2013

Good Practice Guide

(Science)

THRESHOLD LEARNING OUTCOME 5
Personal and professional responsibility

Wendy Loughlin

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Further information about these Good Practice Guides for Science can be obtained from Professors Susan Jones and Brian Yates, ALTC Discipline Scholars for Science.
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Examples of good practice included in this Guide were provided by Gerry Rayner, Chris Thompson and Theo Hughes; Jack Wang and Mark Schembri; Daniel Southam; Peter Healy; Alison Beavis; Natalie Williamson, Greg Metha, John Willison and Simon Pyke; Susan Jones and Ashley Edwards. Examples of good practice included in this Guide and their attributions were correct at the time of writing.

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Background

This Good Practice Guide was commissioned by Professor Susan Jones and Professor Brian Yates, ALTC Discipline Scholars in Science, as part of the ALTC Learning and Teaching Academic Standards (LTAS) Project in Science. Through consultation with science academics, science students, employment groups and professional societies, the LTAS Project in Science resulted in the development of a set of five Threshold Learning Outcomes (TLOs) for undergraduate science students. These TLOs describe the minimum that a science graduate should know and be able to do by the time they graduate. The TLOs for science describe learning in the following domains:

TLO 1: Understanding science
TLO 2: Scientific knowledge
TLO 3: Inquiry and problem-solving
TLO 4: Communication
TLO 5: Personal and professional responsibility.

This Good Practice Guide supports the implementation of Science TLO 5: Personal and professional responsibility, which states that:

Upon completion of a bachelor degree in science, graduates will:

Be accountable for their own learning and scientific work by:

5.1 being independent and self-directed learners

5.2 working effectively, responsibly and safely in an individual or team context

5.3 demonstrating knowledge of the regulatory frameworks relevant to their disciplinary area and personally practising ethical conduct

(Jones, Yates & Kelder, 2011).

This Good Practice Guide aims to:

1. explain what TLO 5: Personal and Professional Responsibility entails
2. provide a brief review of the literature on good practice approaches to teaching TLO 5: Personal and Professional Responsibility
3. present a range of good practice teaching approaches and assessment tasks related to TLO 5: Personal and Professional Responsibility currently used in Australian undergraduate science degrees
4. present an annotated bibliography of resources to support teaching and learning of TLO 5: Personal and Professional Responsibility. These resources include books, journal articles, reports, videos and websites
5. identify future directions and opportunities around TLO 5: Personal and Professional Responsibility.

TLO 5: Personal and professional responsibility

A framework for personal and professional responsibility

During the course of learning and understanding about science (the focus of TLO 1 and the Good Practice Guide for TLO 1), practising experimental and theoretical procedures, and developing an understanding of the scientific approach, a student needs to acquire a framework of accountability, honesty and responsibility for their own scientific learning and to guide them throughout their professional life. Such a framework will provide students with the ability to understand important issues in the science profession such as intellectual property (IP); the need for scientific academic integrity; the importance of results being supported by experimental or observation evidence; and being objective and unbiased. Figure 1 below seeks to summarise the framework in terms of key questions students and staff can apply to their learning and teaching activities. Other approaches, covering some aspects of TLO 5, can be found in the literature (e.g. Ford, 2008; Ernst, 2003).

