information, such as climate data, influences agricultural decisions such as crop selections.

Educational aims: Students will develop an understanding of the weather patterns and climate associated with agricultural production areas across Australia, and will be able to:

1. explain how weather patterns influence the choice of crop and animal production systems
2. source and use data sets to present information
3. explain issues between climate variability and agricultural production options.

Other relevant comments or advice: The assessment has been changed from a restricted set of locations to individual sets for each student and is provided as a set of structured steps. In a dedicated tutorial (BOM and Excel), students explore the BOM website with particular emphasis on the information that is relevant to agriculture. Students draw on this understanding when studying summer and winter crop production opportunities and limitations.

Threshold Learning Outcome 2: Knowledge of Agriculture

Beth R. Loveys, Karina M. Riggs and Amanda J. Able

Universities, as a result of their educative function, have a focus on knowledge and the development of higher order intellectual skills in their graduates. Although knowledge (or remembering) is thought of as the simplest thinking behaviour in the cognitive domain (Anderson et al. 2001; Bloom 1956), it is essential for the development of the higher order capabilities that we demand of our graduates, such as critical thinking and problem-solving (Anderson 2013; Billing 2007).

Knowledge is common amongst the Threshold Learning Outcomes (TLOs) developed for various disciplines including accounting (TLO 2; Hancock et al. 2010); architecture (TLO 1; Savage 2011); creative and performing arts (TLO 1; Holmes and Fountain 2010); engineering and information computer technology (across all 5 TLOs; Cameron et al. 2010); environment and sustainability (TLO 1; Phelan et al. 2015); geography (TLO 1 and 2; Hay & Rashleigh 2010a); history (TLO 1, 2 and 3; Hay & Rashleigh 2010b); law (TLO 1; Kift et al. 2010); and science (TLO 2; Jones et al. 2011) and its sub-disciplines such as biology, biomedical science, chemistry and physics (see ACDS TL Centre 2016 for refinements).

The science TLOs, and adaptations thereof, were designed to be applied to all disciplinary areas within the science cluster (Jones et al. 2011a). The agriculture TLOs strongly reference the science TLOs but they also capture the applied nature of agriculture and the contribution of disciplines other than science to agriculture. Only Agriculture TLOs 2.1 and 2.2 share some similarity with the science TLO for Scientific Knowledge, in terms of having depth of knowledge in a particular disciplinary area and some knowledge of other disciplinary areas. The Science Good Practice Guide for TLO 2 Scientific Knowledge acknowledged that multi-disciplinary science-related degrees need to adapt the science TLO to reflect an integrated approach when designing curricula (Jones 2013).

Threshold Learning Outcome 2: Knowledge of agriculture states that, upon completion of a bachelor-level degree in agriculture or a related sub-discipline, graduates will exhibit breadth and knowledge of agriculture by:

2.1 Demonstrating knowledge of core sciences in the context of agriculture

2.2 Demonstrating broad generalist knowledge of relevant agricultural production systems and their value chains, with specialist knowledge in at least one area

2.3 Understanding how knowledge from different sub-disciplines within agriculture is integrated and applied into practice

2.4 Demonstrating a basic knowledge of economics, business and social science as they apply to agriculture

(Botwright Acuña et al. 2014a)

This chapter provides:

1. discussion of the nature of knowledge and its place in the applied and integrative discipline of agriculture; the impact of a discipline on how knowledge is viewed; and, how that view affects the way we demonstrate the development and/or achievement for TLO 2 Knowledge of agriculture for agriculture students
2. an analysis of the individual sub-TLOs complementary to the succinct explanatory notes provided in the Learning and Teaching Academic Standards Statement for Agriculture
3. examples of assessment practice for TLO 2 across levels I, II and III, and types of assessment; and a list of possible resources for use by teachers in agriculture.

Agriculture: Learning and integrative knowledge

Knowledge has four dimensions (factual, conceptual, procedural and metacognitive) and is the basis for the development of the higher order cognitive domains of understanding, applying, analysing, evaluating and creating (Anderson et al. 2001; Bloom 1956; Krathwohl 2002). The four knowledge dimensions detailed in Table 2.1 are listed in ascending order of complexity but they are not necessarily hierarchical (Anderson et al. 2001; Krathwohl 2002). While the development of the first three dimensions (factual, conceptual and procedural) is important, metacognitive knowledge allows agriculture graduates to deal with the dynamic and complex problems and the unknown situations they are likely to encounter (Pintrich 2002). A graduate with metacognitive knowledge should have a familiarity of the general strategies used for different tasks, when (or under what conditions) those strategies can be used, and to what extent they are effective. They should also have an awareness of self and their own ability to effectively apply strategies and/or implement solutions (Pintrich 2002).

The complexity of the problems likely to face agricultural graduates arises from the holistic manner of agriculture, which "applies technologies and knowledge gained from multiple disciplines to manage agro-ecosystems" while fostering "environmental, economic and social sustainability" (Botwright Acuña et al. 2014a). This interdisciplinary nature of agriculture can make agricultural knowledge difficult to learn and to teach. Principles need to be taught in context, with opportunities to apply knowledge, rather than just teaching facts or details (Blum 1996). Experiential learning, or learning by doing, is seen as a valuable means of ensuring integration of knowledge in agricultural education (Cheek et al. 1994; Knobloch 2003; Monaghan et al. 2015; Roberts 2006). Well-designed experiential or active learning opportunities can ensure all four knowledge dimensions are developed (Cannon and Feinstein 2014).

Creativity, defined as the use of thought processes and intellectual activity to generate new insights or solutions to problems (Mumford et al. 2009), is essential for graduates of agriculture. The application of that creativity, or innovation, usually through the strategic and appropriate implementation of new ideas (Argabright et al. 2012) is also necessary to ensure the sustainability of agricultural systems. The enabling of innovation in agricultural students requires interdisciplinary knowledge to have been constructed appropriately and preferably in an authentic manner (Knobloch 2003).

Table 2.1. The Knowledge Dimensions (adapted from Pintrich 2002).

Dimension	Definition
FACTUAL KNOWLEDGE	**Basic elements that students must know to be acquainted with agriculture or a related discipline and to solve agricultural problems. Includes:** • knowledge of terminology • knowledge of component details.
CONCEPTUAL KNOWLEDGE	**The interrelationships among the basic elements (such as those within the core sciences, business, economics and/or social sciences), within a larger structure (such as an agricultural eco-system or aspects thereof), that enable them to function together. Includes:** • knowledge of classifications • knowledge of principles and generalisations • knowledge of theories, models and structures.
PROCEDURAL KNOWLEDGE	**How to do something: methods of inquiry and criteria for using skills, algorithms, techniques and methods. Includes:** • knowledge of agriculture-specific skills, models and techniques • knowledge of criteria for determining when to use appropriate procedures.
METACOGNITIVE KNOWLEDGE	**Knowledge of cognition in general as well as awareness and knowledge of one's own cognition. Includes:** • strategic knowledge • knowledge about cognitive tasks, including appropriate • contextual and conditional knowledge • self-knowledge.

Although Agriculture was recognised broadly as being interdisciplinary in nature by workshop participants during the development of the LTAS for Agriculture (Botwright Acuña et al. 2013), the common consensus was that "agriculture has its foundation in scientific method" (Botwright Acuña et al. 2014a). Indeed, agriculture is usually taught in a science faculty.

"Content-heavy" curricula in science have resulted in a focus on factual knowledge rather than an ability to apply that knowledge in science degrees (Matthews and Hodgson 2011). The focus on knowledge transmission as well as the increasing pressure on scientific curricula due to the sheer pace of scientific discovery can lead to issues with an over-reliance on traditional teaching methods and an over-dependence on summative assessment (Jones 2014). Because agricultural knowledge draws upon a number of core sciences, the pressure on the curriculum is amplified if a 'factual knowledge' viewpoint is taken by academics.

The need to learn elements of disciplines other than science (such as social science and business) also increases this pressure. Many agriculture degrees therefore tend to have a great breadth of topics but less depth than those disciplines that are less reliant on a global approach that draws upon many disciplines. The focus of agriculture, therefore, has to be upon the capacity of students to use knowledge in an integrated manner rather than just focusing on *having* knowledge.

During the development of the TLOs for Agriculture, the consistent message from industry was that they wanted graduates who could use any knowledge they had or, at the very least, know how to find information that would help them in their jobs. Comments included:

> *"...they [industry] want people who can think about what is required and where to get it"*

> *"...important to have problem solving skills to apply the knowledge"*

> *"Applied degrees are what is needed ... needs to have enough science and practical application and accessibility ... so they can make an impact on industry by asking the right questions"*

(Botwright Acuña et al. 2014b)

Procedural and metacognitive knowledge were, therefore, considered most important, particularly in terms of problem-solving and the application of skills (TLO3). As a result, TLO 2 Knowledge of agriculture focuses not only on having factual and conceptual knowledge (especially TLO 2.1, 2.2 and 2.4) but also includes procedural and metacognitive knowledge by asking graduates to understand how knowledge from different sub-disciplines is integrated and applied into practice (TLO 2.3). The knowledge demonstrated by a student achieving TLO 2 then contributes to their ability to achieve the other TLOs, which also reference all four knowledge dimensions in some way.

The focus that agriculture has on using knowledge rather than just having knowledge can be challenging for teachers, especially in terms of developing authentic activities and related assessment. As previously mentioned, experiential or active learning is common in agricultural education and is useful when demonstrating the interdisciplinary nature of agriculture to students.

The majority of agricultural students have been shown to be, primarily, analytical learners (Rudd et al. 2000) who tend to discern individual components well. This type of learner usually performs best in formal "knowledge-driven" learning settings (Witkin 1976) and are well-suited to scientific careers. However, agricultural students by necessity must spend time having a global view, learning in more informal settings, and developing the interpersonal skills usually associated to a greater extent with careers in business and social sciences (Rudd et al. 2000). The challenge for the teacher, therefore, is to also develop these learning capabilities so that students will achieve the integrative knowledge skills required to meet TLO 2.

Contextualisation will help in meeting this challenge of ensuring integrative knowledge outcomes (Blum 1996; Knobloch 2003; Roberts 2006) but needs to be supported by strategies that allow the progressive acquisition of the underlying disciplinary knowledge (Billing 2007). Students need the opportunity to practise at the appropriate cognitive level to develop a deeper understanding (Crowe et al. 2008). The stage of learning for students, or year level in the degree, should therefore dictate the type and extent of assessment that demonstrates achievement against TLO 2.

The case studies shown later in this chapter have been chosen because they reflect the development of TLO 2 and/or the different knowledge dimensions (Table 1) in agriculture graduates. Instruction must be aligned with assessment at the appropriate cognitive level and not, as often seen in science (Jones 2014), have an over-use of summative assessment that relies on factual recall. Although examples are provided in this chapter of assessments that explicitly evaluate factual recall (e.g. Case studies 2.1A, B and C), we have observed that knowledge is often implicitly assessed by academics who teach agriculture. We believe that this reflects the contextualisation and experiential or active learning that tends to occur in agricultural education.

Active learning and assessment are thought to enable retention of knowledge in agriculture and related topics (Bauerle & Park 2012; Dresner et al. 2014). This learning strategy is, therefore, of importance because it drives the desired knowledge outcomes (DeHaan 2005).

Academics who teach agriculture also design learning activities and assessments that allow students to demonstrate higher orders of understanding, application, synthesis and evaluation. Having knowledge is not often assessed directly, except at earlier year levels. Later in their degrees students tend to be assessed for their ability to transfer knowledge and to use knowledge to solve problems of agricultural importance, rather than the knowledge itself.

The assumption being made by most academics probably follows the progression element of Bloom's taxonomy, that is, in order to be able to use knowledge, students must have basic knowledge or know how to access the necessary information (Billing 2007). Assessment of TLO 2 *Knowledge of agriculture* is often, therefore, implicit in assessments within the other TLOs, signifying its central importance to those TLOs.

The following notes and comments on each of the sub-TLOs for TLO 2 *Knowledge of agriculture* are provided to help teachers to interpret and implement the TLOs following.

TLO 2.1: Demonstrating knowledge of core sciences in the context of agriculture

The core sciences that contribute to agriculture include biology, mathematics, chemistry and physics. These are often taught in the first year of the undergraduate curriculum and, therefore, are often content-heavy. Unfortunately, this can potentially lead to a superficial approach to learning whereby students rote memorise and reproduce facts with the main goal of passing exams (Marton and Säljö 1976). However, this knowledge of the core sciences needs to be set within the context of agriculture so that our students are more easily able to integrate and apply their knowledge to agricultural problems (see TLO 2.3 and TLO 3).

Contextualisation of core sciences using agriculture has also been shown to improve the acquisition of basic science skills (Conroy et al. 1999). If students are asked to place core science knowledge conceptually within a broader construct during their learning, they are more likely to achieve higher order cognitive domains (Hazel & Prosser 1994), for example, by not just simply knowing the elements of photosynthesis but knowing how it relates to food production and respiration within the plant. This move from simple unstructured knowledge to complex, structured and usable knowledge enables the development of the higher order cognitive domain, understanding (Hughes & Magin 1996) and, ultimately, TLO 2.2 and TLO 2.3.

The core sciences could be viewed as "conceptual gateways" or "threshold concepts" that are necessary for students to achieve mastery in their chosen discipline (Meyer & Land 2005). These threshold concepts (not to be confused with TLOs) are often seen as troublesome for both teaching and learning (Perkins 1999) because they might require a significant shift in the student's knowledge, they need to be irreversibly learnt and they underpin integrative understanding (Meyer and Land 2005). In the case of agriculture, examples of threshold concepts might include:

- Knowledge of simple diffusion and osmosis (from chemistry) in order to understand phenomena such as the role of semi-permeable membranes in both plant and animal systems and the role gradients can play in driving cellular processes. For example, understanding of the effect that salinity has on the growth of plants is underpinned by knowledge about how sodium ions will move in solution and across cell membranes.
- Basic mathematical concepts such as rearranging equations in order to solve for different components of an equation depending on which information is known. For example, in the area of plant water relations the components that contribute to plant water stress can be measured and, using simple equations, estimates of osmotic potential made.
- Another example is determining the heritability of genetic traits such as resistance in plants or breeding values of livestock. This involves distinguishing between different types of variance (including phenotypic, genotype and environmental) in order to determine the heritability of certain genes. These problems usually require knowledge of how to correctly rearrange an equation to solve for the unknown component.

Threshold concepts such as these are often not directly assessed. However, a number of the case studies presented later in this chapter assess threshold concepts indirectly but in the context of agriculture. Assessment that addresses this TLO tends to be heavily weighted towards factual recall of foundational knowledge and/or practical skills/methods, as in the sciences, but with some application of core concepts. As such, the case studies that address TLO 2.1 presented later in this chapter are primarily in examination, quiz or test format.

TLO 2.2: Demonstrating broad generalist knowledge of relevant agricultural production systems and their value chains, with specialist knowledge in at least one area

Agricultural systems are diverse and variable and span the entire value chain from production to consumption (Botwright Acuña et al. 2014a). Furthermore, the production of food, fibre or fuel can be managed in many different ways as can the transformation of raw products to value-added manufactured products. Therefore, knowledge must be broad and generalist to be applicable to any of these systems in which a graduate may work in the future. While students may specialise in at least one area, they need to understand how knowledge is structured and integrated.

Broad content knowledge could, therefore, be used in two main ways. Firstly, broad knowledge be taught so that it acts as the basis for the development of graduates' analytical skills and understanding of the scientific research process as well as inspiring curiosity and life-long learning (Anderson et al. 2011). Secondly, being a generalist enables individuals to develop interconnectedness between core concepts and sub-disciplines easily. This ability has been argued as essential for agriculture professionals, especially those that are involved in rural development (McGuire 2012).

Given the interdisciplinary nature of agriculture, professionals need to be equipped to engage with issues beyond their specialisation and appreciate the wider context of their sub-discipline. TLO 2.2 is necessary for students to achieve TLO 2.3, which extends the graduate from having factual, conceptual and procedural knowledge of their chosen sub-discipline and agricultural systems in general, to having metacognitive knowledge. Interestingly, the majority of case studies presented later in this chapter address TLO 2.2, perhaps highlighting the importance of a holistic view and systems approach in agriculture, regardless of the specialisation.

TLO 2.3: Understanding how knowledge from different sub-disciplines within agriculture is integrated and applied into practice

Integration is a key theme in agriculture. The varied and diverse systems as well as the interdisciplinarity of agriculture mean that graduates need to know how to integrate their broad generalist knowledge and specialist knowledge into practice. The inclusion and articulation of this metacognitive knowledge dimension to the Agriculture TLOs is unique amongst the LTAS, except perhaps for the discipline of environment and sustainability that indicates how transdisciplinarity is valued by their field (Phelan et al. 2015).

As previously discussed, the development of integrative knowledge relies upon contextualisation (Blum 1996; Knobloch 2003; Roberts 2006) and drives higher order learning outcomes (DeHaan 2005) including problem-solving (Pintrich 2002). In particular, inclusion of the metacognitive knowledge domain in the TLOs for agriculture, via TLO 2.3, acknowledges the need for students to learn how to solve unique, dynamic and complex problems as required to meet TLO 3 *Inquiry and problem solving* in agriculture. Furthermore, having this metacognitive ability should also give graduates the tools to meet TLO 5.1 (being independent and self-directed learners). A graduate with metacognitive knowledge should have an awareness of their own knowledge and be able to effectively apply learning strategies where new learning is required (Pintrich 2002).

As previously discussed, experiential learning is central to success in reaching all four knowledge dimensions (Cannon & Feinstein 2014) and is seen as integral to agricultural education (Cheek et al. 1994; Knobloch 2003; Monaghan et al. 2015; Roberts 2006) but has as a premise that knowledge will have been constructed correctly during the learning activities (Knobloch 2003). In this case, achieving TLO 2.1 and 2.2 often occurs at earlier stages of the degree with activities and assessment focusing on TLO 2.3 in later years.

That said, by using real-world questions throughout a degree, knowledge is learnt in a contextualised manner and students can be tested for their ability to identify problems that need to be solved using different elements of their expertise (Meyer & Land 2005) (see TLO 3.1). Assessments are, therefore, also likely to need to be more complex and thus assessment design must suit the learning experience. The case studies chosen show that, in general, the assessments that evaluate a student's demonstration of knowledge actually assess application and construction of knowledge.

TLO 2.4: Demonstrating a basic knowledge of economics, business and social science as they apply to agriculture

Although "agriculture has its foundation in scientific method" (Botwright Acuña et al. 2014a), the decisions made within agricultural systems and their value chains are made in the context of economics, business and social science aspects. For example, a farming system integrates the natural resource base and the agricultural "product" with other considerations such as household livelihoods, costs of inputs and outputs in the system, and the rural community.

Knowledge and skills in agricultural economics and business management have been acknowledged as essential in agricultural graduates if they are to provide the support necessary to maintain the competitiveness of Australian agriculture (Ag Institute Australia 2014). As indicated by McGuire (2012), the ability to identify a production problem and solve that problem in a broader context that engages with broader issues (social, environmental and economic) is essential for agriculture professionals.

The contextual requirement of the learning needed to meet this TLO ensures that integrative knowledge of economics, business and social science is developed. As previously discussed, this leads to the development of higher order cognitive domains such as analysis and synthesis. Given that employers appear to prioritise contextual application in graduates, especially for STEM graduates (Rayner and Papakonstantinou 2015), the development of this capacity is quite important especially for critical thinking.

Work-related learning activities that are well designed and assessed may deliver these outcomes (Hills et al. 2003). Learning tasks that closely resemble those found in the workplace ensure students are better prepared for the workplace and more employable (Oliver 2015). For example, the use of university farms has been suggested to contribute towards teaching sustainability, critical thinking and inquiry skills and to foster a sense of belonging to community (LaCharite 2015).

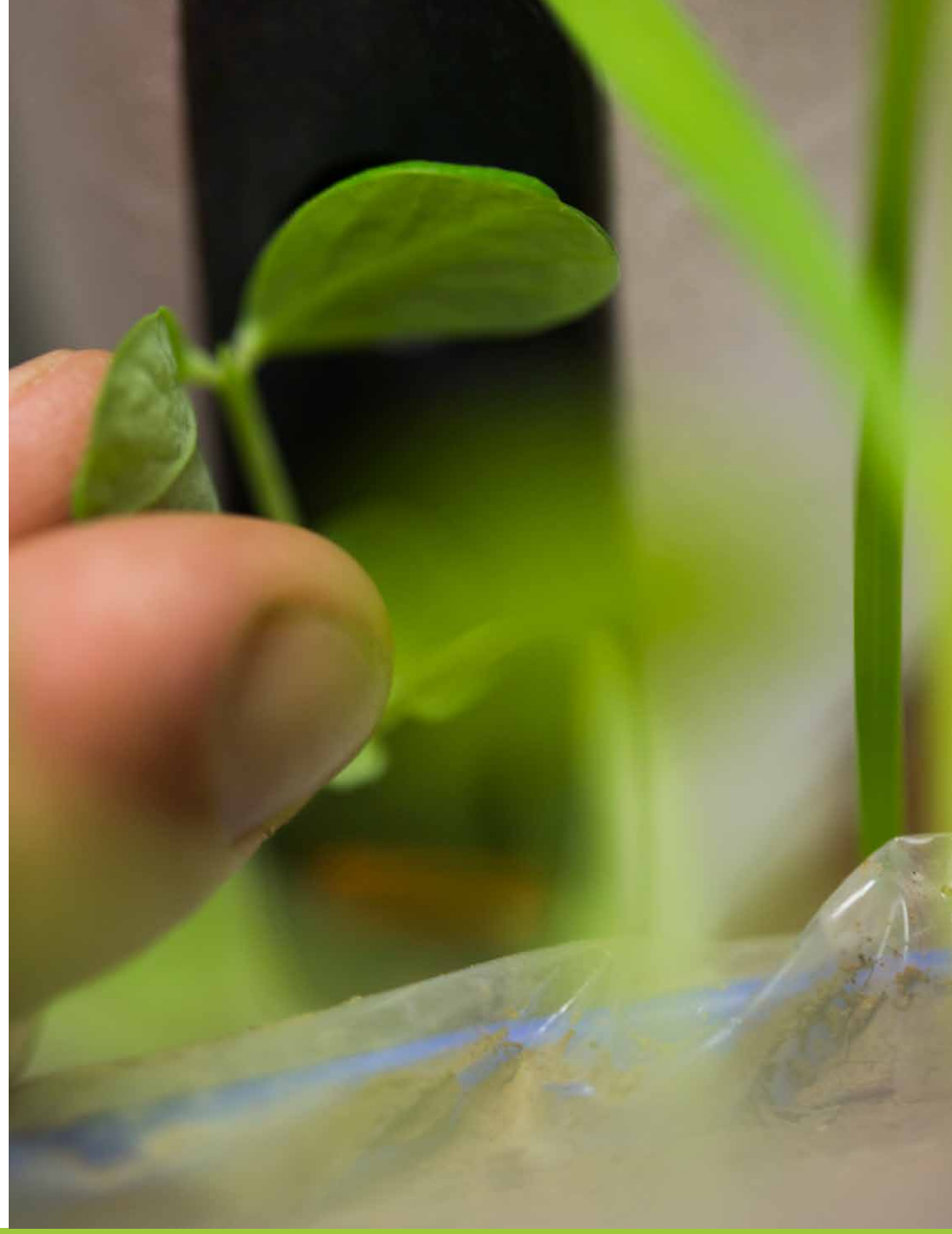
Interestingly, the majority of the assessment case studies that address this TLO have either used a real-life scenario or an authentic situation. The assessment that contributes to TLO 2.4 is very focused on the knowledge gained within allied disciplines but, because it is in context, this TLO improves integrative understanding and critical thinking. Thus, TLO 2.4 prepares students for TLO 3 Inquiry and problem solving (and the ability to solve complex, dynamic problems). Furthermore, the development of knowledge in the social sciences may contribute towards TLO 5 and the development of the student's view of social conscience and/or responsibilities.

Conclusion and future opportunities

Agriculture is undertaken in diverse and variable systems and utilises many disciplines. As such, asking bachelor-level degree students to exhibit breadth and depth of knowledge in agriculture can clearly be challenging. In particular, the potential social or economic consequences of how scientific knowledge is applied within agricultural systems appears of upmost importance to academics, students and industry. *Using* knowledge is more important than having knowledge. Therefore, in helping students to attain TLO 2 *Knowledge of Agriculture*, assessments and activities should, wherever possible:

- develop all four knowledge dimensions (factual, conceptual, procedural and metacognitive)
- integrate the appropriate allied disciplines in science with social science, business and economics
- require students to apply knowledge to authentic scenarios and situations, or, during work-related experiences.

However, the challenge lies in determining which activities and assessments are best suited to these outcomes. Opportunities, therefore, exist to evaluate current teaching practice, specifically for agriculture students, establishing whether those assessments accurately reflect the employability of our graduates and their ability to use all four knowledge dimensions in their subsequent work places.



Resources for TLO 2

Examples of resources that may be of use to academics in addressing this TLO are provided below, categorised by their main knowledge focus. Brief details of how each may be considered in teaching have also been provided.

Agriculture-specific fact sheets by topic

http://www.dpi.nsw.gov.au/aboutus/resources/factsheets/agriculture

https://www.agric.wa.gov.au/

https://www.daf.qld.gov.au/

http://pir.sa.gov.au/

http://agriculture.vic.gov.au/agriculture

http://www.utas.edu.au/tia

Each of the state governments has an agriculture-related department that produces information, especially in the form of fact sheets, which can be useful teaching aids. In most cases, the fact sheets can be found within the links to relevant industries (such as crops, fruits, vegetables, pests and diseases) within each website.

http://www.fao.org/pastoralist-knowledge-hub/knowledge-repository/browse-by-topic/en/

http://www.fao.org/family-farming/resources/en/

The Food and Agriculture Organisation of the United Nations (FAO) has created knowledge hubs or platforms that can be searched to identify resources in various agriculture-related topics. The pastoralist knowledge hub and family farming knowledge platform were released in 2015. The FAO also has a Twitter feed that tweets about the latest available agricultural knowledge resources (FAOKnowledge@FAOKnowledge).