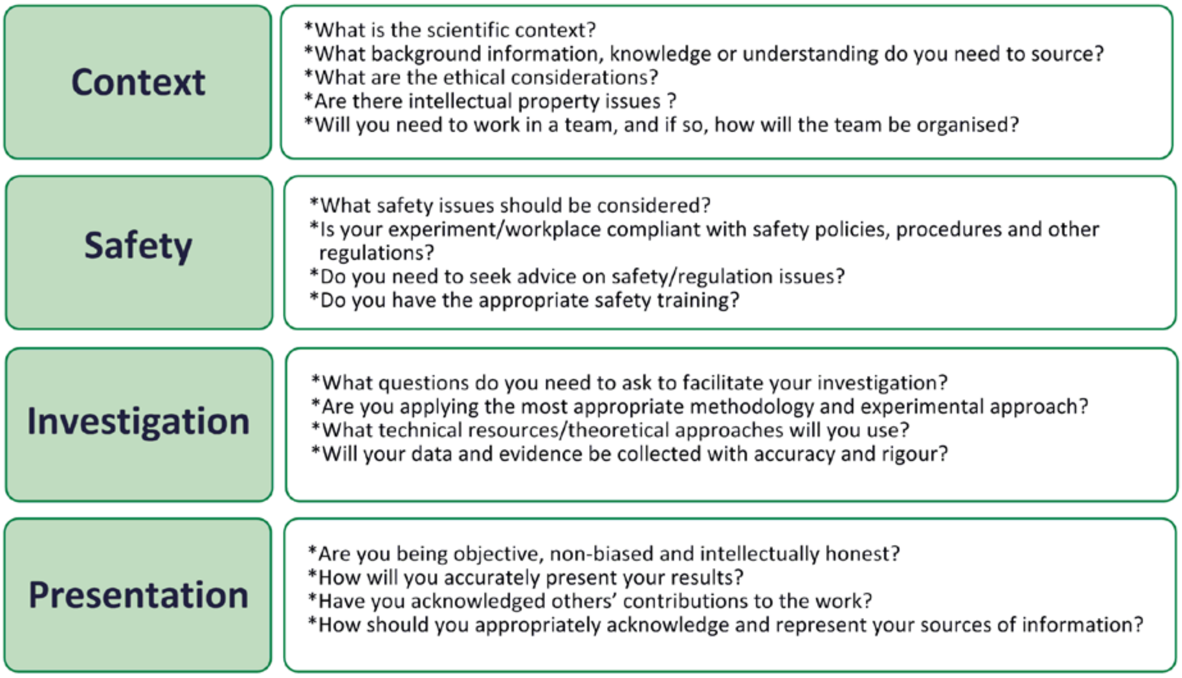

Figure 1. A Framework for Personal and Professional Responsibility

TLO 5: Personal and Professional Responsibility encourages students to embed their learning into the scientific context encountered at university and, ultimately, in their professional working environment. Students need to develop an understanding of personal and professional responsibility from their self-perspective, the team and discipline context, and relevant ethical and regulatory frameworks. Science graduates will be able to participate in socio-scientific discussion and decision-making, and will maintain their own scientific credibility and standards into the future. Curricula for bachelor-level degrees in Science, therefore, need to be designed around the framework presented in Figure 1 to ensure that students meet all aspects of TLO 5 upon graduation.

TLO 5.1: Independent and self-directed learners

> Science graduates will take responsibility for their own learning. They will be able to work autonomously and evaluate their own performance. In order for science graduates to make an ongoing contribution to a society in which scientific knowledge is continually evolving, it is important that they are motivated to continue to learn after graduation. This is also referred to as lifelong learning
> (Jones & Yates, 2011).

Self-assessment and development of independent and self-directed learning

A survey of employers and recruitment agencies (ACDS Occasional Paper No. 2, 2001) found that employers in science seek people with a variety of skills including: the ability to make decisions, being project management-minded, resourcefulness, and good problem-solving skills. Science students must learn to take responsibility for their own learning during their studies and after graduation. Workplaces often place a science graduate in a less-directed environment, where they may need to develop or adapt new skills and understandings. Thus, self-directed learning extends throughout the career of a science graduate, in research, industry or other work environments.

The development of independent and self-directed learning (Baeten et al., 2010; Chung & Behan, 2010; Song & Hill, 2007; Hudspith, Jenkins, & Hills, 2003; Johnstone, & Al-Shuaili, 2001) is linked to the student becoming a self-motivator, self-manager and self-appraiser (Murdoch & Wilson, 2006). In other words, students need to develop autonomy as learners and be able to evaluate their own performance. If students are given opportunities to be independent, they then develop the skills and behaviours of effective, independent learners (Murdoch & Wilson, 2006). Appropriate learning opportunities include activities (such as those where students select from tiered tasks, or laboratory stations, or work in cooperative learning groups) that promote self-management and provide opportunities for individualised instruction.