Agriculture and the environment

http://www.agriculture.gov.au/ag-farm-food/climatechange/climate/communication/factsheets-case-studies-and-dvds/case_studies/case-study-scientists-use-farmers-A-knowledge-to-identify-the-settings-for-successful-mixed-farming

A current example of how knowledge regarding risk assessment in farming from farmers can be used by scientists to predict what a future farm might look like in the face of global climate change.

http://agsciencevideos.blogspot.com.au/

The agricultural science video blog provides YouTube videos of fundamentals in agriculture. Although aimed at secondary school teachers, many of the videos may be usefully integrated into curriculum to cover basic knowledge and concepts.

http://www.chiefscientist.gov.au/2014/07/australia-2025-smart-science-agriculture/

A useful summary from three eminent researchers (Peter Langridge, Michael D'Occhio and Dana Cordell) regarding the science underpinning food production, disease pressures and the economics of global food production and their importance to agriculture in Australia.

http://www.csiro.au/en/Research/AF

Useful summaries of current and active agricultural research areas within CSIRO that could be used to provide examples of how knowledge is the foundation for new discovery and progress.

http://www.environment.gov.au/climate-change/publications

A summary of climate science research with some simple fact sheets that would be useful teaching aids.

http://www.ipcc-wg2.org/index.html

There is plenty of detailed information on this website but the most useful link for TLO2 is to a report: IPCC expert meeting on Climate Change, Food and Agriculture. The state of our current knowledge regarding climate change is explained.

Animal science and production systems

http://www.dairyaustralia.com.au/Animal-management.aspx

Dairy Australia provides a range of information and links to associated resources that may be valuable teaching aids in the development of knowledge about animal management.

http://www.makingmorefromsheep.com.au/

A best practice package containing online modules about sheep production and associated tools.

http://mbfp.mla.com.au/Home

An information package designed to deliver the essential principles and practices for a successful beef business.

http://www.woolwise.com/resources.html

Links to a number of educational resources related to sheep production including a range of manuals and online modules.

Economics, social science, business and policy

http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-region/global/socially-conscious-consumer-trends-sustainability/?id=1410083148827

The website covers issues of social conscience which may influence consumer choice. Discussions on sustainability in terms of ecology, economics, health and philosophy are covered.

http://www.agriculture.gov.au/ag-farm-food

The Department of Agriculture, Fisheries and Forestry website for Agriculture, Farming and Food provides links to resources and policies by industry (e.g. crops, horticulture and biotechnology). Many industries have their own fact sheets which can be useful teaching aids.

http://www.business.gov.au/business-topics/business-structures-and-types/industry-factsheets/Pages/agriculture-industry-fact-sheet.aspx

Provides an overview of the legal, operational and business issues for the agriculture industry and has links to more detailed information that could be useful as a knowledge resource.

http://www.oecd.org/dataoecd/38/10/48224529.pdf

A comprehensive report from 2011 on the increased global pressure to produce food sustainably. Market forces, commodity prices, environmental impacts and more are discussed with respect to using scientific knowledge and evidence-based practice to increase food production sustainably.

http://www.oecd-ilibrary.org/agriculture-and-food/oecd-food-agriculture-and-fisheries-working-papers_18156797

A wide-ranging and diverse selection of current publications looking at the economics of various agricultural industries, ranging from disease in livestock to climate change mitigation to preventing food wastage around the world.

Plant science and crop production

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

The Australian Grains and Research Development Corporation publishes a range of fact sheets of technical research, development and extension that may be valuable teaching aids.

http://plantsinaction.science.uq.edu.au/

A free online textbook on plant biology containing downloadable illustrations and examples relevant to agriculture.

http://www.plantcell.org/site/teachingtools/teaching.xhtml

Teaching Tools in Plant Biology provides a short essay, PowerPoint slides and suggested reading for academics across a range of plant biology topics. Provides basic knowledge of key processes such as photosynthesis and the role of hormones in plant development.


Agriculture is undertaken
in diverse and variable systems
and utilises many disciplines.

Case studies of assessment for TLO 2

The following examples were provided by academics who teach or coordinate units currently or recently offered in Australian university agriculture or related degrees. They capture a number of different assessment styles at different levels and highlight the importance of contextualisation, the development of the different knowledge dimensions, and the preference to assess the application of knowledge (rather than just having knowledge). We have categorised each task according to whether it assesses foundational knowledge of core concepts, knowledge of practical skills/methods or the application and integration of knowledge (Table 2.2).

Table 2.2. Summary of assessment case studies.

* Factual (F), Conceptual (C), Procedural (P), Metacognitive (M) # Shading indicates task addresses that TLO

Category	Task	Level	Knowledge Dimension*	TLO 2#			
				2.1	2.2	2.3	2.4
2.1. Foundational Knowledge	**2.1A.** Online agricultural glossary and quiz	I	F, C				
	2.1B. Plant breeding terminology test	III	F, C, P				
	2.1C. Online soils and landscapes quizzes	I	F, C, P, M				
2.2. Knowledge of Practical Skills/Methods	**2.2A.** Animal and plant biochemistry online practical skills test	II	P				
	2.2B. Plant science online practical exams	II	F, C, P				
2.3. Application and Integration of Knowledge	**2.3A**. Animal production calendars	II	F, C, P				
	2.3B. Soil and water resources fact sheet	II	F, C, M				
	2.3C. Team based learning tests and application exercises in genetics	II	F, C, M				
	2.3D. Crop physiology laboratory reports	II	F, C, M				
	2.3E. Integrative agriculture, food and health essay	II	F, C, M				
	2.3F. Sustainable resource management field analysis	I	F, C, P, M				
	2.3G. Land purchase analysis	II	F, C, P, M				
	2.3H. Sustainable agricultural systems oral examination	III	F, C, P, M				
	2.3I. Group pasture production systems scenario	II	F, C, P, M				
	2.3J. Agricultural development concept note & research proposal	III	F, C, P, M				

Case study 2.1A: Online agricultural glossary and quiz

Unit: Agricultural Systems 1A

University: University of Adelaide

Coordinator/Teacher: Associate Professor Glenn McDonald

Year: Level 1 (Introductory)

Unit context: Agricultural Systems 1A is a core foundation course, taught in the first semester of the first year of the degree, providing a general introduction to the physical, biological and economic characteristics of Australian agricultural systems within a global context. In particular, it examines climatology and meteorology, and characteristics of sustainable production systems and provides an overview of the major Australian industries.

Description of task: An online glossary of agricultural terms is provided in the online Learning Management System and students are asked to learn that from Week 1.

In Week 3, students undertake a quiz that asks students multiple-choice questions related to the definitions of 20 commonly-used terms.

Educational aims: This task specifically meets the intended unit learning outcome that a student will have knowledge and understanding of essential key concepts and terms used in professional practice.

Assessment details: The online quiz is worth 3.3% of the overall grade and takes approximately 15 minutes to complete. Students complete the quiz in Week 3 of semester during the tutorial. The quiz provides online feedback on the correct/incorrect answers.

Other relevant comments or advice: The purpose of the quiz is to allow many students to become more familiar with the "vocabulary" of agriculture. We have students from a variety of backgrounds, many of whom have limited experience in agriculture.

There is a considerable amount of jargon, technical and idiosyncratic terms in agriculture and the purpose of the quiz is to allow students to familiarise themselves with some of the more commonly used terms at an introductory level. This quiz tests factual and conceptual knowledge contributing to TLOs 2.1 and 2.2. It also prepares students for later learning.

Case study 2.1B: Plant breeding terminology test

Unit: Plant Breeding III

University: University of Adelaide

Coordinator/Teacher: Associate Professor Jason Able

Year: Level III (Advanced)

Unit context: Plant Breeding III is a third year elective course in the Bachelor of Agricultural Sciences. This unit introduces the fundamental concepts of plant breeding and plant adaptation that are applicable to agricultural and natural systems with a focus on improvements in productivity and enhanced sustainability of farming systems worldwide.

Description of assessment task: Students are provided with a 'dictionary of terms' to learn in Week 1. They are then asked to define their understanding of the terms during the written terminology test in Week 3.

The terms are referred to often through semester and it is essential that the students have acquired a knowledge and understanding of those terms in order to progress in their learning later in the course. The students are provided with 'flash cards' of the terms and their definitions as a learning resource.

Educational Aims: This activity aims to ensure knowledge and understanding of essential key concepts and terms used in plant breeding. With regards to the unit learning outcomes, the activity contributes to the ability of students to:

1. describe sources and types of genetic variation and explain their importance for plant improvement
2. describe stages within a modern breeding program
3. describe methods used in plant breeding
4. judge which plant breeding methods are appropriate for specific objectives and situations.

Assessment details: Students are given 90 minutes (during class-time) to complete the written test (worth 10%). The test uses 'define the term' and 'define the phrase' style questions. Students are also encouraged to use diagrams (with text) to assist in showing their understanding of the terms.

Other relevant comments or advice: The terminology test was developed to help ensure that students had the basic knowledge needed to move to application, evaluation and synthesis within the plant breeding context. Certainly, there is a clear distinction between those students that engage well with this activity process and those who do not. This is more often than not reflected in the final overall grade for the unit.

TLOs 2.1 and 2.2 are addressed because of the focus on scientific concepts within the specialist knowledge of plant breeding and their impact on agricultural production systems and their value chains.

The flash cards appear to be a good resource with many students being seen using them outside of class in the period leading up to the assessment task.

Case study 2.1C: Online soils and landscapes quizzes

Unit: Soils and Landscapes I

University: University of Adelaide

Coordinator/Teacher: Dr Ron Smernik, Dr Ashlea Doolette

Year: Level I (Introductory)

Unit context: Soils and Landscape I is a first year core unit in the Bachelors of Agricultural Sciences, and Viticulture and Oenology. This unit describes how agricultural and ecological systems are linked to soils and the Australian environment and provides a basis from which sustainability issues can be addressed.

Description of task: Three 1-hour quizzes occur during the semester, which consist of a series of multiple choice questions to be answered online with feedback provided immediately after the quiz in class.

The quizzes allow students to continuously monitor their retention of content and highlight problem areas that can be addressed in workshops.

Educational aims: The quizzes address the intended learning outcomes that students will be able to:

1. understand and explain basic principles underlying the physical, chemical and biological properties of soils in landscapes
2. correctly quantitatively assess and interpret soil characteristics using relevant technologies
3. give a basic description of a soil profile and broadly assign this within the Australian Soil Classification system
4. critically evaluate and confidently interpret soils data, maps and information especially in relation to identifying potential management issues for production enterprises and suggest possible solutions.

Assessment details: The three quizzes occur throughout the semester and each is worth 10% (a total of 30% of the unit). They are delivered online and take students 1 hour to complete.

Other relevant comments or advice: The benefit of this task is the immediate feedback to the student and teachers on student progress in assimilating key knowledge from the lectures and practicals. Assessment of content is spread throughout the course. In our experience, most students prefer this to a heavily-weighted final exam and it encourages students to consolidate their revision in four-week blocks (rather than cramming revision at the end of the subject).

A multiple choice online quiz with automatic marking facilitates rapid feedback (~30 minutes) that is vital to the students' learning. To minimise collusion and cheating, students are provided with a total mark, rather than answers to each question. The quizzes are open book to encourage students to use resources provided or other resources to formulate reasonably rich answers to questions. The questions are not about memorising information found on individual slides from lectures (factual recall) but involve synthesising multiple elements or applying understanding to unfamiliar situations.

This encourages metacognitive development in the context of agriculture and addresses TLO 2.2 and TLO 2.3. The feedback sessions are recorded so they can be viewed later, but we avoid providing documented answers in order to avoid students being advantaged in future years. The idea of running quizzes remotely was considered, but it was decided that scope for collusion was too great.

Case study 2.2A: Animal and plant biochemistry online practical skills test

Unit: Animal and Plant Biochemistry II

University: University of Adelaide

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

Year: Level II (Introductory to Intermediate)

Unit context: Animal and Plant Biochemistry II is a second year core unit in the Bachelors of Agricultural Sciences, Applied Biology, Viticulture and Oenology, Food and Nutrition Science, Animal Science, and Science (Veterinary Bioscience). This unit provides an advanced introduction to the fundamental processes of plant, animal and microbial metabolism. Topics include protein structure and function, mechanisms for and control of enzyme action, the biochemistry of carbohydrate, fat and protein metabolism, energy generation and the fundamentals of nucleic acid biochemistry.

Description of task: This online test assesses the students' ability to perform simple biochemical calculations including a revision of SI units, steps needed in making molar solutions, the calculation of % (w/v) values, selection of the correct-sized pipettes for various applications, calculations needed before performing serial dilutions and interpretation of standard curves.

Questions are delivered as multiple choice, short answer or graph interpretation.

Educational aims: The online test enables students to develop their procedural knowledge and addresses TLO 2.1. It contributes towards the unit learning outcome that students will have demonstrated familiarity and competence with the practical skills and techniques used in biochemical research and analysis. These include experimental planning, the preparation of reagents and use of basic instrumentation (spectrophotometers, centrifuges, chromatographic apparatus etc.), collection of biochemical data and its presentation, and, most importantly, analysis and interpretation of the outcomes of biochemical investigations.

Assessment details: The practical skills test is delivered online via the Learning Management System in Week 3 of semester. All students take the test simultaneously in a quarantined hour as part of their usual contact hours. The test takes approximately 45 minutes to complete and contributes 7.5% of the overall grade.

Other relevant comments or advice: This test could be expanded to cover more practical skills and could be used later in the semester to test the whole practical component. However, it is useful to test the student's ability to perform simple calculations early in the semester to identify and rectify problems or misunderstandings.

We plan further development of this concept using short videos showing the demonstration of practical techniques that the students are required to watch before answering questions – good and bad techniques will be shown and students will be required to identify examples of both.

Case study 2.2B: Plant science online practical exams

Unit: Foundations in Plant Science II

University: University of Adelaide

Coordinator/Teacher: Dr Beth Loveys

Year: Level II (introductory to Intermediate)

Unit context: This is a second year core unit in the Bachelors of Agricultural Sciences, and Viticulture and Oenology. This unit provides an introduction to the structure and function of plants with a specific focus on plants of agricultural and horticultural importance. Attention is given to how plants respond and adapt to their environment and the consequences of these interactions to productivity and quality.

Description of task: Following each set laboratory session (plant anatomy, effects of herbicides on photosynthesis, measurement of plant water status, potassium uptake mechanisms) the students have one week to complete an online exam in the learning management system in their own time.

The questions are a combination of multiple choice, short answer and interpretation of micrographs and diagrams. Students can save and recommence the exams but only one submission is allowed. The questions aim to focus students' thinking about concepts and skills encountered in the practicals.

Educational aims: The practical exams contribute to the development of factual, conceptual and procedural knowledge of students. In particular, the exams address TLO 2.1, 2.2 and 2.3 by assessing core knowledge in the context of agricultural production and by extending student thinking with regards to application into practice. The exams contribute to the intended learning outcomes of the unit. Students should be able to:

1. describe the photosynthetic pathway and explain the role of environmental controls of photosynthetic rate
2. discuss the factors that determine water use efficiency
3. explain how plants acquire, transport and use mineral nutrients
4. identify the basic anatomy of plants as it relates to the physiology of water and nutrient transport and photosynthesis.

Assessment details: The practical exams are delivered online via the Learning Management System in the week following each relevant practical session (usually Weeks 2, 4, 6 and 8 of the semester). Students are able to access the exams from the evening after the practical session and for the following seven days. The exams take approximately one hour to complete with no time restriction. The exams each contribute 5% to the overall grade.

Other relevant comments or advice: These exams are useful to encourage students to revisit concepts covered in the practical session for up to one week after the practical and allow some assessment of the students' understanding without requiring a full practical report write up.

The exams can be created to be automatically marked with immediate feedback or to pose more open-ended questions, depending on the type of material covered and the level of understanding required.

Case study 2.3A: Animal production calendars

Unit: Animal Production

University: Curtin University

Coordinator/Teacher: Dr Susan Low

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelor of Agribusiness. This unit covers the scientific principles (biochemical, anatomical and physiological) that underpin intensive and extensive animal production.

Description of task: This task is designed to build understanding of the annual/seasonal production cycles for a range of animal production industries. It is an individual task where students select one intensive (pigs or poultry) and one extensive (sheep) industry. Students research the structure and management of these operations, identify the main management events that are critical to production, and identify the major products of the operation.

A production management calendar is constructed for each enterprise; each identified management practice must be defined and its importance to the production cycle explained. The task enables students to compare intensive and extensive industries, identifying both similarities and differences within the cycles.

Students should be able to link management strategies to saleable product. The calendar serves as an introduction to the modules covered in the unit – nutrition, growth and development, reproduction and lactation.

Educational aims: This task assesses students' ability to:

1. explain the sequence of management events that are commonly used in animal production operations
2. explain the relationships between management events and saleable product
3. link events within the production cycle to animal physiology through the other learning in the unit.

The focus on production systems and the demonstration of knowledge integration during development of the calendar both address TLO 2.2 and TLO 2.3.

Assessment details: The assessment contributes 15% to the total grade and is submitted via an online Learning Management System. This assessment is designed to familiarise students with production cycles of animal enterprises. Many students in the course have limited or no exposure to livestock production. Creation of production calendars helps students to understand that livestock production is a series of planned management decisions (or processes) that are linked to physiological development, supply of nutrients, successful reproduction and markets.

Other relevant comments or advice: This assessment allows students to understand the sequence of events that are important to meeting production goals.

The assessment can be enhanced by having students prepare calendars for different enterprises. Comparisons could include prime lamb vs wool or dairy vs beef. In addition, similar enterprises in different climate zones could also be compared, for example, lamb production in summer or winter rainfall zones.

Students should be encouraged to use a variety of information sources but need to ensure that the information is relevant to Australia.

Case study 2.3B: Soil and water resources fact sheet

Unit: Soil and Water Resources II

University: University of Adelaide

Coordinator/Teacher: Dr Ron Smernik, Dr Ashlea Doolette

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelors of Agricultural Sciences, and Viticulture and Oenology and an elective in the Bachelor of Science. This unit aims to provide an understanding of important physical, chemical and biological properties of soil and of water quality.

Description of task: Students are given a scenario on a topical issue (e.g. the impact of the Brisbane floods (2013) or of fracking or of soil erosion on the Great Barrier Reef) and several references of varying quality.

Students read and summarise the articles and offer advice to a person or group, such as an employer. The 1000-word assignment is supported by several tutorial sessions during the semester on content and style of writing.

Educational aims: The preparation of the fact sheet allows students to demonstrate their ability to:

1. use interpretation to distinguish between good and bad sources of information
2. assemble a succinct, appropriately evidenced argument with a specific, real-life purpose.

Assessment details: The writing assignment (1000 words) is worth 10% of the overall grade and is due during the mid-semester break, giving students between five and six weeks to complete the task.

Other relevant comments or advice: This assignment provides exposure to literature of varying quality and encourages critical thinking. This task requires a significant investment of time from academics so, in units with high student numbers, it may not be possible to provide sufficient feedback to students to achieve the desired learning outcomes.

This task develops knowledge and skills. As a knowledge development mechanism, the task is most effective when it builds on content about soil and water resources provided in lectures and practicals. Topical or controversial subjects demonstrate to students that their learning is relevant and of broad community interest. The choice of references can help to direct the students towards articles they should read in the course of their study. The main outcome of the task is skill development of written communication and the analysis of diverse and contradictory texts.

It is emphasised to the students that context or the intended audience is important and will impact on what they read and how to write as an "expert" communicating to a less knowledgeable but capable and interested audience about some technical aspect of soil and water science in plain English.

The rubric shows that marks are divided equally between *demonstrating knowledge of content* by providing clear, brief summaries of provided texts and their integration; and *clarity of written expression* including the logical ordering and balancing of information, paragraph and sentence construction, and grammar and spelling.

This assessment addresses the need for students to apply specialist knowledge to the management of soil and water resources, especially in the context of agricultural production systems (TLO 2.2 and TLO 2.3). However, it also substantially addresses TLO 4.

Case study 2.3C: Team-based learning tests and application exercises in genetics

Unit: Genes and Inheritance II

University: The University of Adelaide

Coordinator/Teacher: Associate Professor Cynthia Bottema, Dr Karina Riggs

Year: Level II (Introductory to Intermediate)

Unit context: This is a core unit for second year students in the Bachelors of Agricultural Sciences, Applied Biology, Viticulture and Oenology, Animal Science and Science (Veterinary Bioscience). This unit introduces the nature and structure of genetic material including the role of genes in determining the characteristics of organisms, the basis of inheritance and utilisation of variation in breeding programs and natural selection, and the relationship between genetics and natural or managed populations using real life examples.

Description of task: Individual and team tests assess students' knowledge of Mendelian inheritance, molecular genetics and population/quantitative genetics. Students sit the closed-book test at the end of each module (four weeks of lectures, tutorials and practicals) individually and then immediately re-sit the same test with team members.

Test questions include simple calculations, understanding definitions or the interpretation of data/results. Questions are multiple choice and easy to read as only 10 minutes are allocated to complete the test. Questions are projected onto the screen and students shade in their answer on a score card. In teams, students are presented with a hard copy of the questions and encouraged to discuss the answer before marking the answer on their score card. This process provides instant feedback.

Following the tests, students are required to work through application exercises in class. Pre-class activities that must be completed by students before the test include reading an article, researching a topic or answering quiz questions. Students are provided with real-life scenarios for which they develop a solution. Teachers facilitate students through the stages of the application exercise. Teams vote on the answers using flash cards and a representative from the group is asked to explain the answer.

The application exercises link the content from the lectures and tutorials and are designed so that students leave the class with a product of work such as a flow chart of ideas, a completed section of a summative assessment task or answers to a worksheet.

Educational aims: The test addresses TLO 2.1 while the application exercises assist students to understand the relationships between genetics, model systems (plants or animals), the environment and evolution in context to agriculture, consequently addressing TLO 2.2.

Assessment details: The individual and team tests (three in total) contribute 10% towards the final unit grade. The application exercises are formative.

Other relevant comments or advice: The tests have been implemented to encourage students to revise the concepts presented in the unit during the semester that helps students to identify and rectify any conceptual misunderstandings. Using flash cards provides students with immediate answers. Answers to problematic questions are explained by the lecturer at the end of the team tests. The test sessions are not recorded and attendance is compulsory. The answers to the questions are not released online or in hard copy to avoid replication of answers. Peer assessment tied to the test ensures that students prepare for the tests and application exercises. The provision of relevant or controversial topics for the application exercises ensures student engagement in the task.

Case study 2.3D: Crop physiology laboratory reports

Unit: Broad Acre Crop and Pasture Science

University: Curtin University

Coordinator/Teacher: Dr Sarita Bennett

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelor of Agribusiness. This unit provides students with an understanding of the scientific physiological and ecological principles that underpin crop and pasture production, including drivers of plant growth and development, reproduction, nutrition, genetics, crop and pasture health and associated pests.

Description of task: Students record the results of an experiment in the laboratory to increase their understanding of physiological processes in crop plants. The lab report is subsequently written up as a mini-scientific paper of two pages.

The experiments are set up prior to the laboratory (4–8 weeks). In the lab, a class discussion is held to discuss possible hypotheses and expected outcomes, measurements that should be taken to test the hypotheses, the structure of a scientific paper, and the presentation of results in tables and figures.

As two laboratory sessions are written up as mini-scientific papers, students are able to build on feedback from one paper to the next and learning outcomes are achieved without writing full scientific papers. Examples of possible topics include:

1. waterlogging tolerance in some pasture species and development of aerenchyma
2. specificity of rhizobia, their symbiotic relationship with crop or pasture legumes and subsequent nitrogen production.

Educational aims: This task encourages students to:

1. apply core science as it is relates to agriculture in plant physiology
2. develop specialist knowledge of the role of crop and pasture legumes in agricultural systems
3. construct hypotheses and apply discipline knowledge and the research process to solve problems in crop and pasture production
4. analyse and evaluate data and effectively communicate the outcomes in professional written reports.

Assessment details: The assessment task is worth 20% of the final grade. Students write up their experiments in the format of a two-page scientific paper. Students are provided with information on the set up of the experiment, materials and methods. The layout of a scientific report is discussed in the laboratory, including setting the hypothesis and testing of the hypothesis.

Other relevant comments or advice: This case study suits an experiment that has been pre-set with students being given reasonably defined measurements that need to be taken at one point in time.

In-class discussions lead to the generation of the hypothesis before the experiment begins using the information given. A discussion can be had within the class about the best measurements to answer the hypothesis.

To ensure maximum learning objectives are met it is important that feedback from the first mini-report is given before the next mini-experiment is started.

Case study 2.3E: Integrative agriculture, food and health essay

Unit: Agriculture, Food and Health

University: Western Sydney University

Coordinator/Teacher: Dr Zhong-Hua Chen

Year: Level II (Intermediate)

Unit context: This is a core second year unit in the Bachelor of Sustainable Agriculture and Food Security. This unit emphasises the interaction between food and agriculture, agriculture and the environment, and food and health. It extends students' perspectives for the future of agriculture and its close links with food and health issues.

Description of task: Students write a 2000-word essay on the trend towards an integrated approach to agriculture, food and health. Students provide background on the trend and describe possible advantages and challenges. They must also give international and national examples from government, industry and universities, where an integrated approach has been tried. They are encouraged to include their personal view on this issue in their essay.

Students are provided with a tutorial and a guide to writing essays during Week 6 of the unit. The essay is submitted in Week 12 of the unit.

Educational aims: This assessment task specifically addresses the unit's intended learning outcomes of:

1. exploring the interactions between food and agriculture, agriculture and the environment, and food and health
2. analysing the impacts of food choices on the environment
3. analysing the impacts of food choices on personal health
4. applying conceptual models to the analysis of food supply chains and critically evaluating current and future food supply systems.

Assessment details: The essay contributes 20% of the overall grade. The essay is marked using a rubric that focuses on the ability of students to logically articulate their point of view from the context of the literature and in a logical manner. It specifically assesses content knowledge and integration of knowledge across a number of disciplines specifically contributing towards TLO 2.3.

Other relevant comments or advice: This task can be linked to an international experience for students. Some students have participated in overseas trips to countries such as India, China and Indonesia to experience the importance of linking agriculture with food and health across the world. The students had an amazing experience and they found the contrast between the differing roles of agriculture in Australia and India of interest and subsequently wrote high quality reports after their trip.

Case study 2.3F: Sustainable resource management field analysis

Unit: Sustainable Resource Management

University: University of Tasmania

Coordinator/Teacher: Dr Tina Botwright Acuña

Year: Level I (Introductory)

Unit Context: This is a first year core unit in the Bachelors of Agricultural Science and Agriculture. The unit explores human population growth and the impending global food crisis by introducing agriculture as a managed ecosystem, from the earliest shifting cultivation systems to the most intensive systems currently practised today.

Description of task: Students analyse two of the farms seen on excursions as they relate to the concepts of a managed ecosystem and environmental, social and economic sustainability principles.

Students write a 2000-word report and are expected to address whether the farms are sustainable as presently operating, supporting their opinion using examples from the farm excursions and the literature.

Educational aims: The assessment task specifically addresses the intended unit learning outcome that students will be able to demonstrate knowledge of changes in agricultural practices and systems. Therefore, it specifically contributes to the development of broad, generalist knowledge of relevant agricultural production systems and their value chains (TLO 2.2).

Assessment details: Student reports are worth 25% of the overall grade and are assessed against the following criteria:

1. knowledge of concepts and principles of the farming systems as managed ecosystems, by identifying and using a range of relevant examples from the field sites and by citing credible literature to illustrate the concepts and principles of managed ecosystems
2. analysis and evaluation of information
3. communication, including adherence to the conventions of English expression (structure, punctuation, spelling, grammar), scientific terminology and referencing conventions.

Other relevant comments or advice: Students enjoy the field trips, during which they have an opportunity to speak with the farm manager/owner about sustainability and production. Types of enterprises include an apple and cherry orchard, mixed crop and livestock farm, intensive salad producer and a vineyard. Students select two of these to include in their report.

This unit is taught in first year, first semester, and the report builds on the first assignment of the unit, where students undertake a range of activities that are submitted as a portfolio. Components of the portfolio relevant to the field trip assignment include detailed notes matching examples from one of the field trips to a range of components of a managed ecosystem (e.g. nitrogen, detritus and hydrological cycles, energy and productivity, and biodiversity), an EndNote library of references and a glossary of scientific terms.

Case study 2.3G: Land purchase analysis

Unit: Agribusiness II

University: The University of Adelaide

Coordinator/Teacher: Mr Darren Koopman

Year: Level II (introductory)

Unit Context: This is a second year core unit in the Bachelor of Agricultural Sciences. This unit provides a perspective and an understanding of the key components of Agricultural Business management, with a focus on the management tools used to measure business performance.

Description of task: Students are asked to develop a business plan to secure a loan to purchase land for an agricultural business enterprise. Students select a property currently available for sale, in consultation with the unit coordinator who determines the likely capital base. The students develop an application for finance supported by a detailed business plan explaining how they intend to manage the property.

The application for finance consists of a letter to the manager of the lending institution requesting financial assistance for the proposed business venture. The letter includes the terms and conditions of the loan and makes reference to the business plan developed by the student using their financial analysis/budget for the first seven years after the purchase.

The business plan includes the long-, medium- and short-term goals, with an emphasis on the type of livestock, crops or pastures to be planted, fertiliser regimes, and stock management strategies. The plan includes details of investment needed for the proposal to work, such as new fencing, buildings and the timing of those investments.

Budgets demonstrate the student's ability to meet loan repayments and the ability to cope with unexpected seasonal conditions, such as the effect of a drought that reduced income by 50% in years two and four.

Educational aims: This assessment task contributes towards the unit learning outcomes that state a student should be able to:

1. calculate and record financial aspects of a farm business using a complex spreadsheet
2. demonstrate their understanding of farm financial analysis, including the influence of physical, financial and human resources
3. discuss key principles of production economics theory, and its relevance to management decision making.

The task specifically addresses TLO 2.4.

Assessment details: The case study is worth 60% of the overall grade and is assessed using a rubric that emphasises the accuracy and completeness of budgets/spreadsheets; demonstration of reasoning for decisions in the proposal; and the content and presentation of the proposal in an appropriate, easy-to-read manner.

Other relevant comments or advice: The case study focuses on the business skills developed in the unit at an introductory level. Some of the decisions made may integrate scientific knowledge.

Important elements in the design of this assessment are choosing an appropriate business venture that matches the student's interests; the inclusion of a realistic challenge to productivity such as a drought; and the provision of feedback during the development of the budget spreadsheet. Students are able to submit the draft of their first year business plan for feedback.

Case study 2.3H: Sustainable agricultural systems oral examination

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. The unit develops students' knowledge of agricultural systems in terms of social, economic and environmental sustainability.

Description of task: Students are examined on all topics that have been taught in the unit using an oral examination. The exam is similar in format to an interview and students are advised to treat the exam as an interview.

Students are given a preparation sheet which encourages them to address their answers across the triple bottom line (economic, environment and social) and to think about the implications from many perspectives – from a farming to an international perspective.

Educational aims: Students will demonstrate an ability to integrate concepts thereby demonstrating their broad generalist knowledge of relevant agricultural production systems and basic knowledge of economics, business and social science as they apply to agriculture.

Assessment details: The assessment is worth 30% of the final grade. Students are given 20 minutes preparation time before the exam, and are expected to answer four questions – two short answer and two longer answer. The exam runs for 15 minutes.

Marking criteria for the oral examination are based on the clarity, quality and insightful nature of answers given. To obtain good marks, students are expected to answer beyond the simple repetition of information given in class and to give examples within their answer.

Other relevant comments or advice: The oral examination is conducted by two members of staff who mark each student independently. It is suggested to allow five minutes between exams for discussion, and to timetable no more than five exams between longer breaks.

Students are given their first question on an area they have worked on in some depth during the semester to ensure they are calm (to manage nervousness) in the exam.

All questions are given to at least two students to ensure that the distribution of questions is equitable. However, no two students are given all the same questions. The four questions are on four different topics for all students.

Case study 2.3I: Group pasture production systems scenario

Unit: Crop and Pasture Production II

University: The University of Adelaide

Coordinator/Teacher: Dr Matthew Denton

Year: Level II (Intermediate)

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

Description of task: Students work in groups of three and consider options for providing a pasture system in a target climate in southern Australia, accounting for factors such as soil types, drainage and rainfall.

Group members adopt the roles of typical decision-makers, such as a farmer, private agronomist or a natural resource manager. The group shares a recorded short 10 minute oral presentation that defines the pasture types for their area and most importantly why these have been selected.

Each student is assigned three videos to watch and then prepare a test question. The best two questions, as chosen by the teacher, are then used in a short in-class closed book test.

Educational aims: This assessment task is designed to provide students with:

1. an appreciation of the steps involved in selection of a pasture type and management system in southern Australia
2. an ability to integrate their understanding and knowledge of pasture adaptation and management in the development of an appropriate pasture system.

Assessment details: The scenario is worth 10% of the overall grade. The video (worth 5%) is assessed for the group, using a rubric that focuses on their justification of their pasture type, descriptions of the grazing system and environmental services, and oral presentation skills.

Students are graded on their questions as individuals (worth 2.5%) based on their ability to encourage higher order thinking skills in the development of their questions. Individuals are graded on their answer of the two best questions in a traditional style of test of 30 minutes (worth 2.5%) during in-class time.

Other relevant comments or advice: Limited information is provided in each scenario to ensure some knowledge gaps. Students are given class time to talk through the options and seek out new information. They are also provided with a list of questions to help them with the process. For example: How will you manage the pasture in terms of grazing? How will you manage weeds and fertilisers optimally in your pasture?

Each group is given the details of an industry expert who has agreed to answer questions. To manage this relationship, it is essential to give the students guidelines; students may remain shy about contacting the expert.

Originally, this exercise involved an in-class oral presentation followed by audience questions. This is difficult with larger class sizes and students often do not engage in asking questions. The group video and individual questioning exercises has improved student engagement. Students are often creative with the group video. Improved exam results over time would suggest the learning outcomes for this exercise have been successfully attained.

Case study 2.3J: Agricultural development concept note and research proposal

Unit: Agroecosystems in Developing Countries

University: The University of Sydney

Coordinator/Teacher: Dr Damien Field

Year: Level III (Intermediate)

Unit Context: This unit is a third year elective in the Bachelor of Science in Agriculture. This unit provides students with direct contact with agricultural professionals in a developing country and focuses on themes related to constraints of agricultural development, such as technology adoption, sustainable use of resources, access to credit, and land use change. Learning is achieved via a short series of introductory on-campus seminars, a field trip to a developing country (usually Laos) and group work once back to campus.

Description of Task: Students write a concept note in preparation for their research proposal during the field trip. This includes details of the topic, how it will be developed and a brief analysis of what stimulated their choice, such as field work activities, conversations, observations and experiences. The concept note includes the implications, an evaluation and outcomes of the proposed project. Staff provide verbal feedback to the students.

Students then develop a research proposal, providing the background and justification, research strategy, partnerships, project benefits and references. Evidence is collected during the field trip to Laos. The research proposal follows the format of an Australian Centre for International Agricultural Research (ACIAR) project.

Educational Aims: Students should be able to:

1. present a clear and coherent exposition of knowledge, ideas and empirical evidence both orally and in writing
2. frame research problems in developing countries using appropriate scientific and socio-economic concepts and principles.

Assessment Details: The concept note is 1500 words (20%), while the research proposal is 3000 to 3500 words (40%).

Other relevant comments or advice: Initially students write a long essay on their experience in Laos. Use of an established project proposal format such as the Australian Centre for International Agricultural Research, has focused the task for the students and aligns with TLOs 2.2, 2.3 and 2.4 that require students to integrate their knowledge across agriculture. Students demonstrate their knowledge of relevant agricultural production systems and of the economics and social disciplines and their application to agricultural development. This task also aligns with TLO 1.3.

Some post- and pre-lecture time and group activities during the field trip introduce students to sourcing information in the field and across the broad scientific, economic and social disciplines. This includes a discussion on possible approaches supported by information and examples that are classified into five relevant in-country themes. Specific tasks or questions are also assigned to students during their field trip. Staff report on their experiences and interpretations related to these tasks to broaden the discussion.

These incremental experiences are essential to support the students and build confidence in discerning relevant information. Working with in-country colleagues and student partnerships with the National University of Laos helps with language skills and giving a Laotian national's perspective on the issues students are confronted with for discussion. Enrolment in the unit is competitive. Student feedback is very positive and highlights the benefits of experiencing development issues first hand as well as the challenges they have overcome.


Learning tasks that closely
resemble those found in
the workplace ensure
students are better prepared
for the workplace and are
more employable.

Threshold Learning Outcome 3: Inquiry and problem-solving

Susan Gai Low and Sarita Jane Bennett

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).

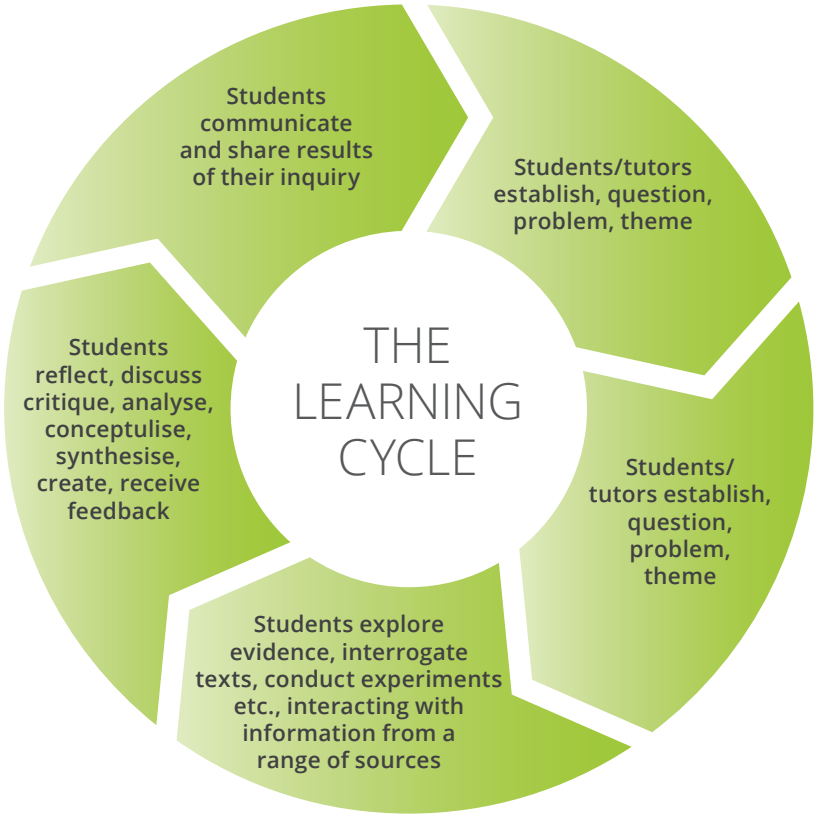


Figure 3.1 The learning cycle (Queens University, 2016)

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=Pou61mRWzIE

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.

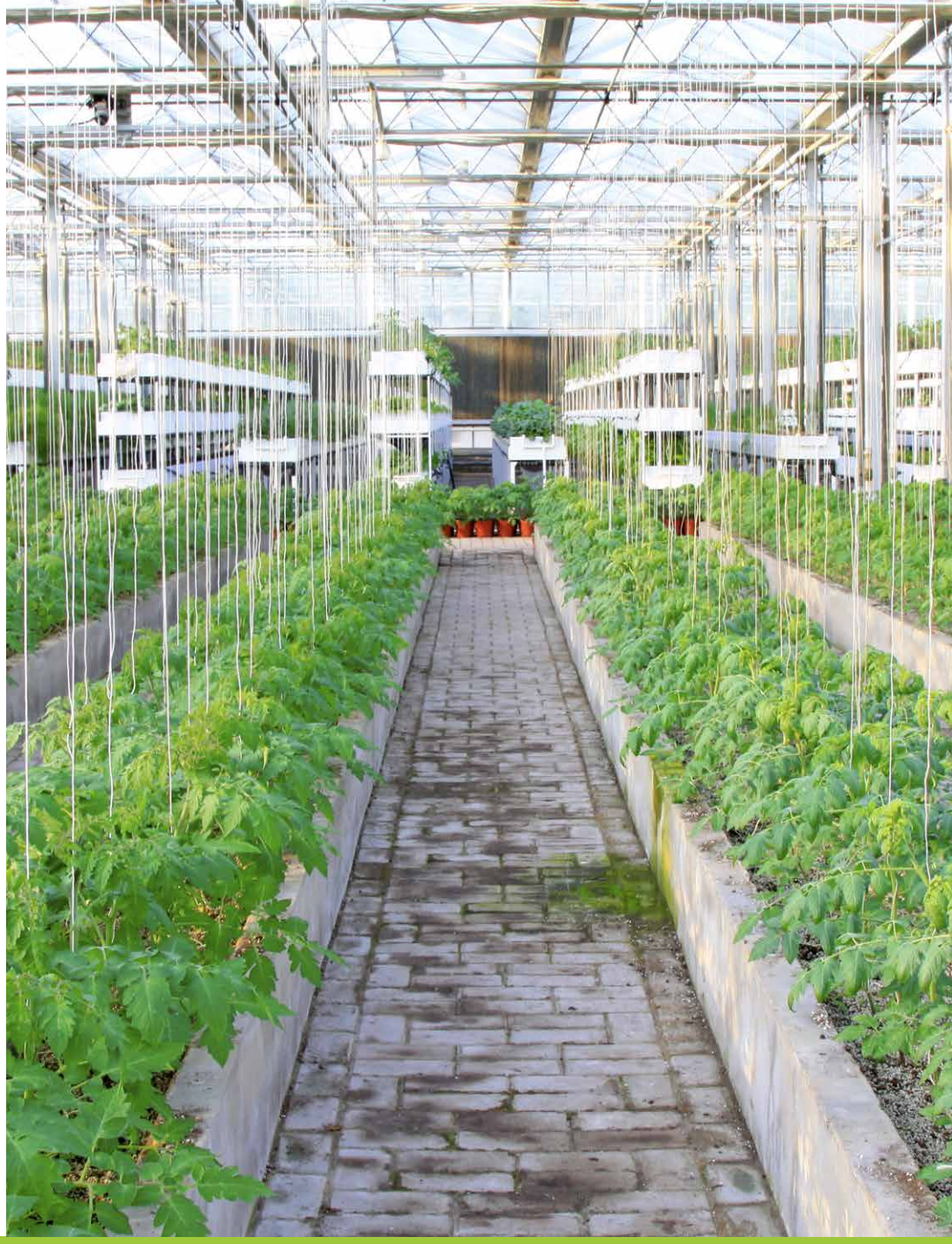
Group oral presentations (10%): are presented in the final week of the semester (week 12). The group oral presentations are 7–8 minutes long with each group member contributing to the presentation. The PowerPoint files are also submitted via the Learning Management System. Mentors guide students in the 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.

Threshold Learning Outcome 4: Communication

Joanna Jones, Marisa J. Collins, Beth R. Loveys and Karina M. Riggs

Communication skills are undeniably important for graduates with a degree in agriculture or a related discipline. Graduates must have the capacity and skills to present a wide variety of content that is contextualised to the audience with whom they are communicating. The communication skills essential in professional practice include basic oral and writing skills, the ability to work in groups or teams with people from a range of backgrounds, and a facility in problem-solving and conflict management (Morreale et al. 2000). These skills must also be sufficiently developed so graduates are proficient in communicating with both scientific and non-scientific audiences in their careers. Developing students' ability to be effective communicators is as important as developing content knowledge (as described in TLO 2) in discipline fields of agriculture (Robinson & Garton 2008).

Being an effective communicator of science and agriculture is multi-dimensional (Mate et al. 2014). When communicating, one must consider multiple aspects including the intended audience, the content to be communicated, the purpose of the communication and the mode of delivery (visual, written or oral). Students also benefit from developing good listening and response practices for effective dialogues with different audiences (Kirkup & Bonfiglioli 2011).

In TLO 4.1 the development of skills to enable dialogue facilitates a two-way process of imparting, questioning and receiving information, which is a TLO specific to agriculture and related disciplines. For a graduate to be an effective communicator they must appreciate the complexity of communication, and develop an awareness of different types of communication strategies and of how to apply them. For example, communication can be used either appropriately or inappropriately, to inform, persuade or mislead.

Graduates must possess the ability to consider how effectively communication genres achieve the specific aims of any given interaction (Mate et al. 2014). Therefore, the learning activities and related assessment tasks that relate to TLO 4 which students complete during their degree must be designed accordingly (Colthorpe et al. 2013). During their degree, scaffolding and feedback against the learning tasks associated with TLO 4 will likely improve learning outcomes for students (Carless et al. 2011). For a student to develop adequate competency in communication, they need opportunities to develop the skills and to practise them throughout their degree.

Threshold Learning Outcome 4 for Agriculture: Communication states that, upon completion of a bachelor degree in an agricultural-related area, graduates will be effective communicators by:

4.1 Understanding methods of effective two-way written and verbal communication with different audiences.

4.2 Communicating with a range of audiences in an agricultural context using a variety of modes.

(Botwright Acuña et al. 2014a)

The agricultural discipline has its basis in the sciences, as described in TLO 2. Effective oral communication of science encompasses the ability to assess and evaluate the needs and priorities of the target audience and the development of empathetic skills to engage listeners, without compromising scientific integrity or accuracy (Bray et al. 2012). Despite the fundamental importance of communication to student success and attainment of learning outcomes, many degrees do not explicitly teach communication skills; instead, the skills are implicit within the assessment design.

Dannels (2001) reported on assessment practices that evaluate the extent to which students actually achieve the valued communication outcomes relevant to their disciplines and identified that these outcomes were underdeveloped. Communication is a central aspect of transferable learning and this process should preferably take place in an authentic or real-life setting, which represents tasks or activities that students will encounter as working professionals (Chan 2011). Many of the examples of assessment relevant to TLO 4 *Communication*, at the end of this chapter, meet this criterion.

To meet the diverse needs of students in acquiring these skills and to make those skills explicit, academics and curriculum designers should give specific consideration to each of the elements of communication addressed by TLO 4. The authors hope to clarify the skills needed by graduates to meet each of those elements, and to aid curriculum designers and academics in this task.

‘Be effective communicators’

Effective communication includes the ability to adapt, be responsive and manage self-awareness during the process of talking and listening (Schirmer et al. 2005). Effective communication in one setting may be ineffective in another. The variation in settings and subtleties of effective communication which occurs in the agricultural context means it is difficult to apply a standard evaluation tool.

Just as the genres, purposes and forms of communication vary among different disciplines, so too do notions about what makes an effective communicator. This is particularly relevant for agriculture graduates who will move into a broad range of sub-disciplines including, for example, agribusiness, social and rural sciences, animal sciences, agronomy, horticulture and plant sciences.

Although embracing and teaching what we know are good standards of communication in agricultural education is important, we also must consider that these standards take on a different sub-disciplinary flavour, depth and theoretical sophistication when our students move from introductory to advanced-level units during their degree (Dannels 2001). Agriculture graduates need to possess skills that enable them to actively engage with different audiences, and to understand the importance of the two-way process of developing dialogue whilst presenting data and information in a range of formats and modes. We explore these concepts further in the context of each sub-TLO 4 below.


Communication skills are undeniably
important for graduates with a degree
in agriculture or a related discipline.

TLO 4.1: Understanding methods of communication

Communication is a diverse and transdisciplinary field and is learnt by agriculture students most effectively when the skills being taught are tailored to an agricultural context. Ideally, the development of communication skills throughout degrees enables students to explore public issues with diverse audiences and purposes, to appreciate the diversity of values and communication skills of others, and to gain an understanding of the importance of communication in their civic and professional development (Dannels 2001). Effective communicators must also deal with the added complexities involved in sensitive issues (Abrams et al. 2015), which is explored further in TLO 5.

World views can be defined as "a set of values that determine how people see and experience life" and are especially important for science communication which should reconcile diverse values to arrive at a shared understanding and common goal (Dietz 2013). This appreciation for others' differing opinions whilst engaging in scientific argument can present a challenge for students.

Communication of scientific argument to a range of audiences: Fundamental to effective communication in a science setting is the need to explicitly recognise and understand the nature of scientific argument, and be able to present a message underpinned by evidence. The information or argument presented must be based on and supported by credible evidence, balanced and comprehensive, objective, logical, and open to challenge and verification (Abi-El-Mona & Abd-El-Khalick 2011).

An "agricultural" argument should also be grounded by context, whether it be a farming system, farm business, regional approach or national strategy (TLO 1). In the past, the emphasis of communication in science disciplines including agriculture revolved around transmission or deficit models of communication — a top-down transferral of facts from scientific to non-scientific audiences (Van Der Sanden & Meijman 2008). This now outdated model assumed that making information available led to improved understanding and a general interest of the public in science (Besley & Tanner 2011).

In order to facilitate effective public engagement, communication should harmonise with audience's existing values, knowledge and attitudes, interpersonal and social contexts, preferred media sources and communication channels (Sakellari 2015). For many sub-disciplines within agriculture this is particularly important as they encompass issues that may be viewed as controversial, in terms of land management, production strategies and overarching issues such as climate change (as discussed in the chapter for TLO 1). The ability of agricultural graduates to effectively communicate sensitive issues is underpinned by their ability to accurately record, refine and interpret data, which is covered in TLO 3.4. The graduates will understand that, while diverse audiences will interpret the data differently, the raw data themselves are inviolate.

Communication as a professional: Recent studies have found that in science degrees analytical, technical and problem-solving skills and science content are being taught successfully but communication skills (oral, interpersonal and written) are consistently falling short of employer requirements (McInnis et al. 2000). Similarly, research shows employers across Australia and New Zealand have found undergraduate skills in communication are poorly developed and do not reflect workplace requirements (Gray et al. 2005; McInnis et al. 2000).

Methods of communication and the importance of different communication skills in a professional workplace change significantly depending on the sub-discipline of agriculture and the audience. For example, the nature of a presentation of information to a scientific audience (generally researchers) differs significantly from a presentation to a non-scientific audience (often farmers and the public). The development of an interactive dialogue is essential in many areas of agribusiness, policy and social sciences. When done well, the engagement or interaction between scientific and non-scientific audiences is pivotal in facilitating public engagement with the information being presented rather than just a superficial public understanding (Besley & Tanner 2011).

Many professional agricultural workplaces require highly developed dialogue skills to enable meaningful two-way interactions between the audience or client and the graduate. A recent study of communication skills integrated into undergraduate degrees across a range of disciplines defined a set of core skills that were 'key' to developing proficiency in graduates' communication skills, particularly to non-scientific audiences (Mercer-Mapstone & Kuchel 2015a). Identification of and understanding the audience and the use of language appropriate for the target audience were the two highest ranked skills fundamental to the development of student communication skills with non-science audiences.

Other highly-rated skills included the identification of the purpose and intended outcome of the communication, prior audience knowledge, content and mode. The importance of identifying and understanding the target audience has also been highlighted in other studies, with Bray et al. (2012) finding that "the audience comes first in any interaction and this focus is non-negotiable". Interestingly, the study by Mercer-Mapstone and Kuchel (2015a) did find that engagement and dialogue were not highly ranked skills in science graduates.

Assessing communication skills: The emphasis and subsequent development of communication skills is often inextricably linked to the design of the assessment tasks. For example, tasks aimed at non-scientific audiences are often taught and assessed more explicitly than those for scientific audiences (Mercer-Mapstone & Kuchel 2015b). In addition, multi-media and group tasks are often also taught more explicitly than individual, written and oral tasks. Strong links between learning outcomes and assessment practices need to be clarified to students. Articulating explicit learning outcomes and aligning teaching activities and assessment tasks facilitates students' abilities to achieve outcomes (Biggs & Tang 2007).

Oral communication: Competence in speaking and listening is considered to be a prerequisite to students' academic, personal and professional success (Morreale et al. 2000). Oral communication is a competency directly connected with disciplinary content, identity and epistemology (Dannels et al. 2011). Students with well-developed oral communication practices also benefit from having a better grasp on the content of the unit and from effective participation in small group discussions where disciplinary content and knowledge is negotiated (refer to Case studies 4A, 4C, 4F, 4K) (Winsor 1999).

The ability to successfully convey sometimes complex problems to a diverse audience requires a significant depth of understanding and knowledge (as briefly discussed in the chapters on TLO 1, TLO 2 and TLO 3). We often do not arrive at a full understanding of a problem ourselves until we are challenged to explain an issue to a peer, colleague or stakeholder. This ability to self-reflect is also critical to the communication process for agricultural graduates.

Delivery of oral presentations: Students need to learn about oral presentations in the same way they need to learn about subject matter (Joughin 2007). This requires teacher awareness to understand students' preconceptions about oral presentations and how they might effect change in conceptual understanding and knowledge of the audience. Involving students in the task of assessment of their peers (Case study 4F) encourages students to foster skills in professional judgement (Magin & Helmore 2001). Further, a study by De Grez et al. (2009) showed that significant improvement in delivery of oral presentations was made regardless of whether feedback was from peers or experts. Therefore, providing students with the opportunity to give and receive feedback from their peers and reflect on the feedback to improve their delivery is of great importance. A secondary benefit of peer feedback is that it reduces the marking load for large classes.

Communicating in context: In addition to the typical "oral presentation" assignment, many disciplines are now recognising and calling for instruction in the oral genres of interpersonal interaction, small-group decision-making, teamwork, negotiation and interviewing skills. These genres, in addition to public speaking, are an opportunity for students to learn what it means to be part of a particular discipline (Dannels 2001). A situated communication pedagogy considers the complex relationship between oral communication genres and disciplinary content knowledge.