Independent learning is fostered by an inquiry-based learning approach, which is ideally suited to the science curricula, including laboratory classes and fieldwork. When used well, and in conjunction with appropriate assessment techniques, the inquiry-based learning approach encourages students to ask questions and pursue investigations, and encourages them to use their learning through an emphasis on reflection and action. When small group activities are used within a class, a short, common question time involving the whole class for shared inquiries can provide mentoring in the processes and skills for effective communication and investigation (Murdoch & Wilson, 2006). The recent literature includes calls for emphasis on an inquiry-based approach to “laboratory experimentation and discovery” to stimulate the discovery process (Schussler et al., 2008; Polacek & Keeling, 2005; Howard & Boone, 1997). Simple ways to emphasise questioning include pre- and post-laboratory questions, which provide students with regular practice in critical thinking and experimental design (Polacek & Keeling, 2005). Recommendations of approaches to inquiry-based laboratory teaching from the student and demonstrator perspectives are described elsewhere (O'Toole, 2012). (Refer also to section on print resources). Approaches to *inquiry and problem-solving* are explored in detail in the Good Practice Guide for TLO 3 (Inquiry and problem-solving) and *communication* in the Good Practice Guide for TLO 4 (Communication).

Key areas for the development of independent and self-directed learning in tertiary science students are:

Investigation and reporting: Science students are more likely to become lifelong learners if they can identify and respond to opportunities in a discipline-specific investigation and make recommendations that solve problems. Defining activities that develop these skills in students include:

(a) *planning the investigation:* assessment of the resources required for the investigation, producing a program of activities for the investigation, determining the method of approach, identifying the technological requirements and development of team approaches

(b) *carrying out the investigation*: identification or analysis of problems, integration of discipline-specific and possible multi-disciplinary issues into the investigation to achieve a sustainable solution, and reflection to ensure that all relevant factors have been taken into account

(c) *reporting on the investigation*: clear and accurate reporting of data, proper referencing and acknowledgment, synthesis of the information and development of conclusion and/or recommendations.

In the mathematical sciences, students need to direct their self-directed leaning to develop a rigorous approach that is deductive and logical in order to extend their own pre-existing knowledge to tackle problems beyond their current level of problem-solving ability. Well-designed tasks, assignments and assessment and well-chosen problems facilitate this process.

Assessment: Studies have shown that students generally develop their learning styles based on the assessment within their subjects. As such, assessment is possibly the most important factor affecting a student's approach to learning (Al Kadri et al., 2011; Scouller & Prosser, 1994). Assessment can also help students to discover and construct knowledge for themselves within a learning paradigm rather than an instruction paradigm to teaching (Barr & Tagg, 1995). Recently, a study has shown that assessment should be "authentic" and be based on activities that replicate the way a professional will perform within their professional environment (Svinicki, 2005; Wiggins, 1998). Types of assessment applicable to science identified in the study include:

- solving unstructured problems which require the learner to make informed choices
- assessment that asks students to go through procedures typical to the science discipline under study
- assessment that requires the student to demonstrate some judgement
- assessment that allows for feedback, practice and second chances to solve the problem being addressed.

Scaffolded learning across the first to final year curricula (for example, beginning with small design, analysis or performance projects, and culminating in a capstone knowledge-transfer experience) also helps science students to develop their learning approach. A structured assessment framework, which gives science students the opportunity to learn from feedback as they progress, should permit transfer of responsibility of learning to students over time and equip them for lifelong learning (Harris, 2005).

Good practice examples

The following good practice examples have been selected to illustrate a range of good practice from subjects currently (as at July 2013) offered in Australian university science degrees which are dedicated to teaching science disciplines such as biology, chemistry, physics, mathematics and related areas such as biomedical science and environmental science. The presentation of good practice examples is deliberately focused on illustrating effective assessment and, where possible, the demonstration of student learning outcomes, and aims to stimulate and engage teaching and learning practice in science.