Integration into multiple units across a degree can also allow for a range of opportunities for students to practise and develop skills over time which has been shown to be key in achieving complex learning outcomes such as communication (Divan & Mason 2015; Knight 2001; Lauer & Hendrix 2009). This 'integration' approach, however, can lead to the under-emphasis of communication skills as learning outcomes when they are 'in competition' with the requirements for students to demonstrate understanding (TLO 1), knowledge (TLO 2), or analytical (TLO 3) skills. The mechanisms by which these skills are learnt are not only shaped by the approach to teaching but also by how the skills are assessed, which can have a significant effect on whether students adopt a deep or a superficial approach to learning (Healey 2000; Prosser & Trigwell 1999).

TLO 4.2: A range of audiences and a variety of modes

An individual who is competent in communication with an agricultural audience can recognise the pre-existing understanding, knowledge and skills of the target audience and select the appropriate mode of delivery to make the topic accessible to the audience. Features of the audience will vary, depending on whether it is a professional workplace, the broader scientific community, the general public, an agriculture-specific audience or primary producers in rural communities.

Types of communication: More traditional forms of agricultural communication such as the research proposal (Stanford & Duwel 2013; Wiegant et al. 2011); review article (DebBurman 2002); laboratory reports and conference presentations allow ease of recognition of scientific argument. Scientific writing is best learnt in the context of authentic scientific inquiry, which aligns with the ability to conduct an investigation in TLO 3 and students taking responsibility for their own learning as discussed in TLO 5 (Jerde & Taper 2004; Moskovitz & Kellogg 2011).

Students benefit most from inquiry-based writing placed within a realistic scientific scenario, using relevant forms of communication (Mate et al. 2014). For newer forms of communication such as wikis, infographics and podcasts, the presentation styles may be more diverse (Baram-Tsabari & Lewenstein 2013) and the scientific argument subtler.

Case study 4B provides a novel approach to teach creative writing and presentation of information, while Case study 4H shows how students can gain experience using multimedia skills. Case study 4G shows a unique way to enable student understanding of different target audiences and how they might modify their writing styles accordingly to convey the same message.

Communicating with a scientific audience: When communicating with a scientific audience with similar skills and expertise, the use of formal modes of communication such as peer-reviewed research papers, literature reviews, conference and oral presentations is common. Assessment of skills in this formal style of communication tends to be well-developed in agricultural degrees in the form of laboratory reports, oral presentations and written documents such as critiques of scientific studies. Accepted styles, formats, language and nomenclature in the discipline guide students during the development of their skills. As mentioned previously, many of these skills are implicitly assessed, which can affect the student's perception that they have learnt these skills.

The development of these generic communication skills is likely a consequence of most lecturers at universities being researchers; the inclusion of particular communication skills in a degree coincides with how researchers communicate to their professional peers (Dietz 2013). Most lecturers are not trained in a diverse range of communication skills outside of those acquired professionally, which makes designing successful assessments and teaching a range of communication skills to students potentially problematic. Explicit instruction that is applied to complex multi-step or scaffolded skill development where the purpose of learning and learning outcomes is made visible to students may help with the development of these skills in both students and teachers (Archer & Hughes 2011).

Communicating with non-scientific audiences: Communication with non-scientific audiences such as the general public requires the development of an additional set of skills. This audience includes a diverse cross-section of the community, with highly variable educational backgrounds and understandings of agriculture. Communication with the general public, therefore, generally focuses on the impact of the science and its relevance. Graduates may need to communicate controversial or sensitive issues; the skills required to present a balanced argument are paramount.

The importance of two-way communication and skills to develop dialogue in TLO 4.1 are particularly relevant in these circumstances. Effective communication with the general public might involve cross disciplinary collaboration, where agriculture graduates work with non-science colleagues. Forms of communication with the general public may include working with traditional media or newer social and electronic media.

Use of contemporary media in communication: Modes of communication considered to relate to popular culture can be effective as they allow the message to reach a broad range of people of varied backgrounds (Tatalovic 2009). For example, fiction and non-fiction comics can be effectively used in enhancing learning about science, and have been suggested as an interesting teaching aid to introduce potentially dull issues in a visually entertaining way (Tatalovic 2009). The Climate Dog animation series uses humorous animations of sheep dogs to explain complex atmospheric phenomena to farmers. The series has been developed in collaboration with the Australian Bureau of Meteorology

and Victorian Department of Primary Industries. Enabling students with skills in the development of these modern approaches to communicating with the general public could be explored. Case study 4B provides an effective example of assessing these skills.

Communication can be enriched by the use of technology and multimedia. Options such as short videos, podcasts, blogs and wikis are of increasing professional relevance for graduates, providing avenues to engage with the community through ongoing dialogue (Mate et al. 2014). Examples are provided in the resources section from the Grains Research and Development Corporation, which employs a range of approaches to communicate science to their stakeholders including farmers, consultants, researchers and the general public.

Technologies including e-newsletters, podcasts, videos and factsheets are increasingly used in tertiary science education to enhance writing, communication, collaboration and research skills in students (Hamstra et al. 2011; Kirkup & Bonfiglioli 2011; Placing et al. 2005). Case studies 4E and 4I exemplify tasks that require students to translate technical information designed for a skilled audience into a message suited to a non-scientific audience.

Extension and adoption in agriculture: Communicating with farmers, primary producers and members of rural communities is unique to the discipline of agriculture. Farmers can be appropriately considered to be an audience different from the general public and the scientific community. Agriculture graduates must be able to communicate with farmers to assist in knowledge development, problem-solving, and prioritising research and development strategies.

The suite of skills and techniques for effective communication with this target audience is generally taught through the sub-discipline of extension and adoption. Van Crowder et al. (1998) state that excellent communication skills are vitally important for agricultural graduates. Too little attention is paid to providing learning to prepare students who will ultimately be agricultural extension workers with the effective communication and facilitation skills for working with diverse rural groups.

In revising curricula for extension training, the shift in thinking and in practice from expert-driven, technology-transfer extension approaches to collaborative learning approaches with participant groups is necessary (Van Crowder et al. 1998). This meets a need for graduates to possess sufficiently well-developed communication skills to fill the gaps in extension due to the current removal of extension officers from most state government departments. Case study 4D provides an example of how to assess a student's ability to package information for farmers. Case study 4E challenges students to adapt a scientific paper to suit a non-scientific audience in the form of a newsletter to growers while maintaining the integrity of the message. Case study 4J assesses students' ability to write a consultancy report appropriate for a grower.

Conclusion

Improving the employment opportunities for graduates requires curricula focused less on specific technical knowledge in agriculture and more on processes and the abilities of students to think and solve problems that are relevant to societal needs. Students should learn skills and develop abilities that are transferable to a wide range of agricultural careers and settings. The discussion within TLO 4.1 furthers this argument to illustrate that graduates need to understand why they must be capable of communicating core concepts in a variety of modes to a diverse range of audiences.

The growing effort to assess competency in communication is an opportunity for the agriculture discipline to fine-tune the definitions, requirements and expectations of communication both for graduates and employers. This will allow benchmarking across the Australian Higher Education sector and give employers increased confidence that agricultural science graduates will possess the necessary skills in the critically important area of communication.

The challenge exists for teachers to develop interesting and challenging curricula to allow students to be introduced to the TLO 4 Communication early in their study, and then to ensure progressive learning and skill development through to advanced year levels. The case studies in this chapter highlight the imbalance in the diversity of tasks with the more diverse in the advanced years. It appears that agricultural educators can improve the scaffolding of teaching communication in the introductory years of the degree and design assessment tasks accordingly. We hope the review of assessment tasks will promote practical, effective solutions and stimulate further discussion about the TLOs related to communication.

Resources for TLO 4

An annotated list of print, video and websites associated with TLO 4 *Communication* is provided in the following sections. Brief details on how each may be used in teaching are provided.

Books

Cargill, M & Belotti M (2004). Written communication in the agricultural and natural resource sciences, The University of Adelaide.

This booklet is a guide for students on how to write different types of assignments including practical reports, essays, critical reviews and literature reviews. It also provides information on how to reference correctly and develop informative figures legends and table titles. The booklet was co-created by staff and students at Adelaide University as an outcome of a Teaching and Development Grant.

Ramachandran Nair, PK & Vimala D Nair (2014) scientific writing and communication in agriculture and natural resources ISBN: 978-3-319-03100-2 (Print) 978-3-319-03101-9 (Online).

This e-book is a useful detailed guide to many of the common forms of communication in sciences with a particular focus on the agricultural sciences. It covers writing books and manuscripts and also oral and poster presentations.

BenYishay, A & Mobarak, AM (2013) Communicating with farmers through social networks. Department of Economics, Yale University, Economic Growth Centre Discussion Paper No. 1030, Economics Department Working Paper No. 121.

This publication gives a unique perspective of the challenges of communication between agricultural extension workers and farmers across 168 villages in Malawi. The paper examines how adoption of new technology and practice can be influenced by communication. This paper can be downloaded without charge from the Social Science Research Network Electronic Paper Collection: http://ssrn.com/abstract=2315229.

Telg, R & Irani, T (2001) Agricultural Communications in Action: A Hands-on Approach. Delmar Cengage Learning.

This book has many examples from real life situations that outline ways to deal with communication issues and problems in agriculture. It covers communication using social media and other online platforms and also web design and video production. Traditional forms of communication such as manuscript preparation and public speaking are also addressed.

Boone, K, Meisenbach, T & Tucker, M (2000) Agricultural communications: Changes and challenges, Wiley-Blackwell. ISBN: 978-0-8138-2167-2.

This text book examines how communication in the field of agriculture has changed over time and the impact of information technology on our communication in the modern world. Many hands-on examples are provided from professionals in agriculture.

Jennings, J, Packham, R & Woodside, D (2011) Shaping change: Natural resource management, agriculture and the role of extension. Australasia Pacific Extension Network. ISBN: 978-0-9577030-7-0.

This publication is a collection of papers relevant for students, teachers, natural resource managers, recent graduates or newly appointed employees. It provides a core body of contemporary knowledge and aims to bring together the diverse range of extension literature.

Journals

Agricultural Communications

http://www.agricommun.com/portal/home

The journal of Agricultural Communications publishes peer-reviewed original research, critical reviews, case study, short papers, book reviews and white papers on various aspects of agricultural sciences and applied biology with particular emphasis on interdisciplinary studies that explore intersections of agriculture in the areas of agricultural machinery, agronomy, animal science, biotechnology, cytogenetic, dairy

science, food science and technology, forestry, horticulture, irrigation, plant breeding, plant microbiology, plant nutrition, plant pathology, poultry, and soil sciences.

Journal of Agricultural Education

http://www.jae-online.org/

The Journal of Agricultural Education (JAE) is a publication of the American Association for Agricultural Education (AAAE). The journal's aim is to promote the profession of agricultural education by facilitating and expediting communication among members of the profession to the end that results of research, trends, developments, and innovations in agricultural education are widely shared. The journal possesses a broad view of agricultural education that includes extension education, communications, leadership development, teacher education and related areas that support the agricultural sciences. The journal publishes studies from a variety of country of origins.

Journal of Agricultural Education and Extension

http://www.tandfonline.com/toc/raee20/current

The Journal of Agricultural Education and Extension informs experts who conduct or use research on agricultural education and extension about research conducted in this field worldwide. Information about this research is needed to improve policies, strategies, methods and practices for agricultural education and extension.

Websites

AgCommunicators

http://agcommunicators.com.au

AgCommunicators are a team of strategic and creative communication and education specialists that help clients connect with their target audience in primary production, science and natural resources by providing services in; professional writing and editing, media liaison, communication campaigns, digital and social media management for industry such as SAGIT, Livestock SA, The Rust Bust, LambEx and Grain Producers SA.

Creating Infograms

https://infogr.am/

This website is useful for students when learning how to create Infograms.

Climate Dogs

https://www.youtube.com/watch?v=xk9LkrTEpBc

The NSW Climate Dog animation series uses humorous animations of sheep dogs to explain complex atmospheric phenomena to farmers. The series has been developed in collaboration with the Australian Bureau of Meteorology and Victorian Department of Primary Industries. Available on YouTube, it is a very popular way to effectively communicate complex meteorological science.

Grains Research and Development Corporation (GRDC)

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

In the area of grain production, the GRDC effectively use e-newsletters, podcasts, videos, factsheets, workshops and a highly interactive website to present current research to farmers in a range of different formats. The information is presented in a sufficiently broad range of modes to enable effective communication of key ideas. In addition, GRDC personalise and make relevant the application of this research by including farmers talking about the application of these ideas on-farm.

Podcasts

ABC Rural Radio Podcasts

http://www.abc.net.au/services/podcasting/programs.htm#rural

ABC Rural Radio programs are all available on podcast.

GRDC Driving Agronomy Podcasts

http://www.grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts

Driving Agronomy podcasts are released weekly and discuss various agronomic issues to assist and inform those in the Australian grain industry.

Precision Agriculture Podcasts

http://www.precisionagriculture.com.au/news-and-articles.php

Precision Ag Podcasts share Australian and Global technical information related to precision agriculture.

Blogs

The Farm Table, Connecting Australian Agriculture

http://www.thefarmtable.com.au/farm-blogs/

This website provides information on the different purposes of blogs, some tips on how to write them, and also some good examples of Australian agricultural blogs.

Mandy Gyles and Co

http://www.mandygylesandco.com.au/new-blog/

Mandy Gyles and Co is a Canberra-based multi-disciplinary company providing specialist communication services in agriculture, research, community and international development. This company regularly post blogs relevant to agriculture.

Modes of communication considered to relate to popular culture can be effective as they allow the message to reach a broad range of people of varied backgrounds.

Case study 4A: Attending an agronomy conference

University: University of Tasmania

Unit: Agronomy

Coordinator/Teacher: Dr Tina Botwright Acuña

Year: Level III (Advanced)

Unit context: This is a core unit in the Bachelor of Agricultural Science and an elective in the Bachelor of Agriculture. This unit examines the current status of crop and pasture research, including physiology, production and management. Farming systems research is also examined through topics such as climate change, tillage systems, crop rotations, modelling, precision farming, integrated weed management, pasture composition and management, intensive pasture management and recent developments in grazing systems.

Description of assessment task: The major practical component is conducted on a project basis, with students working in groups of three with an industry partner on a small research project relating to crop and pasture agronomy.

A list of potential projects, provided by industry and research partners from the Tasmanian Institute of Agriculture, Serve-Ag, Impact Fertilisers, Botanical Resources Australia and Tas Alkaloids, is provided to students. The projects include a range of topics that address real-world issues in crop and pasture agronomy and are either conducted in the glasshouse in pots or in the field. Students are supervised by one of the unit lecturers and the industry/research partner.

Students also have the option of developing their own research project in consultation with teaching staff. Students are expected to show a high degree of commitment and responsibility when working with the industry partner and supervisors in planning and undertaking their projects.

Educational aims: This project aims to provide the student with:

1. knowledge of key concepts and current issues in crop and pasture agronomy and plant breeding in Australian farming systems
2. the ability to analyse, evaluate and justify emerging issues in crop and pasture agronomy in Australian farming systems
3. skills in designing, analysing data and conducting a research project
4. well-developed written and oral communication skills, both individually and in groups (TLO 4.1).

Assessment details: Students present a 12-minute seminar (10% of final grade) on their project to students, teaching staff and industry. The seminar is assessed on the group's knowledge of concepts and current issues related to the research question; analysis, evaluation and interpretation of results, including use of appropriate statistics, and oral communication.

Reports are written using the Australian Society of Agronomy (ASA) Conference Proceedings template. Sub-headings include title, address, abstract, key words, introduction, methods, results, conclusions and references. Text, table and figure formats, including font size, fonts, line spacing are provided in the template and are expected to be adhered to. This task is 15% of the final grade. Assessment criteria are similar to those of the seminar, but are extended to include written communication and adhering to the format of the ASA proceedings.

Other relevant comments or advice: In 2015 the Australian Society of Agronomy conference was held in Hobart when the Agronomy unit was scheduled for delivery. An assessment task was included on critiquing a paper and the associated presentation at the conference. Completion of this task assisted students in preparing their final report and seminar of their research project. The conference provided students with excellent exposure to current research in agronomy plus the opportunity to expand their professional networks with local, national and international conference delegates.

Case study 4B: Communicating microbiology through ‘selfies’

University: University of Tasmania

Unit: Microbes and Man

Coordinator/Teacher: Dr Lyndal Mellefont

Year: Level II (Intermediate)

Unit in context: This is an introductory unit in the Bachelors of Agricultural Science and Agriculture. This unit draws on contemporary and real-world examples to examine the influence and impact of microorganisms on human activities. Students demonstrate their understanding of these interactions by developing communication skills using a variety of media.

In this unit the emphasis is on encouraging students to become critical thinkers and effective communicators about science to a wider audience, i.e. not always scientists, through a variety of novel assessment tasks utilising different forms of media. Students receive training and mentoring in science communication from a lecturer who holds a Master of Science Communication Outreach degree. Thus they are supported in learning the expected standards for the integrity of science and its communication.

Description of assessment task: Students have to research relevant information and present it in a designated slide presentation template. The task aims for students to appreciate the diversity of effective forms of science communication and to gain experience in communicating scientific ideas succinctly.

A digital image and accompanying text is used to convey information to classmates about aspects of microbiology that are not necessarily apparent to the untrained eye. The task builds on the excursion, tutorial and lecture content about how microorganisms affect our day-to-day activities to our benefit and detriment. Students are required to photograph themselves (i.e. a self-portrait, aka ‘selfie’) in an environment that involves five distinctly different aspect(s) of microbiology.

Their ‘selfie’ must be inserted into a PowerPoint slide template with an image size restriction. In addition, font style and size restrictions apply to the text used to describe the influence and impact of the microorganisms or microbiology present in the image. The ‘selfie’ is 4% of the overall grade.

Educational aim: This task requires that students communicate their understanding of microbiology using a range of media (TLO4.2).

Assessment details: Marks are awarded primarily for the integrity of the description of the distinctly different aspects of microbiology and accuracy of relevant information (75%), with the remainder allocated for the ease of identification of the student and the formatting of the ‘selfie’. A signed Personal Consent form is essential as ‘selfies’ are viewed by the class and may be publically displayed.

Other relevant comments or advice: This assessment task provides a welcome outlet for students to display their creativity and personality, with some extremely humorous and engaging ‘selfies’ presented, while at the same time requiring the presentation of accurate scientific information.

A wall of class ‘selfies’ (A4) creates a dynamic and eye-catching display to showcase your students’ efforts. It was particularly rewarding to see non-microbiology staff and students reading the ‘selfies’ corridor displays.

Case study 4C: Communicating meteorological data for production decision-making

University: University of New England

Unit: Sustaining our Rural Environment

Coordinator/Teacher: Dr Janelle Wilkes

Year: Level I (Introductory)

Unit in context: This is a unit in the Bachelors of Agriculture, Agriculture/Business, Agribusiness, Agrifood Systems, Agricultural Economics, and Rural Science, respectively. This unit takes a holistic approach towards how to monitor and manage economic, soil, plant, water and animal systems.

Description of assessment task: The assessment builds the students' written and verbal communication skills and is broken into three parts including: an individual data analysis and graphing project, poster and interview.

On-campus students attend three 2-hour tutorials on how to summarise, graph and perform basic statistical analysis in Microsoft Excel. Detailed videos for distance students have been developed that include instructions on how to produce graphs and scientific expectations.

A poster and interview are presented under timed conditions in class. Students are given data such as daily rainfall from the Bureau of Meteorology (BOM) and they determine two questions that can be answered by the data.

Educational aims: This task aims to:

1. develop an understanding that communication is a two-way process of imparting, questioning and receiving information that requires cultural competence with a range of audiences (TLO4.1).

Assessment details: ***Part 1*** (aims and graph 10%): Data from the BOM is provided. Students develop two aims that can be answered by the data and produce two graphs to answer these aims. For example, long-term and current year daily minimum data for Armidale could be given.

Part 2 (poster 8%): Students self-select into groups of 4–6 and are given four hours in class to complete a task of comparing the data used in Part 1 with another location. For example, if given minimum temperature data students may identify when frost risks are highest for grapes, how many chill days for apples in Armidale vs Orange, or when soil temperatures will be warm enough to sow. Students are expected to divide tasks among group members and research this topic in depth.

Part 3 (Interview 7%): Teams with their poster are interviewed in front of four other groups, with questions asked by teaching staff and students. Students are assessed on their depth of knowledge and understanding of their topic and the questions they ask of other groups.

Other relevant comments or advice: As this unit is taught to a wide range of students and their poster and verbal communication has a component of peer assessment, they must ensure they communicate clearly with a range of audiences. This assessment is highly adaptable, but we have found using the BOM data has allowed students be more creative in their interpretation of the results.

Case study 4D: Creating an extension document and associated media release

University: University of Tasmania

Unit: Farm Business Management and Extension

Coordinator/Teacher: Dr Joanna Jones

Year: Level III (Advanced)

Description of task: This is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit provides students with an overview and understanding of the role that agricultural advisors play in supporting decision-making in farm businesses, focusing on decisions to adopt new or modified technologies and management practices.

Description of assessment task: Generate (a) an extension document (50%) and (b) associated media release (50%) relating to one of the risks identified in a business plan that was developed for a case study property in an assessment task undertaken earlier in the unit. Together the tasks account for 15% of the unit marks.

Students do the analysis in pairs, but must submit individual extension documents and a media release that includes:

1. the background of the risk selected by the student
2. the key strategies for mitigating the risk
3. some information to allow the clients to gauge the cost incurred to manage the risk
4. how managing the risk will improve business success.

The media release acts as a vehicle for students to communicate their findings with the media about dealing with an identified risk. The media release targets Tasmanian rural media agencies such as the Tasmanian Country newspaper or ABC rural radio.

Educational aim: This task aims to enable students to:

1. identify the learning styles of target audiences, and be able to creatively adapt the forms of communication to provide relevant support for decision making (TLO 4.2).

Other relevant comments or advice: The first assessment task in this unit requires students to prepare a business case for investing in a property, using the financial statements provided. Students then select one of the risks identified in the business case as the basis for this assessment task.

Students are introduced to a variety of extension document formats in workshops, and also complete a workshop on working with the media and writing media releases.

Students often provide feedback that they are learning skills that will make them more job-ready.

Case study 4E: Extension and communication of scientific research

University: Curtin University

Unit: Advanced Cropping Systems and Precision Agriculture

Coordinator/Teacher: Dr Sarita Bennett

Year: Level III (Advanced)

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

Description of assessment task: Students are required to write an article for a newsletter, such as GRDC Groundcover, based on a scientific paper. Students identify a recent scientific article from a staff member (they do not need to be the primary author and can be research as well as teaching staff). They are required to read the paper and to interview that staff member about the research reported in the article, research leading from the article and some background about the author and their work.

The communication article includes a summary of the paper, and provides an understanding of why the research was done and how it contributes to the advancement of farming systems in Australia. It can also include further research that has arisen as a result of the published research and some information about the author. The submitted assessment includes a record of the interview and a 2–3 page communication article.

Educational aims: This task aims to enable the student to:

1. understand methods of effective two-way written and verbal communication with different audiences
2. communicate with a range of audiences in an agricultural context using a variety of modes (TLO 4.2).

Assessment details: Students submit their communication article and a record of their interview. Marks are provided for the correct layout of a media-style article including title and 'punchiness' of the first paragraph. The interview component is assessed in relation to the questions being asked rather than the answers given by the author of the paper.

A tutorial is given on writing media releases and papers prior to commencement of the assessment. The assessment is worth 20% of the final grade of the unit.

Other relevant comments or advice: I have used one of the University's media staff who specialises in agriculture to give a tutorial on writing this style of report. There are lots of examples of media releases on the web to show the layout used, including the style of titles, and students are encouraged to read *GroundCover* and similar publications before commencing their report.

I obtain permission from staff before semester commences for students to contact and interview them and provide that list to the students. I also insist that students submit their paper and list of potential staff member interviewees before contacting a staff member to ensure that the students are interviewing all available staff and students are not all selecting the same scientific paper.

Case study 4F: Radio Interview to examine an issue from stakeholder perspectives

University: The University of Queensland

Unit: Conservation

Coordinator/Teacher: Dr Lucy Mercer-Mapstone, Associate Professor Richard Fuller, Dr John Dwyer

Year: Level III (Advanced)

Unit context: This unit is offered in the Bachelor of Agricultural Science. Conservation uses science to help solve real-world problems. This unit explores what can be done to repair the damage done by humans to the planet's species, communities and natural ecosystems.

Description of assessment task: Students work together in groups of three and record a 3–5 minute radio interview based around an interesting or controversial contemporary Australian or overseas issue or problem in conservation. Particularly interesting issues will be those where multiple stakeholders hold strongly opposing views on the best way forward. We play the best recordings to the whole class.

Students can choose to have act as a presenter, and the other two act as interviewees with opposing views on the conservation issue being treated; other appropriate configurations could be attempted. All ideas for topics are submitted and approved by the course coordinator before students start preparing the recording.

Two tutorials (during the Practical sessions in Weeks 1 and 3) are dedicated to learning some of the science communication skills required by students to prepare their radio segment – such as how to identify and analyse a target audience. Students are required, at the start of their recording, to state their target audience and for which radio show the segment is intended.

Educational aims: This task aims that students:

1. identify conservation issues and the key ecological, social and political factors involved with them
2. evaluate arguments about conservation issues, expressing them verbally (TLO 4.1).

Other relevant information or advice: Explicit teaching of communication skills improves the quality and learning in students' assignments. In 2014 we introduced two 15–30 minute activities held during practical classes, and marking criteria, explicitly to teach and assess some of the communication skills targeted in this assignment.

An evaluation of the assessment showed a significant improvement in 2014 from the previous year when much of this information was implicit or absent from the task instructions and teaching activities (Mercer-Mapstone & Kuchel, in press.

A copy of the teaching activity we used to address communication skills (which includes teacher notes, student handouts and marking rubric) is available in Mercer-Mapstone and Kuchel (2015b).

Case study 4G: Explaining core scientific concepts for different audiences

University: The University of Queensland

Unit: Advanced Evolutionary Biology

Coordinator/Teacher: Dr Lucy Mercer-Mapstone, Associate Professor Richard Fuller, Dr John Dwyer

Year: Level III (Advanced)

Unit in context: Evolutionary Biology is a unit in the Bachelor of Agricultural Science. The unit considers the different perspectives available for examining the evolutionary process and ecological diversity

Description of assessment task: Employers of science graduates say they are good are writing laboratory reports, but very poor at writing everything else! Students will often have to write for non-experts, starting with the selection panel at job interviews. This module develops skills for communicating with different audiences by requiring students to explain some key concepts.

Students write short pieces of text to explain each of three core physics or evolution concepts to two audiences: 1) a second-year UQ physics/evolution student, 2) a 16-year-old high school student. The class time for this module includes two 100-minute tutorials for each of the three topics (six tutorials in total). Students bring a draft of their written work to the second tutorial for each topic to receive feedback before they submit their assignment.

Marking criteria that directly assess communication skills in this task include: identifying and understanding a suitable target audience, using style elements to engage an audience, using language appropriate for the target audience, considering levels of prior knowledge of the target audience, separating essential from non-essential factual content in a context that is relevant to the target audience (all selected from the list in Mercer-Mapstone and Kuchel, 2015a) and ensuring accuracy of science description. A full copy of the marking rubric is available at http://espace.library.uq.edu.au/view/UQ:371873

Educational aim: This task aims to have students:

1. articulate the underlying principles of evolutionary biology, and explain how they relate to specific areas of evolutionary interest (including speciation, sexual selection, sociality and human evolution (TLO 4.2).

Other relevant comments or advice: We found that requiring students to explain concepts in language appropriate to different audiences not only teaches them some fundamental principles of communication, but reveals to both students and staff inadequacies in students' understanding as students can no longer hide misunderstandings behind technical jargon.

The success of this assignment hinges primarily on the explicit teaching of communication skills, opportunities for feedback, and the identification of specific and narrow audiences which help students to focus their efforts. We chose audiences familiar to students. Alternatively, students could research specific audiences from the workplace or elsewhere to integrate workplace knowledge into this task.

An evaluation of the assessment in the unit showed a significant improvement in both students' demonstrated understanding of physics and their ability to communicate effectively (Mercer-Mapstone & Kuchel in press). A copy of the teaching activity we used to address communication skills (which includes teacher notes, student handouts and marking rubric) is available in Mercer-Mapstone and Kuchel (2015b).

Case study 4H: Website resource and communication portfolio

University: The University of Queensland

Unit: Communicating in Science

Coordinator/Teacher: Louise Kuchel

Year: Level III (Advanced)

Unit context: This unit is in the Bachelor of Agricultural Science. This unit emphasises the practical approaches and underlying processes for translating scientific discoveries and knowledge into forms that other groups in society can understand.

Description of assessment task: Students create a website using free, click-and-drag software (e.g. www.weebly.com or www.wix.com) and add to this throughout the semester.

There are two parts to the website assignment: 1. short summaries of course content and associated useful resources which students source from the Internet, and 2. a portfolio of communications created by the student.

The intentions of this assignment are to introduce students to some basic, widely used multimedia skills, to develop a useful self-tailored resource that students carry with them beyond graduation, and to provide students with a portfolio of communication they can share with potential employers.

The communication tasks included in the portfolio all focus on science topics and include: copies of professional emails, a peer-reviewed scientific report, an executive summary intended for a business audience, a re-written assignment from a previous course, and an artefact (e.g. brochure, social media release) for a public education campaign. All communication tasks in the portfolio contain annotations made by students to identify important principles, strategies or justifications appropriate to the task that they have used to effectively communicate the science within the material.

Educational aims: The aim of this task is that students:

1. understand how science interacts with different disciplines via different forms of communication
2. identify target audiences and their needs/perspectives for scientific information
3. identify and apply the process of communicating science with journalists, business, public educators and science researchers
4. critically analyse scientific communiqués from a variety of sources, including media, business, and public and science researchers
5. evaluate and justify the choice and effectiveness of scientific communiqués provided to different target audiences
6. analyse and synthesise scientific information in order to develop appropriate key messages from scientific information.

Other relevant comments or advice: Most students love this assignment. Feedback from past students indicates that they refer to their website for tip reminders and/or have modified their website into a form of CV after graduation.

Students can choose whether to password-protect their website or to share their URL name. The assignment works best when some class time is allocated to getting students started on creating the website and to searching for resources to add to the website.

This website assignment combines forms of communication and writing found in most science courses with more modern and diverse forms of scientific communication and writing, and helps students to articulate and showcase some of the skills which will make them employable.

Case study 4I: Policy critique

University: The University of Queensland

Unit: Global Challenges in Agriculture

Coordinator/Teacher: Dr Laura Wendling

Year: Level III (Advanced)

Unit context: This unit is in the Bachelor of Agricultural Science. This unit introduces students to major emerging issues affecting policy and practice in the agricultural, agribusiness, food sciences and rural development fields and equips them to apply their knowledge and skills in a rapidly changing world context.

Description of assessment task: Students select a government policy document addressing a key global challenge in agriculture, agribusiness, food sciences or rural development that is related to the water-energy-food nexus.

The policy document can be an Australian or international policy written in English. Students prepare a written critique (2500 words excluding references) of the selected policy based on lecture content and independent literature review. In their policy critique, they should:

1. outline the policy issue and the desired outcome following implementation of the selected policy. Provide context for the policy - this can include a brief history, any changes and key stakeholders, etc.
2. review linkages between the selected policy and others related to the food security, water and energy nexus.

Educational aims: The aim of this task is that students:

1. understand the major global challenges affecting current and future practices in agriculture, food and rural development
2. appreciate the practice and future directions of their own specialisations and disciplines in a rapidly changing global context
3. communicate with others about the nature and relevance of global challenges
4. apply a keen ethical and social understanding in the practice of their agriculture, food and rural development specialisations
5. apply skills to effectively practise their specialisation in interdisciplinary teams
6. identify personal opportunities for leadership in their future professional, industry or community contexts.

Other relevant comments or advice: Students are provided with examples of policies from Australia related to key global challenges in agriculture. A nominal proportion of the overall assignment marks are apportioned to an online quiz to be completed shortly after the assignment is introduced in class. The online quiz requires students to identify their selected policy and the responsible government body and to provide a web address or PDF document. This review of students' selected policy allows staff to intervene if necessary to ensure the selection of a policy document encompassing an appropriate topic and scope for the assignment.

The individual nature of the assignment necessitates devoting some time to individual discussion with students struggling to identify or interpret a policy document. The value of this assignment, however, is that it provides students an opportunity to explore the linkage between science and public policy, as well as an appreciation for the complex nature of both the issues and legislative instruments used to address global agricultural challenges.

Case study 4J: Field monitoring exercise

University: The University of Queensland

Unit: Plant Protection

Coordinator/Teacher: Associate Professor Vic Galea

Year: Level III (Advanced)

Unit context: This unit is in the Bachelor of Agricultural Science. This unit explores the biology and how to diagnose major pest groups. Pest monitoring including pest, crop sampling and evaluation; development, implementation and analysis of pest management information, professional services, duty of care and ethics are explored.

Description of assessment task: Students are required to manage a commercially grown crop (broad acre or horticultural) for a farmer client to learn and apply the concepts of plant protection in a real-life situation. The aim is to teach the concept of integrated pest management in plant protection, using field experience.

As part of the procedure the students are responsible for locating a farmer co-operator/client and developing a working relationship with their client. They must provide a professional crop monitoring service (with the client aware this is a training exercise) and prepare a preliminary list of the pests relevant to the crop to be monitored as well as a risk assessment analysis which is included in the final report.

A final report is prepared that outlines details of any advice that students gave their client and justifies their decisions.

Educational aims: This task requires that students:

1. understand the biology of pests and pathogens and the interactions between pests and their host plants
2. show knowledge of the classification (identification) of plant pest and pathogen groups and use the most appropriate diagnostic procedures
3. demonstrate an understanding of the concepts of damage levels, such as Economic Injury Levels (EIL) and Economic Thresholds (ET)
4. use current methods for monitoring pests and evaluate and develop strategies for economic management of pests
5. monitor and report on the outcomes of integrated pest and disease management strategies
6. provide professional advice to farmer clients on pest management issues
7. apply the skills required to form a professional relationship with farmer clients
8. demonstrate personal growth and confidence
9. access and use computer-based crop management systems and information services.

Other relevant comments or advice: This is a transformational activity for students on many levels. The first hurdle they have to overcome is the uncertainty they have around interacting with the farmer client. Many students lack confidence in their ability to converse with farmers and in their ability to make meaningful recommendations. These concerns are gradually eroded throughout this exercise as students gain confidence in their ability to collect meaningful crop pest data, come to grips with the processes of crop management and realise that the farmer client is just as interested in them as they are in their client.

Case study 4K: Action learning project report and conference seminar

University: The University of Queensland

Unit: Food for a Healthy Planet

Coordinator/Teacher: Professor Susanne Schmidt

Year: Level I (Introductory)

Unit context: This unit in the Bachelor of Agricultural Science. This unit addresses a pertinent challenge of humankind: how to feed 12 billion people while maintaining the integrity and function of our planet. The unit confronts students with contrasting viewpoints for a nuanced understanding of the multidimensional aspects of food consumption and production.

Description of assessment task: The Action Learning Project (ALP) is a 5-student team mentored by experts. Students are organised into groups of five and then select a study topic area from a list of 20 that have been developed by other lecturers within the university. These lecturers agree to mentor the students for five hours (10 x 30 minute sessions) across semester as the student group develops a literature review and seminar on their chosen topic.

The seminars are presented by the groups at a student conference day that mimics a full-scale scientific conference. Students actively develop research and communication skills within a supportive community of practice. The students also have the option of developing their own topics if they wish, with feedback from the course-coordinator.

This process of short sessions with their expert is designed to give a continual line of feedback on their ideas/direction and progress.

Educational aims: Students should be able to:

1. understand the impacts of agriculture in context of human and environmental health
2. understand processes involved in food consumption and food production
3. collaborate effectively with peers and experts
4. collate, critically evaluate and communicate scientific knowledge to a peer audience
5. solve problems and interpret information using quantitative skills.

Other relevant comments or advice: The ALP helps to develop knowledge and skills to advance critical thinking and develop ideas. The activities are designed to lead the students from the initial research of an unfamiliar topic to becoming an expert and sharing their knowledge with peers and lay and expert audiences.

A key learning outcome is the evaluation of information and gauging its reliability. Sources can be broadly grouped into public domain sources, open access scientific literature and subscription scientific literature. Skill development is scaffolded with research information being discussed within teams, then analysed and synthesised as an annotated bibliography that is a preliminary activity in this assessment.

The conference presentation emphasises team work with students sharing the speaking and being strongly encouraged to “tell a story” rather than a collection of facts. Students are to assume the audience has no prior knowledge. This encourages them to present in a style appropriate for a non-scientific audience.

The students are provided with extensive materials to develop their bibliography, scientific report and their conference presentation, with tutors and the experts working with them throughout semester on these activities. Overall most students find this assessment really enjoyable as they are empowered to select topics of their choice and start learning to think and act like scientists.

Threshold Learning Outcome 5: Personal and professional responsibility

Tina Botwright Acuña

TLO 5 closely follows that for Science (Jones et al. 2011). As such, teachers in agriculture and related disciplines can also refer to the Good Practice Guide for Science TLO 5 for a review of the literature, resources and case studies that were collated by Loughlin (2013).

Key differences are the emphasis in TLO 5 for agriculture on students' accountability for their professional work, whereas scientific work is emphasised for TLO 5 for science. In this respect, TLO 5 for agriculture is similar to other professional degrees, such as Engineering and Information and Computer Technology (ICT). For example, the Engineering and ICT Outcome Area 'Needs, context and systems' notes that graduates should "recognise the ethical implications of their professional practice" (Cameron et al. 2010).

In the Good Practice Guide for TLO 5, Loughlin (2013) argues that being accountable, honest and responsible for their own scientific learning requires students to acquire a framework that can guide them throughout their professional life. Loughlin (2013) sought to summarise a possible framework in terms of key questions students and staff can apply to their learning and teaching activities.

This framework has been revised, in the context of the agriculture TLOs and the emphasis on professional practice, in Figure 5.1. The framework highlights that student learning addressing TLO 5 usually occurs with the attainment of the other TLOs, particularly in having an integrative understanding of agriculture (TLO 1), being able conduct investigations that address dynamic complex problems in agriculture (TLO 3) and being an effective communicator (TLO 4).

This chapter aims to guide academics in the implementation of TLO 5 by providing a brief review of the literature for each subcomponent of TLO 5 and providing examples of their practice in teaching. An annotated list of print, video, websites and legal resources is also provided.

Threshold Learning Outcome (TLO) 5 for agriculture on Personal and Professional Responsibility states that, upon completion of a bachelor-level degree in agriculture or a related sub-discipline, graduates will be accountable for their own learning and professional work by:

5.1 Being independent and self-directed learners.

5.2 Working effectively, responsibly and safely in an individual and team context.

5.3 Demonstrating knowledge of the regulatory frameworks relevant to their specialist area in agriculture.

5.4 Personally practising ethical conduct.

(Botwright Acuña et al. 2014a)

Figure 5.1: **A framework for Personal and Professional Responsibility in agriculture, adapted from Loughlin (2013)**

CONTEXT

- What is the agricultural context?
- What understanding of the major biophysical, economic, social and policy drivers that underpin agricultural practice and how they contribute to practice change do you need to source?
- What are the ethical and regulatory considerations?
- Are there any intellectual property issues?
- Will you need to work in a team and, if so, how will this be organised?

SAFETY

- What safety issues should be considered?
- Have you completed a risk assessment and addressed all the hazards you identified?
- Is your experiment/workplace compliant with safety regulations, policies and procedures?
- Do you need to seek advice on safety/regulations?
- Do you have the appropriate equipment, tools and safety training?

INVESTIGATION

- What contemporary issue or opportunity in Agriculture is being addressed?
- Are you applying the appropriate methodology and experimental approach?
- What technical tools or theoretical techniques will you use?
- Will your data and evidence be collected with accuracy and rigour?

COMMUNICATION

- Are you being objective, non-biased and intellectually honest?
- How will you accurately present your results?
- What mode of communication is suited to your intended audience?
- How might the information be adopted?
- Have you acknowledged others' contribution to the work?
- How should you appropriately acknowledge and represent your sources of information?


Learning that is pursued
throughout life: learning that is flexible,
diverse and available at different
times and in different places.

TLO 5.1 Being independent and self-directed learners

Lifelong learning is defined as learning that is pursued throughout life: learning that is flexible, diverse and available at different times and in different places. It allows graduates to make responsible decisions and take appropriate actions to maximise their own learning (Zimmerman 1986). Lifelong learning crosses sectors, promoting learning beyond traditional schooling and throughout adult life (Delors 1996).

The development of the AgLTAS statement prompted discussion among academics, industry and students on the attributes required by graduates to develop lifelong learning. Industry expressed their expectations that agriculture graduates have the ability to "think about what is required and where to get [source] it", so that "they can make and impact on industry by asking the right questions" (Botwright Acuña et al. 2014b). Although these statements reflect the need for graduates to gather information and utilise it to make decisions or solve problems as required in addressing TLO 3: Inquiry and problem-solving, they imply that students will undertake these tasks in an independent, self-directed manner.

The development of independent learning skills can be challenging as it requires a degree of student self-motivation and the ability to understand their own approach to learning (known as metacognitive knowledge as discussed in the chapter discussing TLO 2). Students need the opportunity to develop independent learning skills across their degree to assist them to be self-regulated, motivated and autonomous in their own learning process. To achieve this requires appropriate curriculum design (Field et al. 2015). Methods may include experiential learning and student-led inquiry-based learning. Blended learning and development of flipped classroom approaches are also useful.

Experiential learning has been described by educational theorists, in particular Kolb (1984), as the creation of knowledge through the transformation of experience, which is produced when people make or revise meaning out of their experiences. A review of the literature shows that experiential learning was adopted in the Land Grant colleges in the United States (Andreasen 2004) and Australian universities (Patterson 2007) from around the late 1980s onwards. It is prevalent in "real-world" learning activities of the agriculture discipline. Numerous examples of teaching activities that employ this approach are provided in other chapters of this Good Practice Guide. They include undergraduate research projects, practicals undertaken in the complex managed environment on university or commercially-owned farms, and work-integrated learning where a student is expected to apply their knowledge to the workplace. The need for these types of learning opportunities was frequently voiced by students, academics and industry in the workshops held nationally to inform the development of the AgLTAS statement (Botwright Acuña et al. 2013). For example, one participant from industry stated that graduates need a "base level of practical experience – at a minimum (field) tours but would be better for them to work in real context (in the real world)".

Mastery of concepts and skills in context is regarded as essential to develop the higher order thinking necessary for analysing complex systems and the employability skills necessary to prepare students for the work after graduation, and to develop as a self-regulated learner (Lebow 1993). Students are coached by staff to develop autonomy, with allowances for making mistakes. This process requires goal-setting and critical analysis of progress. Consistent with TLO 1, this has a social context where problems need to be considered from various perspectives (Parr & Trexler 2011). Students can generalise their knowledge into other units of study. This approach to learning is better known in the agriculture discipline as Participatory Action Research or PAR (Carberry 2001). PAR is used to promote the adoption of new practices and technology by researchers working together with the farming community, and is crucial to future gains in productivity and for global food security (Commonwealth of Australia 2012).

Work-integrated learning programs in agriculture reinforce the link between theory and practice and are featured in most Australian degrees in agriculture. When undertaken early in a course, work-based learning was found to help clarify students' career interests and goals and to promote personal development (Esters & Retallick 2013) to improve their future employability outcomes. Employability can be defined as "a set of achievements – skills, understandings and personal attributes – that make graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy" (Yorke 2006b). An example of work-integrated learning, where students undertake a placement in industry that is assessed, is described in Case study 5A.

Student-led inquiry is also regarded as promoting self-directed learning. Briefly, student-led inquiry encourages students to ask questions and pursue investigations and encourages group activities in class with an emphasis on reflection and action. Users of this guide are directed to the review of student-led inquiry and associated resources with respect to TLO 5 for Science by Loughlin (2013).

Extensive resources on inquiry-oriented learning are also available at the website Inquiry Oriented Learning in Science by Kirkup and Mears (2015) while the chapter discussing TLO 3 in this Good Practice Guide has focused upon the benefits of inquiry-based learning for agriculture students. An example of student-led inquiry, where students manage the growth of a crop, is presented in the Case study 3B. The chapter discussing TLO 3 also has numerous examples of project-based and problem-based learning.

Blended modes of content delivery offer greater flexibility for a diverse student cohort. The use of digital technology in learning and teaching, consistent with contemporary norms in society, is one approach that caters to students who prefer to have ready access to information rather than through lectures (O'Flaherty & Phillips 2015; Prensky 2001).

"Flipped" or inverted classrooms use digital technology, usually in the form of pre-recorded lectures, to free class time from lecture by assigning students instructional content as homework in preparation for class (Mellefont & Fei 2014). As this material is stored online in a learning management system, it can be accessed repeatedly by students in preparation for in-class activities or potentially for exam revision. This promotes students to be independent learners (Mason et al. 2013; O'Flaherty and Phillips 2015). An example of the use of a flipped classroom in teaching laboratory classes in microbiology is provided in the Case Study 5C.

TLO 5.2 Working effectively, responsibly and safely in an individual and team context

Individual and team work: TLO 5.2 requires students to work effectively both individually and in teams. Curriculum mapping, however, has shown that, typically, neither is explicitly taught to students and is instead implicitly expected and assessed as a part of a learning activity (Botwright Acuña et al. 2016).

As individuals, the opportunity to manage time through student-led inquiry, project-based and work-integrated learning is important to being an effective worker – and is achieved through meeting the requirements of TLO 5.1. Collaborative learning in small teams of four to five students is similarly an important aspect of active learning and is a commonly used approach to teaching in higher education (Burke 2011; Davies 2009).

One approach is for teachers to instruct students in the advantages and disadvantages of team work, so that the team can maximise the benefits while reducing obstacles (Beebe & Masterson 2003). Advantages may include, for example, greater breadth of resources and the stimulation of creativity. Students also gain a better understanding of themselves and the world view and perspectives of others, which in part also addresses TLO 4. In addition, team work is highly valued by employers (Fearon et al. 2012). Problems can, however, arise due to 'group think', with possible pressure to conform to the majority opinion and/or to dominant individuals, or when there is unequal effort among team members.

A choice needs to be made by teachers to randomly assign or allow students to self-select into teams. Random assignment has an advantage of maximising heterogeneity. In contrast, students have a tendency to select team members based on friendship groups (Burke 2011) or cultural background. Research has suggested that learning outcomes of students are improved when students are assigned to teams by the teacher rather than if teams self-select (Felder & Brent 2001).

Students could be explicitly taught the stages of development or the lifecycle of a group (Tuckman 1965):

1. **Forming** – students in a new team need time to get to know each other.
2. **Storming** – the inclination of team members to push against agreed roles, creating conflict, or the feeling of uncertainty if the objective of the group work is poorly described or not aligned with the learning objectives, or if the workload is too onerous. It will be important for the teacher to reinforce listening skills and how to give and receive constructive criticism (Burke 2011). Case study 5D provides an activity on conflict resolution using a video that may be useful.
3. **Norming** – team members start to resolve their differences and appreciate each other's strengths, with work progressing towards the goal. Developing and implementing a plan of action in the team is recommended, with each member allocated an agreed role e.g. leader, organiser, editor, researcher, writer or presenter.
4. **Performing** – work leads to achieving the team's goal, with little disruption in performance should team members join or leave the group.
5. **Adjourning** – when the work is complete and the team disbands.

Grading of team work can be challenging. Decisions will need to be made whether to grade the process or product of team work, and who will assign the grade – teachers, students or both (Burke 2011). A single grade can create tension if some team members did not contribute equally, while assigning of individual grades may create competition among members and undermine the effectiveness of the team. Burke (2011) suggests using separate criteria to assess the process of team work e.g. attendance, participation, time management, active listening, evidence of cooperation, professionalism and engagement with the task.

Criteria to grade the product of a team-based activity could include e.g. content, structure, organisation and accuracy. Examples of assessment in TLO 2 and TLO 3 indicate how the ability of teams to work together is assessed through team-based learning activities or peer assessment.

Workplace health and safety (WHS): similar to individual and team work, WHS is introduced to a laboratory or workplace setting as part of completion of a task, but is usually not explicitly assessed. Students should be provided information on WHS with reference to university policy and legal requirements. Figure 5.2 shows an example of WHS information provided to students in unit outlines by the School of Land and Food at the University of Tasmania. Figure 5.2, which is drawn from Safe Work Australia (2011) is accompanied by text (shown right).

Note that all the steps are important – including the need to review control measures. By providing students with the information and involving students in the process we are enhancing their understanding of the WHS requirements in a workplace, be that in a university setting or in a work placement. Furthermore, an Agriculture graduate should know their WHS obligations and understand some of the challenges and solutions to common health and safety issues they are likely to encounter in the workplace. This would emphasise the business context in which agriculture and agribusiness are operating. An example of this is provided in Case study 5E.

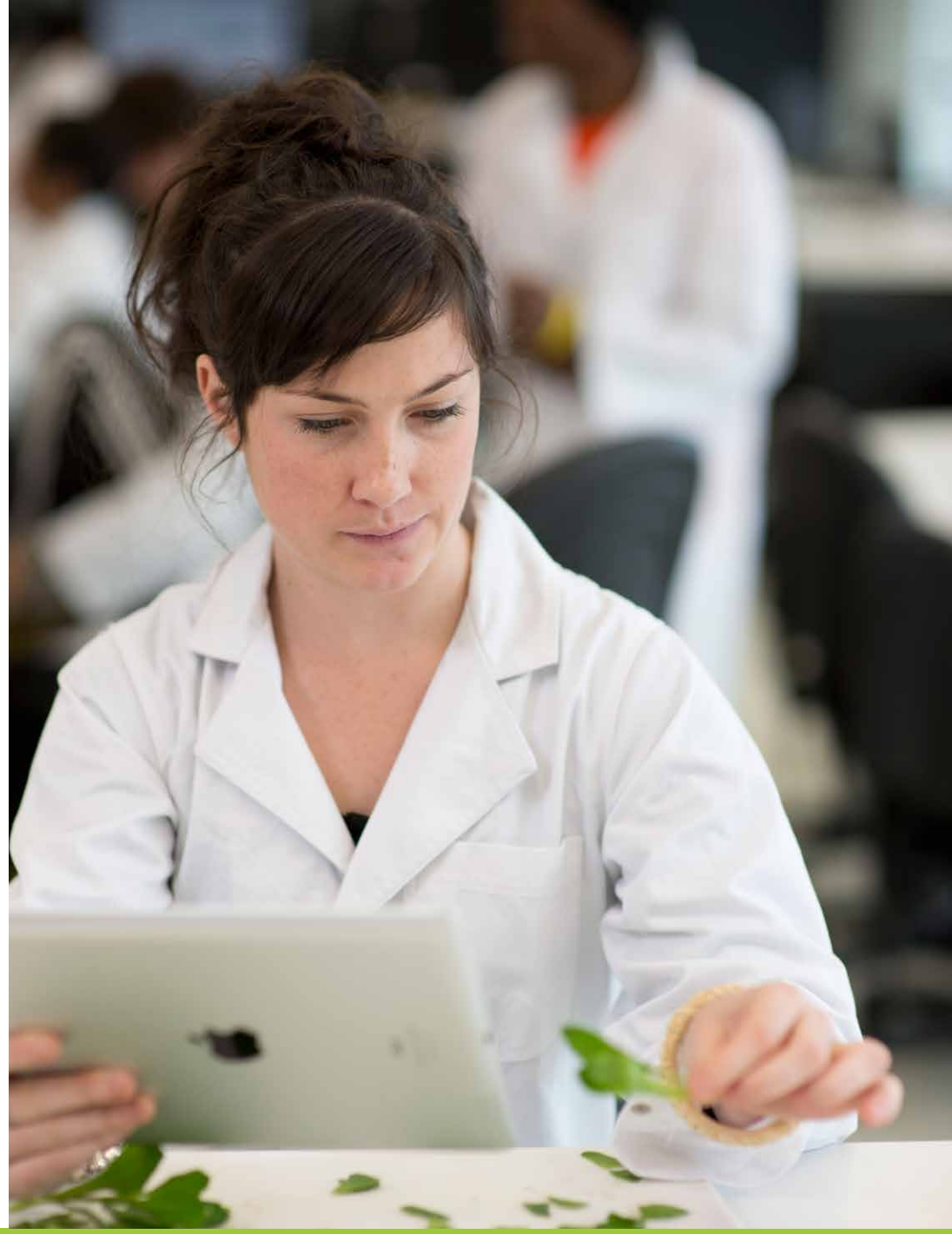
The resources section of this chapter also lists material that could support teaching agriculture students about their duties, potential hazards they may face in managing agricultural workplaces, and resources to help them address these. The herbicide report in Case study 5F requires students to access information from the Poisons Standard to support their analysis.