This Guide cannot attempt to reference all the good practice happening in Australian universities. The authors would like to acknowledge the leadership and innovation of all those academics passionate about developing inquiry skills in their students and to encourage the dissemination of good practice. To ensure consistency, all examples below are called subjects; they may be variously named units or courses at the institutions where they are offered. The Australian Council of Deans of Science Teaching and Learning Website (<www.acds.edu.au/tlcentre>) is a further source of information.

Good Practice Example 1

Inquiry-orientated learning in first year laboratories

Subject: Biology, Chemistry and Physics in Bachelor of Science

University: Monash University

Authors: Gerry Rayner (gerry.rayner@monash.edu)
Chris Thompson (Chris.Thompson@monash.edu)
Theo Hughes (Theo.Hughes@monash.edu)

Year level: Year 1, Semesters 1 and 2, open to both science and non-science students

Description: First year biology, chemistry and physics units were restructured to incorporate inquiry-oriented learning (IOL) practicals. The IOL activities were badged in order to distinguish them from more traditional recipe-based laboratory activities. The IOL practicals were strongly aligned with unit curricula and each IOL provided contextual links with lectures, readings and online assessment activities. The IOL activities incorporated a blend of inquiry attributes such as hypothesis testing, critical thinking, problem-solving and collaborative learning (Figure 2 below).

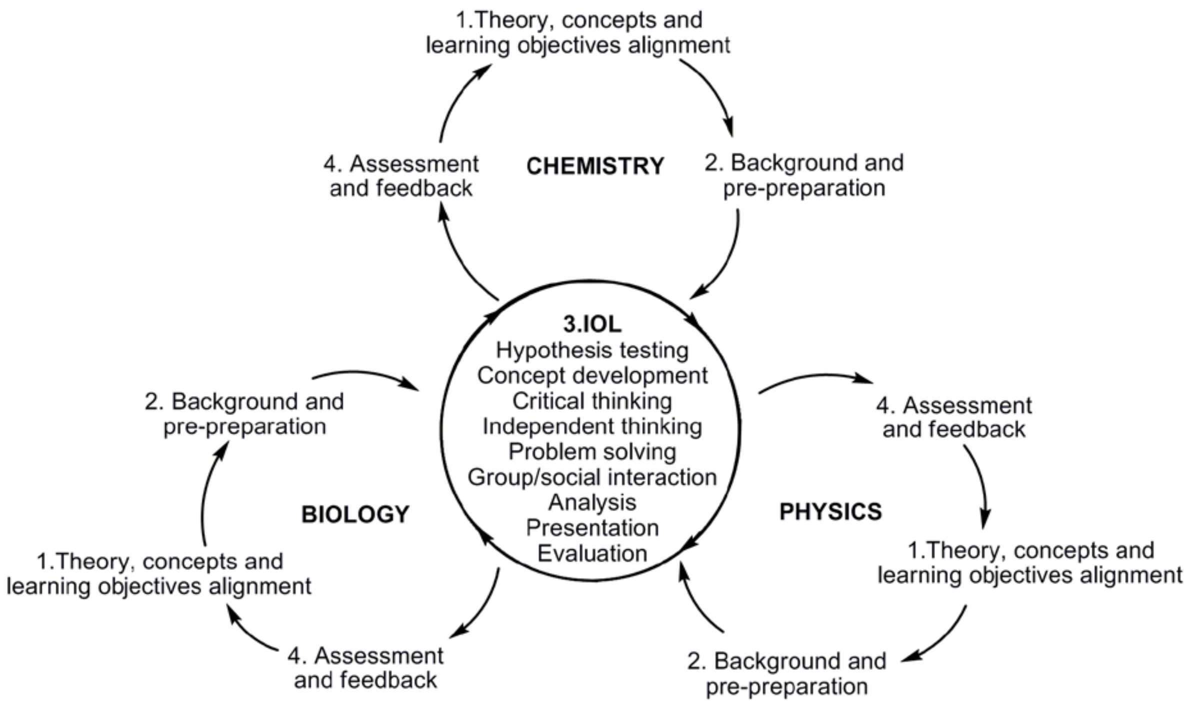

Figure 2: Design of inquiry-oriented learning (IOL) practicals for Biology, Chemistry and Physics at first year level

Laboratory assessment: The form of laboratory assessment while particular to each unit, in general, is based on varying combinations of: (i) submission of design plans for feedback and refinement; (ii) submission of laboratory reports for evaluation, annotation and feedback; (iii) student performance in the laboratory, assessed by proficiency in equipment use, group interactions and discussions, and good laboratory practices; (iv) peer- and teaching-associated assessment of group work such as posters and PowerPoint presentations, based on weighted rubrics; (v) submission of student-derived answers, drawings and figures for evaluation, annotation and feedback; and (vi), summative assessment of learning through end-of-practical tests and quizzes.