"The University recognises that hazard identification, risk assessment and controls are a critical part of everyday work. Figure 5.2 shows the risk management process. Students are required to undertake a risk assessment prior to commencing any laboratory and/or field activity on or off campus. Supervisors assist students in identifying potential hazards and assessing risks for your project and will assist you with sign off on any documentation. Risk assessments (RA) are not required for activities that are considered routine or if a current Safe Work Procedure (SWP) is already in place to manage the project/task."

Figure 5.2. The risk management process (Safe Work Australia 2011).

Learning outcomes related to WHS could include how a student demonstrates that they:

- understand legal and ethical obligations including under corporations and work health and safety law, and the role of an agriculture graduate as a workplace leader
- understand risk assessment and risk management principles including the use of hierarchy of controls as they apply to a range of risks affecting agricultural business – including the productivity gains from good risk assessment and healthy and safe work design
- apply safety systems and safety management principles and concepts in a range of theoretical and practical situations through research and practical application; understand the importance and value of good work design and eliminating hazards before they are introduced into the workplace; and understand that hazards may be physical, psychosocial, biomechanical or cognitive
- are familiar with safety hazards and appropriate solutions relevant to a range of agricultural workplaces, and understand how to maintain their personal safety. These hazards include but are not limited to, for example:
  - outdoor work/UV radiation, extreme heat and cold
  - muscular-skeletal disorders
  - working with animals
  - rural plant (including tractors, quad bikes)
  - agricultural chemicals
  - diesel engines
  - dust
  - water-borne pathogens
  - fatigue
  - remote and isolated work, solitary work.



TLO 5.3 Demonstrating knowledge of the regulatory frameworks relevant to their specialist area in agriculture

Government regulations as they relate to agriculture are diverse and embedded throughout the value chain. Agricultural policy in Australia has promoted the intensification of farming practices, farm consolidation and the development of improved business management capacity.

The federal government's intent to introduce or revise agricultural policy is communicated through Green and White Papers. A Green Paper is commissioned to engage stakeholder feedback and discuss a number of options and potential directions that could be adopted by the Australian Government through legislation. An example related to Agriculture is the 'National Food Plan' (Department of Agriculture, Forestry and Food 2012).

In comparison, a White Paper states government policy, such as 'Agricultural Competitiveness White Paper' (Commonwealth of Australia 2015). The mechanism by which government policy is applied is through a legislative instrument such as new or amended Commonwealth Act(s) and Regulation(s). Agriculture graduates should have an appreciation of the acts and regulations relevant to their area of specialisation.

The resources section of this chapter includes links to a range of government departments and agencies, acts and regulations. These include, but are not limited to: climate change; industrial chemical use and safety; environment and environmental protection; pesticides and veterinary medicines; radiation; food safety; gene technology; animal welfare; water resources; human research; poisons; quarantine; marketing of agricultural commodities and exports; and work health and safety.

Consequently, there is wide scope in learning and teaching in agriculture to integrate knowledge and application of legislation in the curriculum. This will underpin student professional practice after graduation. Case study 5F is one example.

TLO 5.4 Working effectively, responsibly and safely in an individual and team context

The statement on the nature and extent of agriculture in Botwright Acuña et al. (2014a) notes that the discipline "adopts a stewardship role to foster environmental, economic and social sustainability". As such, agriculture has a responsibility for the careful supervision of managed ecosystems for society.

A range of ethical questions relating to agriculture may be covered in agriculture degrees, such as the assessment of technological changes affecting farm populations; the utilisation of farmland and other resources; the deployment of intensive agriculture; the modification of ecosystems; animal welfare; the professional responsibilities of agro-ecologists and food scientists; the use of biotechnology; and the safety, availability, and affordability of food. TLO 1: Understanding agriculture requires graduates to understand these and related issues; TLO 5 calls for graduates to personalise this in their professional conduct. Case study 5H requires students to apply knowledge of agriculture to a debate on genetically-modification, while acknowledging the world view of others.

TLO 5, as for TLO 2, is often only explicitly taught and assessed in the introductory learning phases of a degree. Take plagiarism, for example. Scientific literacy and referencing are typically explicitly taught and assessed in first year, as described in Case Study 5G. A study of academics at the University of Tasmania and The University of Adelaide surprisingly found that practising ethical conduct was often taken to refer to plagiarism and collusion, which by third year was no longer necessarily taught but instead an expectation and not explicitly assessed (Botwright Acuña et al. 2016). The requirements for academic referencing and definition and the implications of plagiarism are stated in a unit outline but may not be explicitly assessed. If assessed, ethical conduct might usually be one element of a rubric and be regarded as a part of communication (TLO 4).

Knauft (2015) recommends that ethics in agriculture can be explicitly taught by exposing students to an ethics framework, such as the Nuremburg Code that describes ethics principles for human research, or to the Belmont Report (United States Department of Health and Human Services 2015). These include the following key concepts:

- respect for persons – that individuals should be treated as autonomous agents and persons with diminished autonomy are entitled to protection
- beneficence – persons are treated in an ethical manner by also making efforts to secure their wellbeing, which is enacted by doing no harm, and maximising possible benefits while minimising possible harm
- justice –to each person an equal share, according to: individual need; individual effort; societal contribution; and, merit.

Approaches to teaching agricultural ethics can include debates (such as Case study 5H on genetically modified organisms), or requiring background reading from science and ethics journals, emphasising an appreciation of multiple perspectives and world views (which is in part reflected in TLO 4). Such approaches, and the allocation of class time to discussion, improves student understanding of ethical issues (Loike et al. 2013).

Conclusion and future challenges

TLO 5 rounds off the preceding TLOs by requiring students to demonstrate their ability to demonstrate personal and professional responsibility. It requires students to develop skills to work safely in individual and team contexts, which promotes lifelong learning and bridges the gap between an undergraduate education at university and the workplace. The challenge for teachers is to provide students with the opportunity in the curriculum to develop these skills and attitudes, and to explicitly teach and assess them.

Helen Righton and her team at Safe Work Australia are gratefully acknowledged for their contribution of ideas and resources for Chapter 5.

Resources for TLO5

An annotated list of print, video, websites and legal resources associated with TLO 5: *Personal and Professional Responsibility is provided.*

Print resources

Resources to promote the importance of holistic risk assessment

The WHS Body of Knowledge is a collection of reading material aimed at undergraduate students covering key work health and safety concepts. It includes chapters covering the concept of a hazard, and risk and risk assessment – these could be useful background reading:

- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/Documents/633/How_to_Manage_Work_Health_and_Safety_Risks.pdf
- http://www.ohsbok.org.au/wp-content/uploads/2013/12/15-Hazard-as-a-concept.pdf?ce18fc
- http://www.ohsbok.org.au/wp-content/uploads/2013/12/31-Risk.pdf?ce18fc
- http://www.ohsbok.org.au/wp-content/uploads/2013/12/OHS-BOK-OHS-Risk-and-decision-making-May-2015.pdf?ce18fc

Other suggested reading:

- *Occupational Risk Control: Predicting and preventing the unwanted*, Derek Viner, Publisher Gower Publishing Ltd, ISBN13 9781472419705
- *Risk makes sense: Human judgement and risk*, Dr Robert Long and Joshua Long, Scotoma Press, ISBN 9780646570945
- *Surviving and thriving in uncertainty: Creating the risk intelligent enterprise*, Frederick Funston and Stephen Wagner, Wiley, ISBN 978-0-470-24788-4

Supporting resources on work health and safety

The following handouts explain a manager's general duties: some cover specific issues which may arise in certain agriculture fields:

- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/work-related-injuries-fatalities-australian-farms
- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/interpretive-guideline-section-27
- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/growing-managing-forests
- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/guide-ultraviolet-radiation
- http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/good-work-design

Actual or hypothetical case studies about WHS Regulators' activities to support agricultural industry:

- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/case-studies/pages/improving-remote-workers-health-and-safety
- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/case-studies/pages/cattle-transfer---a-winning-innovation
- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/case-studies/pages/supporting-the-sheep-and-beef-cattle-industry

A number of case studies are included in:

- http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/886/work-related-fatalities-unsafe-design.pdf

Templates/guides/checklists on 'how to comply' are included in:

- http://worksafe.tas.gov.au/__data/assets/pdf_file/0010/286939/Advisor_Safety_Management_Toolkit.pdf
- https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0006/82824/leading-safe-business-checklist.pdf

- https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0009/82890/advice-sheet-3-safe-work-procedures.pdf
- http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/886/work-related-fatalities-unsafe-design.pdf

Links to useful material/reading lists/research on barriers to the adoption of safe work practices in agricultural industries include:

- http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/107/BeyondCommonSense_Report_Barriers_AdoptionOfSafety_AgricultureIndustry_2006_ArchivePDF.pdf
- https://rirdc.infoservices.com.au/items/15-068
- https://rirdc.infoservices.com.au/items/14-127

Video resources

Selected video resources on work place health and safety are included in:

- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/vss/pages/alive-and-well
- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/vss/pages/safety-on-outback-stations
- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/vss/pages/farm-safety-its-important
- http://www.safeworkaustralia.gov.au/sites/swa/australian-strategy/vss/pages/working-safely-chemicals

Websites

Australian Government Climate Change Authority

http://www.climatechangeauthority.gov.au/

The Climate Change Authority provides independent expert advice on Australian Government climate change mitigation initiatives. The Authority was established under the *Climate Change Authority Act 2011*.

Australian Government Department of Agriculture and Water Resources - legislation

http://www.agriculture.gov.au/about/legislation

Legislation administered by the Minister for Agriculture is listed on the Department of Agriculture and Water Resources website. The wide-ranging legislation set out for the department in the Administrative Arrangements Order relates to (but is not exclusive to): agricultural industries; soils; rural adjustment and drought support; quarantine; primary industries research; commodity marketing, administration of international organisations and agreements; agricultural exports; and, food security policies. A complete list of legislative instruments is available at the website.

Australian Government Department of Health, National Industrial Chemicals Notification and Assessment Scheme

http://www.nicnas.gov.au/

The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) is a statutory scheme administered by the Australian Government Department of Health. A range of state, territory and Commonwealth government agencies share regulatory responsibility for chemical safety in Australia, with each chemical being regulated according to its use, whether as a therapeutic good (e.g. medicine), veterinary medicine, pesticide, food additive or industrial chemical (which includes any chemical with a use not falling into one of the other categories).

Australian Government Department of Health, Office of Chemical Safety

http://www.health.gov.au/internet/main/publishing.nsf/Content/ohp-ocs.htm

The Office of Chemical Safety (OCS) undertakes a number of regulatory functions in relation to chemicals. These functions include: administration of the National Industrial Chemicals Notification and Assessment Scheme (NICNAS); provision of human health risk assessment services to the Australian Pesticides and Veterinary Medicines Authority (APVMA) on agricultural and veterinary (AgVet); and, management of the Poisons Standard for industrial and AgVet chemicals.

Australian Government Department of the Environment

http://www.environment.gov.au/

The Minister of the Australian Government Department of the Environment (AGDE) administers a range of legislation detailed on their website, pertaining to (but not exclusive to): emissions; renewable energy; carbon credits; climate change; environmental

protection; fuel quality; hazardous waste; meteorology; greenhouse and energy reporting; natural resources management (financial assistance); ozone protection and synthetic greenhouse gas; product stewardship; water act. Links to selected Acts are included in the following section.

Australian Pesticides and Veterinary Medicines Authority

http://apvma.gov.au/

Chemicals used in agricultural and veterinary medicine products are approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Once a product is registered, it is approved for the purposes and uses stated on the product's label. The APVMA considers applications for permits that allow for the legal use of chemicals in ways different from those set out on the product label. Information provided in the APVMA website relates to regulations and permits; chemicals and products; compliance and enforcement; and, expert scientific advice relating to pesticides and veterinary medicines.

Australian Radiation Protection and Nuclear Safety Agency

http://www.arpansa.gov.au/

Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) regulates Commonwealth entities using radiation with the objective of protecting people and the environment from the harmful effects of radiation. ARPANSA undertakes research, provides services, and promotes national uniformity and the implementation of international best practice across all jurisdictions. Information on regulation and licensing pertaining to radiation is available at the ARPANSA webpage.

ChemCert

http://www.chemcert.com.au/

ChemCert is an industry-based non-profit organisation established in 1999. As the peak accreditation body it works with all industry sectors throughout Australia for the training, up-skilling and industry accreditation for users of Agricultural and Veterinary (AgVet) chemicals.

Food Standards Australia New Zealand (FSANZ)

http://www.foodstandards.gov.au/

FSANZ is a bi-national government agency that develops and administers the Australia New Zealand Food Standards Code, which lists requirements for foods such as additives, food safety, labelling and genetically modified (GM) foods. Enforcement and interpretation of the Code is the responsibility of state and territory departments and food agencies within Australia and New Zealand.

Inquiry-oriented Learning in Science

http://www.iolinscience.com.au/

IOL is a student-centred, activity-intensive, approach to learning. This website provides accumulated evidence, collated and created resources and useful links to connect teachers to IOL ideas and tools.

Office of the Chief Scientist

http://www.chiefscientist.gov.au/

Australia's Chief Scientist provides high-level independent advice to the Prime Minister and other ministers on matters relating to science, technology and innovation. The Chief Scientist ensures science frameworks and practices meet appropriate standards.

Office of the Gene Technology Regulator

http://www.ogtr.gov.au/

The Office of the Gene Technology Regulator has been established within the Australian Government Department of Health to provide administrative support to the Gene Technology Regulator in the performance of the functions under the *Gene Technology Act 2000*. Resources are available at the website on applications related to gene technology, approved genetically-modified organisms (GMOs), the import and export of GMOs and transport, storage and disposal of GMOs

MindTools: online resources for group formation

https://www.mindtools.com/pages/article/newLDR_86.htm

The MindTools website contains numerous helpful online documents on leadership. This particular page provides more detail on the group lifecycle of 'forming, storming, norming and performing'.

Safe Work Australia

http://www.safeworkaustralia.gov.au/sites/SWA

Safe Work Australia leads the development of national policy to improve work place health and safety and workers' compensation arrangements across Australia.

Acts, regulations, guidelines and codes of practice

Agricultural and Veterinary Chemicals Code Regulations 1995

https://www.comlaw.gov.au/Series/F1996B00288

These regulations provide a nationally consistent regulatory framework for agricultural and veterinary chemicals. The website provides links to amendments to the code.

Australian code for the care and use of animals for scientific purposes 8th edition (2013)

https://www.nhmrc.gov.au/guidelines-publications/ea28

The Code promotes the ethical, humane and responsible care and use of animals used for scientific purposes. The ethical framework and governing principles set out in the Code provide guidance for investigators, teachers, institutions, animal ethics committees and all people involved in the care and use of animals for scientific purposes.

Australian Animal Welfare Standards and Guidelines

http://www.animalwelfarestandards.net.au/

Animal Welfare Standards and Guidelines for cattle and sheep are waiting on endorsement by the Agriculture Minister. Updated information will be available from the website.

Australian Radiation Protection and Nuclear Safety Act 1998

https://www.comlaw.gov.au/Details/C2015C00525

The purpose of this Act is to protect the health and safety of persons and the environment from the harmful effects of radiation. Each state has further legislation.

Climate Change Authority Act 2011

https://www.comlaw.gov.au/Details/C2011A00143

The Climate Change Authority is to conduct reviews under the *Clean Energy Act 2011*; the *Carbon Credits (Carbon Farming Initiative) Act 2011*; the *National Greenhouse and Energy Reporting Act 2007*; and *the Renewable Energy (Electricity) Act 2000*.

Corporations Act 2001

https://www.comlaw.gov.au/Details/C2015C00336

Agriculture graduates need to understand their ethical and legal obligations and their role as workplace leaders. This Act makes provision in relation to corporations and financial products and services, and for other purposes.

Environment Protection and Biodiversity Conservation Act 1999

https://www.comlaw.gov.au/Series/C2004A00485

The Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places defined in the Act as matters of national environmental significance.

Food Standards Code

https://www.comlaw.gov.au/Search/Australia%20New%20Zealand%20Food%20Standards

The Food Standards Code comprises four chapters, including 1) general food standards; 2) food product standards; 3) food safety standards (Australia only); and 4) primary production standards. Each chapter is further divided into sections.

Gene Technology Act 2000

https://www.comlaw.gov.au/Series/C2004A00762

The object of this Act is to protect the health and safety of people, and to protect the environment, by identifying risks posed by or as a result of gene technology, and by managing those risks through regulating certain dealings with GMOs.

Guidelines for Ethical Research in Australian Indigenous Studies

http://aiatsis.gov.au/research/ethical-research/guidelines-ethical-research-australian-indigenous-studies

The Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) has created the Guidelines for Ethical Research in Australian Indigenous Studies (GERAIS) to ensure that research with and about Aboriginal and Torres Strait Islander peoples follows a process of meaningful engagement and reciprocity between the researcher and the individuals and/or communities involved in the research.

Industrial Chemicals (Notification and Assessment) Act 1989

https://www.comlaw.gov.au/Details/C2015C00428

The objects of the Act are the provision of a national system of notification and assessment of industrial chemicals. Parts of the Act are relevant for agricultural and veterinary chemicals, and to food additives.

National Statement on Ethical Conduct in Human Research (2007) – Updated May 2015

https://www.nhmrc.gov.au/guidelines-publications/e72

The National Statement is developed jointly by the National Health and Medical Research Council, the Australian Research Council and Universities Australia. It replaced the 1999

National Statement on Ethical Conduct in Research Involving Humans. It is intended for use by researchers, ethical review bodies, those involved in research governance and potential research participants.

Poisons Standard 2015

https://www.comlaw.gov.au/Details/F2015L00128

This schedule describes the classification and use of chemicals that are poisons and regularly updated.

Quarantine Act 1908

https://www.comlaw.gov.au/Series/C1908A00003

The Act details measures relating to the examination, seizure, prevention and control of vessels, installations, human beings, animals, plants or other goods or the environment.

Regulatory Science Network

http://apvma.gov.au/node/15496

There are nine government agencies and departments responsible for the regulation of chemicals and biological agents in Australia, including the APVMA. In 2011 the Regulatory Science Network (RSN) was established to help forge closer ties between these bodies. The RSN provides a forum for scientists and technical staff to discuss regulatory scientific issues and improve interagency cooperation.

Water Act 2007

https://www.comlaw.gov.au/Details/C2015C00272

The Act pertains to the Murray-Darling Basin Agreement and its amendments e.g. *the Water Amendment Act 2008*. The objectives of the Act are to enable the Commonwealth, in conjunction with the Basin States, to manage the Basin water resources in the national interest. This includes, for example, ensuring the return to environmentally sustainable levels of extraction for water resources; the protection of ecological values and ecosystem services of the Basin; improved water security for all users of the Basin; natural resource management; administration practices; collection, collation, analysis and dissemination of information about Australia's water resources and the use and management of water in Australia.

Work Health and Safety/Occupational Health and Safety Acts

Work health and safety is regulated by State and Territory Governments. There is a separate Act in each jurisdiction. The Commonwealth Act only applies in Commonwealth Government workplaces and at a limited number of other workplaces; otherwise State and Territory laws apply.

Commonwealth Work Health and Safety Act 2011

https://www.comlaw.gov.au/Details/C2011A00137

The main object of this Act is to provide for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces.

ACT – *Work Health and Safety Act 2011*
http://www.legislation.act.gov.au/a/2011-35/default.asp

NSW – *Work Health and Safety Act 2011*
http://www.legislation.nsw.gov.au/maintop/view/inforce/act+10+2011+cd+0+N

NT – *Work Health and Safety (National Uniform Legislation) Act*
http://notes.nt.gov.au/dcm/legislat/legislat.nsf/linkreference/work%20health%20and%20safety%20%28national%20uniform%20legislation%29%20act

Qld – *Work Health and Safety Act 2011*
https://www.legislation.qld.gov.au/LEGISLTN/CURRENT/W/WorkHSA11.pdf

SA – *Work Health and Safety Act 2012*
https://www.legislation.sa.gov.au/LZ/C/A/WORK%20HEALTH%20AND%20SAFETY%20ACT%202012.aspx

Tas – *Work Health and Safety Act 2012*
http://www.thelaw.tas.gov.au/tocview/index.w3p;cond=;doc_id=1%2B%2B2012%2BAT%40EN%2B20160302000000;histon=;prompt=;rec=;term=

Vic – *Occupational Health and Safety Act 2004*
http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/750e0d9e0b2b387fca256f71001fa7be/$FILE/04-107A.pdf

WA – *Occupational Safety and Health Act 1984*
http://www.slp.wa.gov.au/legislation/agency.nsf/docep_main_mrtitle_650_homepage.html


TLO 5 bridges the gap
between an undergraduate
education at university
and the workplace.

Case study 5A: Industry placement report and seminar

University: University of Tasmania

Unit: Industry Project

Coordinator/Teacher: Associate Professor Dugald Close

Year: Level III (Advanced)

Unit context: This is a core unit in the Bachelor of Agriculture in which students undertake a compulsory industry placement where they are expected to examine and analyse a range of management practices/industry issues in agriculture. Students work alongside industry personnel to gain a first-hand insight into the industry and develop their professional networks to assist with the gathering of information.

Description of assessment task: Each student presents a seminar to the class and academic supervisors outlining their industry project.

The unit is undertaken through self-directed learning with academic supervision and mentoring.

Group tutorials are offered throughout the semester that cover different aspects of agricultural enterprise investigation, analysis and report writing.

Educational aims: Students should be able to:

1. Demonstrate first-hand experience and knowledge of the operational context of an industry of interest
2. Communicate an understanding of a specific technical aspect of the chosen industry that has been experienced
3. Effectively communicate learnings from operational experience and from targeted research of a specific technical aspect to academic staff and peers.

Assessment details: Assessment tasks include an industry placement report (40%), a specialisation report (40%) and a seminar (20%). The industry placement report is a piece of critically-reflective writing about the placement with reference to literature.

The specialisation report provides a more in-depth analysis on a technical aspect relevant to the industry placement. Assessment criteria include the relevance and source of information; critical analysis and synthesis; structure and style. Both reports are between 4000 –5000 words. Students describe their industry project or a component of it in a 15-minute seminar and are assessed on their application of knowledge and communication to a scientific and industry audience.

Other relevant information or advice: The coordinator has a key role in locating potential placements for the students, so it is important that the coordinator have a wide professional network and contacts with industry.

One-on-one discussions with students are scheduled at the start of the unit to explore and negotiate placements that best suit their interests and needs. The placement provider needs to a clear understanding of the educational aims of the unit. This is formalised through a Work-Integrated Learning Placement Agreement, which includes details of the provider, the timing of the placement, scope of study, reporting requirements and insurance.

Case study 5B: Sustainable management of a barley crop to maximise yield

University: University of Tasmania

Unit: Crop Production

Coordinator/Teacher: Dr Tina Botwright Acuña

Year: Level II (Intermediate)

Unit in context: This is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit provides students with an overview of intensive and extensive crop production and management. Study includes agro-ecological aspects of fruit, vegetable and grain crop production in Australia and the growth and development of the major crop species.

Description of assessment task: Students work in small teams of five to six to design and implement crop management strategies to maximise dry matter production of a cereal crop. Management of inputs of water and fertiliser, and pest and disease control are expected to be environmentally sustainable and to adhere to relevant regulations.

Students are provided with a range of resources at the start of the activity and learning is supported by the teaching staff, for example working through the application of their knowledge of plant requirements for nutrients by calculating a fertiliser budget based on soil samples from the site.

Students are also expected to provide a risk assessment and research appropriate pest management strategies, which are applied by professional staff in the school in accordance with WHS regulations.

Educational aims: The aims of this placement relate to the following:

1. Knowledge: Understand the key processes and modern scientific thinking as it relates to crop production in Tasmania and Australia
2. Analysis: Analysis and evaluation of emerging issues in crop production in Australian farming systems
3. Practical skills in crop production: Competency in appropriate scientific skills to conduct glasshouse and laboratory experiments based on principles of crop production and management
4. Communication: Well-developed written and oral communication skills, both individually and in groups.

Assessment details: Students submit an Excel workbook that addresses the following criteria:

1. knowledge of crop production methods including identification of crop management practices to maximise biomass production of barley which is supported by relevant sources of information
2. practical skills in crop production, including proficiency in field techniques (completion of a nutrient budget; appropriate experimental design; a risk assessment; monitoring of climate, pests and disease, crop growth, other crop attributes as decided by the team, final harvest) and participation in the team (evidenced by list of activities)
3. recording, collation, analysis of data and use of appropriate statistics
4. communication (English conventions, terminology, referencing).

Other relevant comments or advice: The activity provides an opportunity to reinforce key learning outcomes in recording, collating and presenting data using Excel before students start their advanced units of study.

The detailed list of activities provided evidence to assess the relative contribution of students to team work. While students were expected to research appropriate techniques for the management of pest and diseases, it was not implemented by students and, instead, undertaken by professional staff.

In general, we had a favourable response from the students about this activity, who liked the opportunity for self-directed work and to submit an assignment in the format of an excel workbook, instead of a written report. This format provided opportunity for teaching staff to identify issues with data entry and manipulation.

Case study 5C: Use of a 'flipped classroom' for microbiology laboratory classes

University: University of Tasmania

Unit: Microbiology

Coordinator/Teacher: Dr Lyndal Mellefont

Year: Level II (Intermediate)

Unit context: This is a core unit in the Bachelor of Agricultural Science. This unit provides students with a basic knowledge of microbiology including bacteria, fungi, protozoans and viruses. The unit considers the place of microorganisms in the evolution of life on earth, their structure, chemistry, biology and ecology and consideration of their role in disease, ecosystems, food production and biotechnology.

Description of assessment task: Students undertake a 3-hour laboratory class once a week in microbiology to put unit content into practice.

The introductory lecture for the laboratory class is provided to students in a 'flipped classroom' mode as an optional activity. This lecture and review of the laboratory manual are used by students to prepare for the laboratory class. Flipped classrooms reverse classroom content and homework. Students are exposed to material prior to attending class, usually in the form of pre-recorded lectures, and while in class undertake work typically done as homework with guidance and support from the teacher. Class time is freed from lecture and allows more time for active learning higher at a higher cognitive level.

Educational aims: Students are required to:

1. safely and competently perform fundamental laboratory techniques used in the practice and study of microorganisms within a PC I/II microbiology laboratory
2. select, undertake and interpret appropriate tests to differentiate and classify microorganisms on the basis of the morphology, metabolism and genetics.

Assessment details: Laboratory skills and understanding are assessed in a 3-hour practical exam undertaken in the last week of semester that is worth 30% of the overall grade.

Other relevant comments or advice: Flipped classrooms are a simple way to free class time from lecture and, especially if digital technology is utilised, they can provide a continuously available resource to students for revision purposes. If students are absent they do not necessarily miss content. Digital technology allows a resource to be compiled that caters to different learning styles and preferences through judicious use of different types of media, e.g. audio, text, images, video etc. They are of particular use in a microbiology laboratory where the use of personal digital technology in class as a teaching aid is precluded due to safety considerations.

Despite the many positives, there are some less favourable aspects of the flipped classroom to consider. There is no guarantee that students will engage with content. This can be overcome by viewing metrics as a hurdle requirement to succeed in a unit/assignment etc. or ensuring that the content contains assessable material. Additionally, a shift in learning culture is required by students i.e. they must assume a more responsible role for their own learning. This may be resisted by more passive or reluctant learners, and students may feel isolated in their learning.

Technical issues also need to be considered with respect to accessing and running digital technology. While no correlation was found between student usage of 'flipped' content and their exam grade, students reported that they used them for revision purposes for this assessment task (Mellefont & Fei, 2014).

Case study 5D: Group conflict resolution video

University: The University of Adelaide

Unit: Professional Skills in Agricultural Sciences III

Coordinator/Teacher: Dr Ian Nuberg

Year: Level III (Advanced)

Unit context: This is a core capstone unit for the Bachelor of Agricultural Science. This unit has two components: 1. Communication theory and skills (60%), and 2. Professional Internship (40%). Communication theory and skills is coursework undertaken in the first half of Semester 2, in Year 3 of the degree.

Description of assessment task: Groups of three to four students work together within a committee during the semester. One of the tasks the committee must complete is the production of a 10-minute YouTube video illustrating the principles of conflict resolution in a professional setting.

This assessment activity is supported by lectures/tutorials on conflict resolution and management techniques. Each group must research the content of their scenario (within an agriculturally-related workplace) and the production processes required for the final output. Students also assess each other's contribution to the activity.

Educational aims: Students have the opportunity to practise and demonstrate effective and professional group work while researching specific agricultural content for their end product. This task specifically addresses the unit intended learning outcomes for a successful student to be able to communicate effectively and professionally; effectively deal with various media and situations of conflict resolution; and to understand the conditions of professional practice.

Assessment details: The conflict resolution video is worth 10% of the overall grade. Students are given details of the assignment in Week 4 of the semester. Videos are presented and assessed in class in Week 8 of the semester. A peer assessment formula is also used to determine contribution of members in the group.

Other relevant comments or advice: There are two main considerations with this activity:

1. The need for groups to work together effectively. This can be challenging but the inclusion of peer assessment seems to aid in this requirement.
2. The number of scenarios or potential roles provided to the class. Only providing a single scenario or set of roles based on previous years can lead to derived videos that have not extended students appropriately. Multiple scenarios and multiple roles are therefore preferable.

This format could also be used to develop negotiation skills e.g. by using a scenario of an agribusiness company takeover.

Case study 5E: Exposure assessment and risk characterisation of food and food-borne pathogens

University: University of Tasmania

Unit: Advanced Food Safety Management

Coordinator/Teacher: Associate Professor Tom Ross

Year: Level III (Advanced)

Unit in context: This unit is an elective in the Bachelor of Agricultural Science. This unit considers the cause and nature of specific hazards posed by various food-borne pathogens, chemical and physical objects, and the scientific basis of new technologies for detection and quantification of these hazards in foods.

Description of assessment task: Students select a food, or type of food, which a food-borne hazard can contaminate. They then choose a particular population of interest (e.g. all Australians, all Tasmanians, immunity-compromised Tasmanians etc.) who are likely to eat or be exposed to that food.

In the first part of this assessment task, students need to try to estimate, in an objective manner, the likely exposure of their chosen population to the hazard and assess the risk to that population, i.e. the disease burden that their exposure to the food-borne hazard will cause.

In the second part of this assessment task, students are assessed on their capacity to source and synthesise information required to analyse risk attributable to the specific hazard in a particular food, with a focus on assessing the exposure and disease severity, and to present this information in a useful form.

Educational aims: Students should gain:

1. an understanding of the range, nature and mode of action of natural ingredients and contaminants in foods that can harm people who eat these foods
2. an understanding of the challenges in assuring food safety
3. familiarity with a range of tools, approaches and resources that can be used to differentiate important from trivial hazards and to develop systems to limit foodborne hazards to acceptable levels
4. knowledge of a range of approaches to reduce the level, and probability of the presence of, a range of hazards in food
5. knowledge and skills to be able to effectively use those tools, technologies and approaches to better manage the safety of foods.

Assessment details: For the first assessment task, students should demonstrate an understanding of the range, nature and mode of action of natural ingredients and contaminants in foods. This task is between 1500 to 2000 words in length and worth 15% of the overall grade.

For the second assessment task, students are required to demonstrate a thorough understanding of the tools required to manage risks associated with foodborne hazards and to communicate this risk. The report is between 1200 to 1800 words in length and is worth 10% of the overall grade.

Other relevant comments or advice: This assessment task builds on an initial report, which identified a specific food or group of foods and a food-borne hazard. A final report then requires students to evaluate risk management options and an implementation strategy for their control for the selected food and food-borne hazard.

Case study 5F: Herbicide management

University: University of Tasmania

Unit: Crop Protection

Coordinator/Teacher: Dr David Parsons

Year: Level III (Advanced)

Unit in context: This is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit studies the principles behind management of crop insect and weed pests and diseases.

Details of assessment task: Trays are planted each with a mixture of ryegrass, barley, lucerne and canola in the week then Block A is sprayed with one of eleven herbicides or water immediately after sowing. A second application of the same herbicide is applied to Block B six weeks later. Each tray is sprayed only once and each herbicide is applied in accordance with the commercial recommendation. Eleven herbicides are then applied: Basta®, Boxer Gold®, Fusilade®, Gesatop®, Goal®, Kamba®, Roundup®, Stomp®, Totril®, Tryquat® and Verdict®.

Students need to make detailed weekly observations about the effects of the herbicides on the plants in Blocks A and B and decide which tray ID (labelled 1-12) has been sprayed with which herbicide (or water). For each herbicide, students describe:

1. active constituent
2. herbicide group
3. poison schedule and safety precautions
4. recommended rate of application for a specified cropping situation of their choice
5. mode of action and anticipated symptoms on the plant.

Educational aims: Students should:

1. demonstrate the importance of weeds, their identification and management in pasture and cropping systems
2. compare and contrast the uses and limitations of chemical, cultural, biological control and host resistance for management of crop pests and diseases
3. have a conceptual understanding of the factors affecting implementation of integrated pest and disease management.

Assessment details: Students describe their results in a report (15%, 2500 words) and briefly comment on the sustainable usage of herbicides in agricultural production systems, highlighting how herbicides can be incorporated into Integrated Weed Management programs.

Other relevant comments or advice: It is necessary to set this activity up well in advance and to locate a source of the weed seed. Take care in applying the herbicide treatments evenly to the plants as the uneven development of symptoms will confuse students.

During class, it is helpful to go to the glasshouse and describe some of the visual symptoms of the plants, as not all students will have prior experience in doing this. Occasionally the herbicide will not result in the expected symptoms due to, for example, temperature differences. Students are encouraged to consider the potential for atypical plant responses to the herbicide when preparing their reports.

It is necessary to explain to students how to interpret Material Safety Data Sheets (MSDS) and the herbicide label instructions that are supplied by the manufacturer. Registered herbicides are approved for the purposes and uses stated on the product's label. These differ among herbicides so it is important to check to avoid 'off-label' use e.g. Herbicide A may be registered for use on canola, whereas Herbicide B may be registered for use on canola and barley.

Case study 5G: Information literacy and referencing

University: University of Tasmania

Unit: Sustainable Resource Management

Coordinator/Teacher: Dr Tina Botwright Acuña

Year: Level I (Introductory)

Unit in context: This is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit explores human population growth and the impending global food crisis by introducing agriculture as a managed ecosystem, from the earliest shifting cultivation systems to the most intensive systems currently practiced today.

Description of assessment task: Students participate in a tutorial where they are first introduced to the concept of information literacy, how to locate source material and how to critically assess its relevance to the topic.

This is followed by an activity where students create an EndNote library. Students first enter several different types of references into their database. This requires students to correctly identify and match components of the reference to the database fields. Secondly students export references from Web of Knowledge or a journal webpage directly into the database.

Finally, students try out the EndNote cite-while-you-write function. Students submit their EndNote library as part of their first assignment, which is assessed for academic integrity and adherence to the Harvard style of referencing.

Educational aims: Students should:

1. demonstrate knowledge of changes in agricultural practices and systems
2. understand major ecosystem processes in agricultural systems
3. understand concepts of social, economic and environmental sustainability in agricultural production
4. develop information literacy skills relevant to tertiary study (accessing information, critical analysis of information, academic integrity, scientific writing including referencing, use of the online Learning Management System).

Assessment details: Students submit a portfolio of work for their first assessment task (Weeks 1 to 5), consisting of summaries of two readings, notes for one out of two field trips, a reflection on their participation in tutorials, a glossary of scientific terms and an EndNote library of 20 references. This assignment is worth 15% of the overall grade.

Other relevant comments or advice: We have positive feedback from students who appreciate that EndNote is introduced early in their degree as it assists with referencing their academic work.

Students are encouraged to continue to use referencing software as they progress through their course, although it is not compulsory.

We reinforce that citation software such as EndNote is a tool and only as accurate as the information entered into the database and then used by the students in their writing.

Case study 5H: Debates on genetically modified organisms

University: University of Tasmania

Unit: Crop Protection

Coordinator/Teacher: Associate Professor Calum Wilson, Dr Karen Barry, Associate Professor Geoff Allen

Year: Level III (Advanced)

Unit in context: This is a core unit in the Bachelor of Agricultural Science and Bachelor of Agriculture. This unit studies the principles behind management of crop insect and weed pests and diseases.

Description of assessment task: For the debate, groups of 3– 4 students are allocated the affirmative or negative team. Each student provides a 5-minute verbal presentation and is expected to support their team line and rebut the opposing team. Before the debates, students are allocated a specific topic related to the general theme of the debates, in this case Genetically Modified Organisms (GMOs). Students prepare a 2-page fact sheet on this topic.

All of these fact sheets are graded, then collated and available to students to help with their debate preparation. Each group produces a one-page summary of their debate with key references listed. The summary includes the title of the debate, main points and issues. Examples of topics related to GMOs include:

1. Outcrossing of herbicide resistant GMO crops with wild species and non-GMO crops poses an unacceptable risk for the environment and human health.
2. Crop plants that express *Bacillus thuringiensis* provide a sustainable approach to insect pest control.
3. Cisgenics and intragenics are acceptable alternative to transgenics for genetic manipulation of plants for improved crop protection traits.
4. GMO technologies are critical to obtain effective disease-resistance within the limited gene pool present of our major crop plants.

Educational aims: Students should:

1. demonstrate the importance of weeds, their identification and management in pasture and cropping systems
2. compare and contrast the uses and limitations of chemical, cultural, biological control and host resistance for management of crop pests and diseases
3. have a conceptual understanding of the factors affecting implementation of integrated pest and disease management
4. demonstrate team work and oral presentation skills.

Assessment details: The assessment task is worth 7.5% of the overall grade. Students are assessed individually on the evidence in support of argument and critical analysis of the literature; presentation skills, including the ability to logically organise ideas and their rebuttal of the opposing team's ideas.

Other relevant comments or advice: To enable inclusiveness and support skill development in group work, debate teams are nominated by staff to ensure a mix of student diversity and ability. A "check-up" session is held between staff and each debate group about four weeks prior to the debates to ensure preparation is underway and that all team members are contributing.

Grading is conducted on the individual student presentation regardless of which team wins the debate. A popular vote determines the winning team of each debate.

References

Abadi A. (2003). Learning to manage a risky business. Presented at 47th Annual Conference of the Australian Agricultural and Resource Economics Society. 12–14 February 2003, Freemantle, WA.

Abi-El-Mona I & Abd-El-Khalick F. (2011). Perceptions of the nature and 'goodness' of argument among college students, science teachers, and scientists. *International Journal of Science Education, 33*, 573–605.

Abrams KM, Zimbres T & Carr C. (2015). Communicating sensitive scientific Issues: The interplay between values, attitudes, and euphemisms in communicating livestock slaughter. *Science Communication, 37*, 485–505.

ACDS TL Centre (2016). Science TLOs. http://www.acds-tlcc.edu.au/science-threshold learning-outcomes/using-the-science-tlos/ Accessed 2 April 2016.

Ag Institute Australia. (2014). Ag Institute Australia submission to the Federal Government Agricultural Competitiveness White Paper (IP459). http://www.aginstitute.com.au/Submissions/AIA%20White%20paper%20submission%20FINAL.pdf. Accessed 5 February 2016.

Alcaraz-Rodriguez R, Villasana M & Alvarez MM. (2014). Fine tuning entrepreneurship education: How do programs impact entrepreneurship characteristics in students? Paper contributed to 9th European Conference on Innovation and Entrepreneurship. Belfast, UK, 18–19 September 2014.

Anderson JR. (2013). *The architecture of cognition.* New York, NY: Psychology Press.

Anderson LW, Krathwohl DR & Bloom BS. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Boston: Allyn & Bacon.

Anderson WA, Banerjee U, Drennan C, Elgin S, Epstein I, Handelsman J, Hatfull G, Losick R, O'Dowd D & Olivera B. (2011). Science education. Changing the culture of science education at research universities. *Science, 331*, 153–154.

Andreasen R. (2004). Integrating experiential learning into college of agriculture capstone courses: Implications and applications for practitioners. *NACTA Journal, 48*, 52–57.

Archer A & Hughes C. (2011). *Explicit instructions: Effective and efficient teaching*, New York: Guilford Press.

Argabright K, McGuire J, King J. (2012). Extension through a new lens: Creativity and innovation now and for the future. *Journal of Extension, 50*. http://www.joe.org/joe/2012april/comm2.php Accessed 2 April 2016.

Australian Bureau of Statistics (ABS) (2012). 1301.0 Year Book Australia > Environment > Water. http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Water~279 Accessed 7 January 2016.

Australian Bureau of Statistics (2013). Topics @ a Glance – Agriculture. http://www.abs.gov.au/websitedbs/c311215.nsf/web/agriculture Accessed 7 January 2016.

Australian Bureau of Statistics (2014). Submission to the Agricultural Competitiveness Issues Paper (IP391). http://agwhitepaper.agriculture.gov.au/IP%20Submissions%20for%20publication/2014-04%20April/IP391%20Australian%20Bureau%20of%20Statistics.pdf Accessed 25 February 2016.

Australian Council of Deans of Agriculture (2014). Submission to the Agricultural Competitiveness White Paper (IP538). http://agwhitepaper.agriculture.gov.au/IP%20Submissions%20for%20publication/2014-04%20April/IP538%20Australian%20Council%20of%20Deans%20of%20Agriculture.pdf Accessed 25 February 2016.

Australian Government. (2015). Agricultural Competitiveness White Paper – At a Glance. http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-whitepaper-at-a-glance.pdf Accessed 25 February 2016.

Australian Government Productivity Commission (2014). Submission to the Agricultural Competitiveness Taskforce (IP534). http://www.pc.gov.au/research/supporting/agricultural-competitiveness-taskforce/agricultural-competitiveness-submission.pdf Accessed 25 February 2016.

Australian Government (2015). *Higher Education Standards Framework (Theshold Standards) 2015*. F2015L01639. Department of Education and Training.

Baeten M, Dochy F, Struyven K, Parmentier E & Vanderbruggen A. (2016). Student-centred learning environments: An investigation into student teachers' instructional preferences and approaches to learning. *Learning Environments Research, 19*, 43–62.

Baeten M, Kyndt E, Struyven K & Dochy F. (2010). Using student-centred learning environments to stimulate deep approaches to learning: Factors encouraging or discouraging their effectiveness. *Educational Research Review, 5,* 243–260.

Baram-Tsabari A & Lewenstein BV. (2013). An instrument for assessing scientists' written skills in public communication of science. *Science Communication, 35*, 56–85.

Barrett T. (2005). Understanding problem-based learning, Ireland: Centre for Excellence in Learning and Teaching, NUI Galway and All Ireland Society for Higher Education (AISHE) Dublin.

Barron B & Darling-Hammond L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. Book Excerpt. George Lucas Educational Foundation.

Barrows HS. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 68*, 3–12.

Bauerle TL & Park TD. (2012). Experiential learning enhances student knowledge retention in the plant sciences. *HortTechnology, 22*, 715–718.

Bawden RJ, Macadam RD, Packham RJ & Valentine I. (1984). Systems thinking and practices in the education of agriculturalists. *Agricultural Systems, 13*, 205–225.

BBCH. (2016) BBCH Decimal Code. http://www.jki.bund.de/fileadmin/dam_uploads/_veroeff/bbch/BBCH-Skala_englisch.pdf Online resource. Accessed 2 April 2016.

Beebe S & Masterson J. (2003). *Communicating in small groups*. Massachusetts, Boston: Pearson Education Inc.

Bell RL, Smetana L & Binns I. (2005). Simplifying inquiry instruction. *The Science Teacher, 72*, 30–33.

Bell S. (2010). *Project-based learning for the 21st century: Skills for the future*. The Clearing House, 83, 39–43.

Bell T, Urhahne D, Schanze S & Ploetzner R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education, 32*, 349–377.

Besley JC & Tanner AH. (2011). What science communication scholars think about training scientists to communicate. *Science Communication, 33*, 239–263.

Biggs JB & Collis KF. (1982). *Evaluating the Quality of Learning: The SOLO Taxonomy (Structure of the Observed Learning Outcome)*. New York: Academic Press.

Biggs J & Tang C. (2007). Teaching for Quality Learning at University. Maidenhead, England: Open University Press McGraw-Hill.

Billing D. (2007). Teaching for transfer of core/key skills in higher education: Cognitive skills. *Higher Education, 53*, 483–516.

Bloom BS. (1956). *Taxonomy of Educational Objectives: The Classification of Education Goals. Cognitive Domain. Handbook 1*. London: Longman.

Blum A. (1996). *Teaching and learning in Agriculture: A guide for agricultural educators*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Botwright Acuña T, Able A, Kelder J, Bobbi P, Guisard Y, Bellotti W, McDonald G, Doyle R, Wormell P & Meinke H. (2014a). *Learning and Teaching Academic Standards Statement for Agriculture*, Sydney: Office for Learning and Teaching. http://www.olt.gov.au/resource-defining-learning-outcomes-informing-curricula-design-agriculture Accessed 2 April 2016.

Botwright Acuña T, Kelder J-A, Lane P, Hannan G & Jones S. (2013). Developing threshold learning outcomes for agricultural science. *International Journal of Innovation in Science and Mathematics Education, 21*, 54–66.

Botwright Acuña T, Kelder JA, Able AJ, Guisard Y, Bellotti WD, McDonald G, Doyle R, Wormell P & Meinke H. (2014b). Academic, industry and student perspectives on the inclusion of 'vocational knowledge' in a *Learning and Teaching Academic Standards Statement for Agriculture. Journal of Learning Design, 7*, 1–15.

Botwright Acuña TL, McDonald G, Kelder J & Able AJ. (2016). Implementing the threshold learning outcomes for Agriculture at two Australian universities. *Journal of Teaching and Learning for Graduate Employability, 7*, 2–21.

Bray B, France B & Gilbert JK. (2012). Identifying the essential elements of effective science communication: What do the experts say? *International Journal of Science Education, Part B, 2*, 23–41.

Bradbear C & Friel S. (2013). Integrating climate change, food prices and population health. *Food Policy, 43*, 56–66.

Brew A, (2006). *Research and teaching: Beyond the divide*. New York, NY: Palgrave MacMillan.

Brown PJ. (2010). Process-oriented guided-inquiry learning in an introductory anatomy and physiology course with a diverse student population. *Advances in Physiology Education, 34*, 150–155.

Burke A. (2011). Group work: How to use groups effectively. *The Journal of Effective Teaching, 11*, 87–95.

Cameron I, Hadgraft R & Wright S. (2010). *Engineering and ICT: Learning and Teaching Academic Standards Statement*. Strawberry Hills, NSW, Australia: Australian Learning and Teaching Council. http://www.olt.gov.au/resource-engineering-ict-ltas-statement-altc-2010 Accessed 2 April 2016.

Cannon HM & Feinstein AH. (2014). Bloom beyond Bloom: Using the revised taxonomy to develop experiential learning strategies. *Developments in Business Simulation and Experiential Learning, 32*, 348–356.

Capon N & Kuhn D. (2004). What's so good about problem-based learning? *Cognition and Instruction, 22*, 61–79.

Carberry P. (2001). Are science rigour and industry relevance both achievable in participatory action research?10th Australian Society of Agronomy Conference. Australian Society of Agronomy: Hobart, 1–12.

Carless D, Salter D, Yang M & Lam J. (2011). Developing sustainable feedback practices. *Studies in Higher Education, 36*, 395–407.

Chan V. (2011). Teaching oral communication in undergraduate science: Are we doing enough and doing it right? *Journal of Learning Design, 4,* 71–79.

Charles Sturt University (2014). Response to Agricultural Competitive Issues Paper (IP560). https://www.csu.edu.au/__data/assets/pdf_file/0011/991577/Response-to-the-Agricultural-Competitiveness-Issue-Paper-April-2014-.pdf Accessed 25 February 2016.

Chase A, Pakhira D & Stains M. (2013). Implementing process-oriented, guided-inquiry learning for the first time: Adaptations and short-term impacts on students' attitude and performance. *Journal of Chemical Education, 90*, 409–416.

Cheek JG, Arrington LR, Carter S & Randell RS. (1994). Relationship of supervised agricultural experience program participation and student achievement in agricultural education. *Journal of Agricultural Education, 35*, 1–5.

Clough MP. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science & Education, 15*, 463–494.

Colthorpe, K, Rowland, S & Leach, J. (2013). *Good Practice Guide (Science) Threshold Learning Outcome 4: Communication*. Office for Learning and Teaching. http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011 Accessed 2 April 2016.

Commonwealth of Australia. (2012). Australia in the Asian Century White Paper 2012. Department of the Prime Minister and Cabinet, Canberra, Australia http://www.asiaeducation.edu.au/verve/_resources/australia-in-the-asian-century-white-paper.pdf Accessed 2 April 2016.

Commonwealth of Australia. (2015). Agricultural Competitiveness White Paper. Canberra http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf. Accessed 2 April 2016.

Conroy CA, Trumbull DJ & Johnson D. (1999). *Agriculture as a rich context for teaching and learning, and for learning mathematics and science to prepare for the workforce of the 21st century*. Transitions from Childhood to the Workforce Teaching and Learning Conference. September 17–19, Cornell University, Ithaca, NY. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.197.5726&rep=rep1&type=pdf Accessed 2 April 2016.

Crowe A, Dirks C & Wenderoth MP. (2008). Biology in bloom: Implementing Bloom's taxonomy to enhance student learning in biology. *CBE-Life Sciences Education, 7*, 368–381.

Dale E. (1946). The cone of experience. Audio-visual Methods in Teaching, 1, 37–51.

DAFF (2012). National Food Plan Green Paper. Department of Agriculture Fisheries and Forestry, Canberra. http://www.daff.gov.au/__data/assets/pdf_file/0009/2175156/national-food-plan-green-paper-072012.pdf Accessed 2 April 2016.

Dannels DP. (2001). Time to speak up: A theoretical framework of situated pedagogy and practice for communication across the curriculum. *Communication Education, 50*, 144–158.

Dannels DP, Housley Gaffney AL & Martin KN. (2011). Students' talk about the climate of feedback interventions in the critique. *Communication Education, 60*, 95–114.

Davies W. (2009). Groupwork as a form of assessment: Common problems and recommended solutions. *Higher Education, 58*, 563–584.

De Grez L, Valcke M & Roozen I. (2009). The impact of an innovative instructional intervention on the acquisition of oral presentation skills in higher education. *Computers and Education, 53*, 112–120.

DebBurman SK. (2002). Learning how scientists work: Experiential research projects to promote cell biology learning and scientific process skills. *Cell Biology Education, 1*, 154–172.

DeHaan RL. (2005). The impending revolution in undergraduate science education. *Journal of Science Education and Technology, 14*, 253–269.

Delors J. (1996). Learning: The treasure within. Report to the UNESCO of the International Commission on Education for the Twenty-first Century. UNESCO Publishing. http://unesdoc.unesco.org/images/0010/001095/109590eo.pdf Accessed 2 April 2016.

Deng F, Chen D-T, Tsai C-C & Chai CS. (2011).Students' views of the nature of science: A critical review of research. *Science Education, 95*, 961–999.

Dietz T. (2013). Bringing values and deliberation to science communication. Proceedings of the National Academy of Sciences of the United States of America, 110, 14081–14087.

Divan A & Mason S. (2015). A programme-wide training framework to facilitate scientific communication skills development amongst biological sciences Masters students. *Journal of Further and Higher Education, 39*, 1–25.

Dresner M, de Rivera C, Fuccillo KK & Chang H. (2014). Improving higher-order thinking and knowledge retention in environmental science teaching. *BioScience, 64*, 40–48.

Driscoll J. (2000). *Practising Clinical Supervision*. London, UK: Bailliere Tindall.

Driscoll J. (2007). *Practising Clinical Supervision: A reflective approach for healthcare professionals*. 2nd ed. Edinburgh, UK: Bailliere Tindall Elsevier.

Driscoll J. (1994). Reflective practice for practise. *Senior Nurse, 13*, 47–50.

Edelson DC, Gordin DN & Pea RD. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences, 8*, 391–450.

Elby A & Hammer D. (2001). On the substance of a sophisticated epistemology. *Science Education, 85*, 554–567.

Engel PG & van den Bor W. (1995). Agricultural education from a knowledge systems perspective: From teaching to facilitating joint inquiry and learning. *European Journal of Agricultural Education and Extension, 1*, 1–23.

English MC & Kitsantas A. (2013). Supporting student self-regulated learning in problem- and project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 7*, 6.

Esters L & Retallick M. (2013). Effect of an experiential and work-based learning program on vocational identity, career decision self-efficiacy, and career maturity. *Career and Technical Education Research, 38*, 69–83.

Fearon C, McLaughlin H & Tan Yoke E. (2012). Using student group work in higher education to emulate professional communities of practice. *Education & Training, 54*, 114–125.

Felder R & Brent R. (2001). Effective stategies for cooperative learning. *Journal of Cooperation and Collaboration in College Teaching, 10*, 69–75.