Good Practice Example 2

Inquiry-orientated learning in a final year research-intensive course

Subject: Molecular Microbiology

University: The University of Queensland

Authors: Dr Jack T.H. Wang (t.wang1@uq.edu.au)
Professor M.A. Schembri (m.schembri@uq.edu.au)

Year level: Year 3, Semester 1, open to science and non-science students

Description: MICR3003 (Molecular Microbiology) is a course offered within the Microbiology major in the final year of the Bachelor of Science program. This research-intensive course directly engages students in the problem-solving approaches typically applied within scientific research by embedding a five-week-long Undergraduate Research Experience (URE) into its curriculum. This URE involves the identification and isolation of novel vaccine antigen targets against bacterial causes of Urinary Tract Infections (UTIs), spanning across weekly three-hour laboratory sessions over five weeks. The learning objectives of this module revolve around the use of inquiry-based learning by students in order to develop professional scientific skills. By providing students with the opportunity to engage with authentic research questions in searching for novel UTI vaccine targets, the MICR3003 URE was able to facilitate independent and self-directed learning of core scientific competencies in laboratory, analytical and communication skills.

Laboratory assessment: Assessment of student development in inquiry-based learning was made through weekly laboratory performance and note-keeping tasks that were monitored and marked by instructors at the conclusion of each week's laboratory sessions. This culminated in a final laboratory report that followed the formatting expectations and guidelines consistent with professional scientific publication standards. Students were marked on their ability to effectively communicate scientific findings, as well as their capacity to critically analyse the validity of experimental observations through comparisons with relevant peer-reviewed scientific literature.

Good Practice Example 3

Student-motivated and student-directed learning in class

Subjects: Principles and Processes in Chemistry 100, Biological Chemistry 110, Reactivity and Function in Chemistry 120, Introduction to Chemistry 180, Chemical Structure and Spectroscopy 201 and Analytical Chemistry and Spectroscopy 301

University: Curtin University

Authors: Daniel Southam (D.Southam@curtin.edu.au)

Year level: Year 1, from introductory through to major-level, and Years 2 and 3 in selected sub-disciplines

Description: A student-centred and active pedagogy has been adopted across the first year chemistry program to engage students in their learning. Process Oriented Guided Inquiry Learning (POGIL) is designed around a learning cycle paradigm heavily influenced by social constructivism. This form of instruction places a carefully crafted activity in the hands of a small group of students, guided by the instructor as a facilitator of learning. In this POGIL implementation, two-thirds of the lecture presentation is replaced by facilitated learning with up to 120 students in teams of three working together through a carefully crafted activity. Each student is given a group work role and they self-manage their progress through the activity, with interjection from the facilitator and whole-class discussion where necessary. Examples of activities are drawn from published works and in-house authored materials on topics from an introductory to an advanced level.

Student outcomes: Demonstrated benefits of the use of POGIL include improvements to student performance, and student engagement with the concept, each other and the instructor. This leads to a learning environment that develops valued and transferable skills, such as effective communication and teamwork, and motivates students to engage with their learning. In the university context, desirable positive impacts on affective constructs were observed, such as attitude towards learning chemistry (Xu, Southam & Lewis, 2012). Additionally, the implementers are seeing improvements on major summative assessments, such as final exams, in topics taught with POGIL rather than in those taught traditionally.

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

Working effectively, responsibly and safely: A graduate in science will understand how to take responsibility for themselves and others in the conduct of scientific investigations or in other work situations. This term includes the occupational health and safety requirements of some forms of scientific work. It also includes, for example, an understanding of time management and the onus on individuals to fulfil their role as part of team projects.