Field R, Duffy J & Huggins A. (2015). Teaching independent learning skills in the first year: A positive psychology strategy for promoting law student well-being. *Journal of Learning Design, 8*, 1–10.

Friedel C, Irani T, Rudd R, Gallo M, Eckhardt E & Ricketts J. (2008). Overtly teaching critical thinking and inquiry-based learning: A comparison of two undergraduate biotechnology classes. *Journal of Agricultural Education, 49*, 72–84.

Froyd J & Simpson N. (2010). Student-centered learning addressing faculty questions about student centered learning. Presented at Course, Curriculum, Labor, and Improvement Conference, Washington DC, 30 (11). http://ccliconference.org/files/2010/03/Froyd_Stu-CenteredLearning.pdf Accessed 2 April 2016.

Gray FE, Emerson L & MacKay B. (2005). Meeting the demands of the workplace: science students and written skills. *Journal of Science Education and Technology, 14*, 425–435.

Hamstra D, Kemsley JN, Murray DH & Randall DW. (2011). Integrating webinar and blogging technologies into chemistry seminar. *Journal of Chemical Education, 88*, 1085–1089.

Hanauer DI, Jacobs-Sera D, Pedulla ML, Cresawn SG, Hendrix RW & Hatfull GF. (2006). Teaching scientific inquiry. *Science-New York then Washington, 314*, 1880.

Hancock P, & Freeman M. (2010). *Business, Management and Economics: Learning and Teaching Academic Standards Statement for Accounting*, Sydney: Australian Learning and Teaching Council. http://www.abdc.edu.au/data/Accounting_LS/Accounting_Learning_Standards_-_February_2011.pdf Accessed 2 April 2016.

Hanson DM. (2006). *Instructor's Guide to Process-Oriented Guided-Inquiry Learning*, Lisle: Pacific Crest.

Hay I & Rashleigh J. (2010a). *Arts, Social Sciences and Humanities GEOGRAPHY Learning and Teaching Academic Standards Statement*, Sydney: Australian Learning and Teaching Council. http://disciplinestandards.pbworks.com/w/file/fetch/52684122/altc_standards_GEOGRAPHY_080211_v2.pdf Accessed 2 April 2016.

Hay I & Rashleigh, J. (2010b). *Arts, Social Sciences and Humanities HISTORY Learning and Teaching Academic Standards Statement*, Sydney: Australian Learning and Teaching Council. http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-resources-geography-and-history-2011 Accessed 2 April 2016.

Hazel E & Prosser M. (1994). First-year university students' understanding of photosynthesis, their study strategies and learning context. *The American Biology Teacher, 56*, 274–279.

Healey M. (2000). Developing the scholarship of teaching in higher education: a discipline-based approach. Higher Education Research and Development, 19, 169-189.

Helle L, Tynjälä P & Olkinuora E. (2006). Project-based learning in post-secondary education – theory, practice and rubber sling shots. *Higher Education, 51*, 287–314.

Hills J, Robertson G, Walker R, Adey M & Nixon I. (2003). Bridging the gap between degree programme curricula and employability through implementation of work-related learning. *Teaching in Higher Education, 8*, 211–231.

Hmelo-Silver C. (2004). Problem-based Learning: What and how do students learn? *Educational Psychology Review, 16*, 235–266.

Hofstein A & Lunetta VN. (2004). The laboratory in science education: Foundations for the twenty–first century. *Science Education, 88*, 28–54.

Holmes J & Fountain W. (2010). *Learning and Teaching Academic Standards Project: Creative and performing arts, learning and teaching academic standards statement*, Sydney, Australia: Australian Learning and Teaching Council. http://www.olt.gov.au/resource-creative-performing-arts-ltas-statement-altc-2010 Accessed 2 April 2016.

Howitt SM & Wilson AN. (2015). Developing, expressing and contesting opinions of science: Encouraging the student voice. *Higher Education Research and Development, 34*, 541–553.

Hughes C & Magin D. (1996). Demonstrating knowledge and understanding. In P. Nightingale et al. (eds.). *Assessing Learning in Universities*, 127–161. Sydney: University of New South Wales Press.

Hugo G, Feist H & Tan G. (2013). Internal migration and regional Australia. Australian Population and Migration Research Centre, 1. https://www.adelaide.edu.au/apmrc/pubs/policy-briefs/APMRC_Policy_Brief_Vol_1_6_2013.pdf Accessed 25 February 2016.

Jerde CL & Taper ML. (2004). Preparing undergraduates for professional writing. *Journal of College Science Teaching, 33*, 34–37.

Jones S, Yates B & Kelder J. (2011). *Learning and Teaching Academic Standards Project – Science Learning and Teaching Academic Standards Statement*. Australian Learning and Teaching Council. Strawberry Hills, NSW, Australia. http://www.olt.gov.au/system/files/altc_standards_SCIENCE_240811_v3.pdf Accessed 2 April 2016.

Jones SM. (2013). *Good Practice Guide (Science) Threshold Learning Outcome 2: Scientific Knowledge*. Sydney, Australia: Office for Learning and Teaching. http://www.acds-tlcc.edu.au/wp-content/uploads/sites/14/2013/01/Science-Good-Practice-Guide-2013-TLO2.pdf Accessed 2 April 2016.

Jones SM. (2014). Assessing the science knowledge of university students: Perils, pitfalls and possibilities. *Journal of Learning Design, 7*, 16–27.

Jordan NR, Bawden RJ & Bergmann L. (2008). Pedagogy for addressing the worldview challenge in sustainable development of agriculture. *Journal of Natural Resources & Life Sciences Education, 37*, 92–99.

Joughin G. (2007). Student conceptions of oral presentations. *Studies in Higher Education, 32*, 323–336.

Kahn P & O'Rourke K. (2004). *Guide to curriculum design: Enquiry-based learning*. Higher Education Academy, 1–10. http://www.ceebl.manchester.ac.uk/resources/guides/kahn_2004.pdf Accessed 2 April 2016.

Kahn &, O'Rourke K. (2005). Understanding enquiry-based learning. In: *Handbook of Enquiry and Problem Based Learning*. Barrett, T, Mac Labhrainn, I, Fallon, H. (Eds.). Galway, CELT. http://www.aishe.org/readings/2005-2/chapter1.pdf Accessed 2 April 2016.

Katkin W. (2003). The Boyer commission report and its impact on undergraduate research. *New Directions for Teaching and Learning*, 2003, 19–38.

Kift S, Israel M & Field R. (2010). *Bachelor of Laws Learning and Teaching Academic Standards Statement*, Sydney: Australian Learning and Teaching Council. http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-resources-law-2011 Accessed 2 April 2016.

Kim MC, Hannafin MJ & Bryan LA. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education, 91*, 1010–1030.

Kirkup L. (2013). Inquiry-oriented learning in science: *Transforming practice through forging new partnerships and perspectives*. Australian Government Office for Learning and Teaching, Sydney. Accessed 25 June 2013. http://www.iolinscience.com.au/about/final-report/ Accessed 2 April 2016.

Kirkup L. (2015). Inquiry-oriented learning. Global Engineering Deans Conference (GEDC) Adelaide. http://www.gedcouncil.org/sites/default/files/Inquiry%20Oriented%20Learning%20-%20Les%20Kirkup.pdf Accessed 2 April 2016.

Kirkup L & Bonfiglioli C. (2011). Research-inspired learning revitalises the curriculum for first-year science majors. *International Journal of Innovation in Science and Mathematics Education, 19*, 1–15.

Kirkup L & Johnson L. (2013). *Good Practice Guide (Science) Threshold Learning Outcome 3: Inquiry and problem-solving*, Sydney: Office for Learning and Teaching. http://www.acds-tlcc.edu.au/wp-content/uploads/sites/14/2013/01/Science-Good-Practice-Guide-2013_FINAL-TLO3.pdf Accessed 2 April 2016.

Kirkup L & Mears A. (2015). Inquiry Orientated Learning in Science. http://www.iolinscience.com.au/ Accessed 2 April 2016.

Kirkup L, Pizzica J, Waite K & Srinivasan L. (2010). Realizing a framework for enhancing the laboratory experiences of non-physics majors: From pilot to large-scale implementation. *European Journal of Physics, 31*, 1061.

Kirschner PA, Sweller J & Clark RE. (2006). Why minimal guidance during instruction does not work: An analysis of the gailure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*, 75–86.

Knauft D. (2015). *Ethics in the agricultural curriculum. Agricultural higher education in the 21st century. A global challenge in knowledge transfer to meet world demands for food security and sustainability*. Zaragosa, Spain. Ramagosa, I, Navarro, M, Heath, S, Lopez-Francos, A. (Eds.) 35–42.

Knight PT. (2001). Complexity and curriculum: A process approach to curriculum-making. *Teaching in Higher Education, 6*, 369–381.

Knobloch NA. (2003). Is experiential learning authentic? *Journal of Agricultural Education, 44*, 22–34.

Kolb D. (1984). *Experiential learning: Experience as the source of learning and development*, Englewood Cliffs, NJ: Prentice-Hall Inc.

Krathwohl DR. (2002). A revision of Bloom's taxonomy: An overview. T*heory into Practice, 41*, 212–218.

Krumwiede T & Bline D. (1997). Encouraging active learning through the use of student developed problems. *Accounting Educators Journal, 9*, 116–129.

Kuhlthau CC, Maniotes LK & Caspari AK. (2012). *Guided inquiry design: A framework for inquiry in your school*. Santa Barbara, California: Libraries Unlimited.

Kuhn D, Black J, Keselman A & Kaplan D. (2000). The development of cognitive skills to support inquiry learning. *Cognition and Instruction, 18*, 495–523.

LaCharite K. (2015). Re-visioning agriculture in higher education: The role of campus agriculture initiatives in sustainability education. *Agriculture and Human Values, 32*, 1–15.

Lauer T & Hendrix J. (2009). A model for quantifying student learning via repeated writing assignments and discussions. *International Journal of Teaching and Learning in Higher Education, 20*, 425–433.

Lebow D. (1993). Constructivist values for instructional systems design: Five principles toward a new mindset. *Educational Technology Research and Development, 41*, 4–16.

Lederman NG. (2007). Nature of science: Past, present and future, in SK Abell and NG Lederman, (eds.), *Handbook of research on science education*. Mahwah, NJ: Lawrence Erlbaum Associates, 831–880.

Lim KH, Hu W, Maynard LJ & Goddard E. (2014). A taste for safer beef? How much does consumers' perceived risk influence willingness to pay for country-of-origin labeled beef. *Agribusiness, 30*, 17–30.

Loike J, Rush B, Scweber A & Fishchbach R. (2013). Lessons learned from undergraduate students in designing a science-based course in bioethics. *CBE-Life Sciences Education, 12*, 701–710.

Loughlin W. (2013). *Good Practice Guide (Science). Threshold Learning Outcome 5: Personal and professional responsibility*. Office for Learning and Teaching, Sydney, Australia. http://www.acds-tlcc.edu.au/wp-content/uploads/sites/14/2013/01/Science-Good-Practice-Guide-2013-TLO5.pdf Accessed 2 April 2016.

Loveys BR, Kaiser BN, McDonald G, Kravchuk O, Gilliham M, Tyerman S & Able AJ. (2014). The development of student research skills in second year plant biology. I*nternational Journal of Innovation in Science and Mathematics Education, 22*, 15–25.

Macquarie University (2015). Teaching and assessing cognitive capabilities for undergraduate students – Critical, creative and innovative thinking. http://staff.mq.edu.au/teaching/curriculum_assessment/critical_creative/ Accessed March 2016.

Magee D & Meier A. (2011). Science education and culture: Inquiry-based learning. *Journal of Intercultural Communication, 27*. http://www.immi.se/intercultural/ Accessed 2 April 2016.

Magin D & Helmore P. (2001). Peer and teacher assessments of oral presentation skills: How reliable are they? *Studies in Higher Education, 26*, 287–298.

Major CH & Palmer B. (2001). Assessing the effectiveness of problem-based learning in higher education: Lessons from the literature. *Academic Exchange Quarterly, 5*, 4–9.

Mallawaarachchi T & Green R. (2013). A productivity approach to evaluating on-farm sustainable land management interventions. Contributed paper prepared for presentation at the 57th AARES Annual Conference, Sydney, New South Wales, 5–8 February 2013.

Marton F & Säljö R. (1976). On qualitative differences in learning: Outcome and process. *British Journal of Educational Psychology, 46*, 4–11.

Mason GS, Shuman TR & Cook KE. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *Education, IEEE Transactions on Education, 56*, 430–435.

Mate K, Riveros C, Weidenhofer J, Goldie B, Scott J, Moscato P, Johnstone D & Milward E. (2014). Strategies for enhancing communication between students, academics and researchers participating in large-scale undergraduate research projects. *International Journal of Innovation in Science and Mathematics Education, 22*, 14–29.

Matthews KE & Hodgson Y. (2011). Evidencing learning standards in science: Graduate perceptions of gaining knowledge and skills at two research-intensive universities. Proceedings of The Australian Conference on Science and Mathematics Education. University of Melbourne, 28 –29 September 2011, 114-120.

Mayhew MJ, Simonoff JS, Baumol WJ, Wiesenfeld BM & Klein MW. (2012). Exploring innovative entrepreneurship and its ties to Higher Educational experiences. *Research in Higher Education, 53*, 831–859.

McAlpine I & Dudley N. (2001). Teaching soils online using a problem-based learning design. Proceedings of the Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (ASCILITE 2001). University of Melbourne, 9 –12 December 2001, 387–396.

McCarthy JP & Anderson L. (2000). Active learning techniques versus traditional teaching styles: Two experiments from history and political science. *Innovative Higher Education, 24*, 279–294.

McComas WF. (2014). *Process-orientated guided instruction (POGIL). The Language of Science Education*. Springer, 78–78.

McGuire SJ. (2012). Developing future experts in agriculture for development: Some thoughts on the challenges of capacity. *Journal of International Cooperation for Agricultural Development, 12*, 3–7.

McInnis C, Hartley R & Anderson M. (2000). What did you do with your science degree. A national study of employment outcomes for Science degree holders 1990-2000. University of Melbourne. http://melbourne-cshe.unimelb.edu.au/__data/assets/pdf_file/0005/1494716/ScienceR.pdf Accessed 2 April 2016.

McSweeney P & Rayner J. (2011). Developments in Australian agricultural and related education. *Journal of Higher Education Policy and Management, 33*, 415–425.

Mellefont L & Fei J. (2014). Using Echo360 Personal Capture software to create a 'flipped' classroom for Microbiology laboratory classes. Presented at Rhetoric and Reality: Critical perspectives on educational technology. Proceedings ASCILITE Dunedin 2014, Dunedin, NZ.

Mercer-Mapstone L & Kuchel L. (2015a). Core skills for effective science communication: A teaching resource for undergraduate science education. *International Journal of Science Education: Part B Communication and Public Engagement, 5*, 1–21.

Mercer-Mapstone L & Kuchel L. (2015b). Teaching scientists to communicate: Evidence-based assessment for undergraduate science education. *International Journal of Science Education, 37*, 1613–1638.

Mercer-Mapstone L, Kuchel L. (2016) Teaching scientist to communicate: Adaptable learning activities to develop communication skills in undergraduate science. *Teaching and Learning Inquiry*, *4*, (in press).

Meyer JH & Land R. (2005). Threshold concepts and troublesome knowledge (2): Epistemological considerations and a conceptual framework for teaching and learning. *Higher Education, 49*, 373–388.

Mezirow J. (1991). *Transformative dimensions of adult learning*. San Francisco, CA: Jossey-Bass.

Michael J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*, 159–167.

Michel N, Cater JJ & Varela O. (2009). Active versus passive teaching styles: An empirical study of student learning outcomes. *Human Resource Development Quarterly, 20*, 397–418.

Minhas PS, Ghosh A & Swanzy L. (2012). The effects of passive and active learning on student preference and performance in an undergraduate basic science course. *Anatomical Sciences Education, 5*, 200–207.

Monaghan K, Swisher M, Koenig RL & Rodriguez JC. (2015). Education for sustainable agriculture: A typology of the role of teaching farms in achieving learning goals and objectives. *Environmental Education Research, 21*, 1–24.

Morreale SP, Osborn MM & Pearson JC. (2000). Why communication is important: A rationale for the centrality of the study of communication. *Journal of the Association for Communication Administration 29*, 1–25.

Moskovitz C & Kellogg D. (2011). Inquiry-based writing in the laboratory course. *Science, 332*, 919–920.

Mullen JD & Crean J. (2007). Productivity growth in Australian agriculture: Trends, sources, performance. *Research Report*. Surry Hills, Australia: Australian Farm Institute.

Mumford MD, Hunter ST & Byrne CL. (2009). What is the fundamental? The role of cognition in creativity and innovation. *Industrial and Organizational Psychology, 2*, 353–356.

Naidu S. (2004). Directing assessment at supporting learning. In U. Bernath & A. Szücs (Eds.), Supporting the Learner in Distance Education and E-Learning, Proceedings of the Third EDEN Research Workshop, Carl von Ossietzky University of Oldenburg, Germany, March 4–6, 2004 (77– 82).

Nossal K. (2012). Innovative capacity and productivity: An empirical analysis of Australian grain growers. Paper presented at the 56th Australian Agricultural and Resource Economics Society (AARES) Conference, 7–10 February 2012. Fremantle, Western Australia.

Nossal K & Sheng Y. (2010). Productivity growth: Trends, drivers and opportunities for broadacre and dairy industries. *Australian Commodities, 17,* 216–230.

O'Flaherty J & Phillips C. (2015). The use of flipped classrooms in higher education: A scoping review. *Internet and Higher Education, 25*, 85–95.

Oliver B. (2015). Redefining graduate employability and work-integrated learning: Proposals for effective higher education in disrupted economies. *Journal of Teaching and Learning for Graduate Employability, 6*, 56–65.

Parkin S, Johnson A, Buckland H & White E. (2004). *Learning and skills for sustainable development: Developing a sustainably literate society*. London: HEPS. https://www.forumforthefuture.org/sites/default/files/project/downloads/learningandskills.pdf Accessed 25 February 2016.

Parr B & Edwards MC. (2004). Inquiry-based instruction in secondary agricultural education: Problem-solving-An old friend revisited. *Journal of Agricultural Education, 45*, 106–117.

Parr DM & Trexler CJ. (2011). Students' experiential learning and use of student farms in sustainable agriculture education. *Journal of Natural Resources and Life Sciences Education, 40*, 172–180.

Parr DM, Trexler CJ, Khanna NR & Battisti BT. (2007). Designing sustainable agriculture education: Academics' suggestions for an undergraduate curriculum at a land grant university. *Agriculture and Human Values, 24*, 523–533.

Patterson TF. (2007). The rise and fall of innovative education: An Australian university case study. *Innovative Higher Education, 32*, 71–84.

Perkins D. (1999). The many faces of constructivism. *Educational Leadership, 57*, 6–11.

Phelan L, McBain B, Ferguson A, Brown P, Brown V, Hay I, Horsfield R & Taplin R. (2015). *Learning and Teaching Academic Standards Statement for Environment and Sustainability*, Sydney: Office of Learning and Teaching. http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-statement-environment-and-sustainability-2015 Accessed 28 March 2016.

Pintrich PR. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory Into Practice, 41*, 219–225.

Placing K, Ward M-H, Peat M & Teixeira PT. (2005). Blogging in science and science education. Proceedings of the Blended Learning in Science Teaching and Learning Poster Presentation. University of Sydney, 30 September 2005. 159.

Pratley JE& Hay M. (2010). The job market in agriculture in Australia. *Agricultural Science, 22*, 35–40.

Prensky M. (2001). Digital natives, digital immigrants Part 1. *On the Horizon, 9*, 1.

Pretty J, Sutherland WJ, Ashby J, Auburn J, Baulcombe D & Bell M. (2010). The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability,* 8, 219–36.

Prince M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*, 223–231.

Prosser M & Trigwell K. (1999). *Understanding learning and teaching: The experience in higher education.* McGraw-Hill Education (UK).

Queens University (2016). Inquiry-based learning. https://www.qub.ac.uk/directorates/AcademicStudentAffairs/CentreforEducationalDevelopment/CurriculumDevelopment/Linkingresearchandteaching/Inquiry-basedlearningIBL/ Accessed 28 March 2016.

Rayner G & Papakonstantinou T (2015). Employer perspectives of the current and future value of STEM graduate skills and attributes: An Australian study. *Journal of Teaching and Learning for Graduate Employability, 6,* 100–115.

Rhykerd RL, Tudor KW, Wiegand BR, Kingman DM & Morrish DG. (2006). Enhancing experiential learning through a hands-on crop production and marketing contest. *NACTA Journal, 50*, 25–30.

Ritman K, Kelley G, Bruce S, Walcott J & Loch A. (2011). Agricultural innovation — necessity is the mother of invention. Australian Government, Australian Bureau of Agricultural and Resource Economics and Sciences. Outlook Conference Paper. Australian Department of Agriculture, Canberra.

Roberts TG. (2006). A philiosophical examination of experiential learaning theory for agricultural educators. *Journal of Agricultural Education, 47*, 17.

Robinson JS & Garton BL. (2008). An assessment of the employability skills needed by graduates in the College of Agriculture, Food and Natural Resources at the University of Missouri. *Journal of Agricultural Education, 49*, 96-105.

Rudd R, Baker M & Hoover T. (2000). Undergraduate agriculture student learning styles and critical thinking abilities: Is there a relationship? *Journal of Agricultural Education, 41*, 2-12.

Safe Work Australia. (2011). How to manage work health and safety risks. Code of Practice. http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/633/How_to_Manage_Work_Health_and_Safety_Risks.pdf Accessed 2 April 2016.

Sakellari M. (2015). Cinematic climate change, a promising perspective on climate change communication. *Public Understanding of Science, 24*, 827–841.

Savage SM. (2011). Learning and Teaching Academic Standards Statement for Architecture, Building and Construction, Education, Sydney: Australian Learning and Teaching Council. http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-project-report-2011 Accessed 2 April 2016.

Savery JR. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning, 1*, 9–20.

Schirmer JM, Mauksch L, Lang F, Marvel MK, Zoppi K, Epstein RM, Brock D & Pryzbylski M. (2005). Assessing communication competence: a review of current tools. Family *Medicine, 37*, 184–192.

Schleenbecker R & Hamm U. (2013). Consumers' perception of organic product characteristics: A review. *Appetite, 71*, 420–429.

Schmidt HG, Loyens SMM, van Gog T & Paas F. (2007). Problem-based learning is compatible with human cognitive architecture: commentary on Kirschner, Sweller and Clark (2006). *Educational Psychology, 42*, 91–97.

Schmidt HG, Rotgans JI & Yew EH. (2011). The process of problem-based learning: What works and why. *Medical Education, 45*, 792–806.

Schoffstall AM& Gaddis BA. (2007). Incorporating guided-inquiry learning into the organic chemistry laboratory. *Journal of Chemical Education, 84*, 848.

Sheng Y, Nossal K & Ball E. (2013). Comparing agricultural total factor productivity between Australia, Canada and the United States. Contributed paper prepared for presentation at the 57th AARES Annual Conference, Sydney, New South Wales, 5–8 February 2013.

Shi M, Yang R, Lu N & Deng P. (2011). Construction of 'guided-learning' and reformation on practice education of 'agricultural plant pathology' based on data statistics. *Advances in Computer Science, Environment, Ecoinformatics and Education, 216*, 73–77.

Spronken-Smith R & Walker R. (2010). Can inquiry-based learning strengthen the links between teaching and disciplinary research? *Studies in Higher Education, 35*, 723-740.

Stanford JS & Duwel LE. (2013). Engaging biology undergraduates in the scientific process through writing a theoretical research proposal. *Bioscene: Journal of College Biology Teaching, 39*, 17–24.

Steel A. (2013). *Good Practice Guide (Bachelor of Laws): Law in Broader Contexts*. Office for Learning and Teaching, Strawberry Hills NSW. http://www.lawteachnetwork.org/resources/gpg-broadercontexts.pdf Accessed 2 April 2016.

Stoutjesdijk P & ten Have J. (2013). *Using enabling technologies to meet demands for food security and sustainability*. Department of Agriculture, ABARES.

Tan DK, Koppi A & Field DJ. (2014). The student perspective in developing graduate attributes through problem-based learning in first year agricultural science. Proceedings of The Australian Conference on Science and Mathematics Education. University of Sydney, 29– 30 September 2014, 170–175.

Tatalovic M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication, 8*, A02.

Tuckman B. (1965). Developmental sequence in small groups. *Psychological Bulletin, 63*, 384–399.

United States Department of Heath and Human Services. (2015). Belmont Report. http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.html Accessed 2 April 2016.

Van Crowder L, Lindley WI, Bruening TH & Doron N. (1998). Agricultural education for sustainable rural development: Challenges for developing countries in the 21st century. *The Journal of Agricultural Education and Extension, 5*, 71–84.

Van Der Sanden MC & Meijman FJ. (2008). Dialogue guides awareness and understanding of science: An essay on different goals of dialogue leading to different science communication approaches. *Public Understanding of Science, 17*, 89–103.

Wang W & Coll RK. (2005). An investigation of tertiary level learning in some practical physics courses. *International Journal of Science and Mathematics Education, 3*, 639–669.

Wiegant F, Scager K & Boonstra J. (2011). An undergraduate course to bridge the gap between textbooks and scientific research. *CBE-Life Sciences Education, 10*, 83–94.

Wilkes J, Godwin J & Gurney LJ. (2015). Developing information literacy and academic writing skills through the collaborative design of an assessment task for first year engineering students. *Australian Academic & Research Libraries, 46*, 164–175.

Winsor DA. (1999). Genre and activity systems: The role of documentation in maintaining and changing engineering activity systems. *Written Communication, 16*, 200–224.

Witkin HA. (1976). Cognitive style in academic performance and in teacher-student relations. *Individuality in Learning, 38*, 72.

Yucel R. (2013). *Good Practice Guide (Science) Threshold Learning Outcome 1: Understanding Science*, Sydney, Australia: Office for Learning and Teaching. http://www.acds-tlcc.edu.au/wp-content/uploads/sites/14/2013/01/Science-Good-Practice-Guide-2013-TLO2.pdf Accessed 2 April 2016.

Yorke M. (2006a). *Employability in higher education*. Raabe Academic Publishers.

Yorke M. (2006b). *Employability in higher education: What it is – what it is not. Learning and Employability Series 1*. York, UK: The Higher Education Academy.

Zadoks JC, Chang TT & Konzak CF. (1974). A decimal code for the growth stages of cereals. *Weed research, 14*, 415–421.

Zimmerman B. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Education Psychology, 11*, 307–313.

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