Individual context: Science graduates will be able to work independently with limited supervision.

Team context: Science graduates will have gained the skills to function effectively as members or leaders of scientific or multidisciplinary teams. They will appreciate that science is primarily a collaborative activity (Jones & Yates, 2011).

Safe work environs: Responsible students in an individual or team context

Workplace health and safety is both a shared and an individual responsibility. A safe working environment facilitates effective and responsible work by the individual and the team. Science students need to comply with health and safety policies and procedures, during laboratory or fieldwork activities. Students should be advised to conduct their activities (including laboratories and field work) in a manner which prevents personal injury or injury to others, and damage to property; to cooperate with and actively participate in the safety management systems within their subjects and courses; to have a personal responsibility to seek assistance when needed; and to report accident, injury or threats. In addition, teaching laboratories that require students to perform experiments competently and to make judgements about priorities and information requirements, will assist students to develop an understanding of responsibility and effective working relationships with peers and supervisors.

In many science experimental areas as well as theoretical areas (such as physics, mathematical sciences), students need to gain skills and function as members of interdisciplinary teams and to learn to work collaboratively and communicate This places a responsibility on students to fulfil roles in teams and improve their skills, such as time management, during their undergraduate studies. Reflective learning (Brockbank & McGill, 2007) by students throughout their degree is one way to create an overt awareness in students of effective and responsible actions within work, individual and team environs. A reflective learning report by students could include:

- ***Self-management:*** (a) the way they have managed their own work; (b) whether they have completed tasks in a safe, competent and timely manner; (c) whether they have coped with change; (d) whether they needed to demonstrate professional ethics and (e) whether they needed to exercise initiative beyond the given instruction.

- ***Working with others; team management:*** (a) did they communicate effectively with others; (b) have they developed and maintained trust and confidence of peers through competent performance; (c) have they sought input from internal and external sources to enhance communication and (d) have they tried to build and maintain network relationships and, in doing so, sustain a team ethic.

A final year science student may be involved in project work or work integrated learning (Costley, 2007) and, therefore, will be expected to start developing a professional approach to the work placement or project. In this context, a reflective learning report could also include:

- ***Professional approach:*** (a) did the student demonstrate the use of appropriate techniques and equipment in the project; (b) were they organised, on time and respectful to their colleagues; (c) did they demonstrate an awareness of issues such as environmental, safety, community or political issues; (d) did they seek a range of information to develop and strengthen the project and (e) did they interact with appropriate specialists to achieve agreed outcomes and develop broader knowledge.

Workplace Health and Safety: The discipline context

In preparation for their workplace environment, science students will be exposed to managing, measuring and documenting workplace health and safety relevant to their major discipline of study. Defining activities would cover an awareness of the management of safety, environment and risk in projects or laboratory classes and would include questions such as:

- Has a plan for the management of occupational health and safety and environmental control been established?
- What risk identification has been made? Have the potential impacts been assessed and what measures are in place for the prevention of accidents?
- Has an analysis of the experimental outcomes been conducted to determine where improvements can be made?

Each discipline area (for example, chemistry, biology, physics and environmental science) brings extra considerations with respect to workplace health and safety. Science graduates in these areas will be aware of discipline-specific issues. The key areas for workplace health and safety in science include:

- ***Basic workplace health and safety:*** This includes fire safety instruction, ergonomics (posture, repetitive strain, and workstation use) and manual handling
- ***Biological safety*****:** A biological hazard – or biohazard – is an organism or substance derived from an organism that poses a threat to human and animal health. Examples of common biohazards students may encounter in laboratories include bacterial cultures in petri dishes and human blood and tissues. Students need to be trained as to what precautions will prevent exposure to biological hazards. In undergraduate laboratories, many manipulations of biological agents are performed using pipettes, syringes with

needles, and scalpels. Use of this equipment has an inherent risk of sharps injury; students need to know how to handle sharps safely.

- ***Chemical safety:*** Many chemicals are classified as hazardous, with the hazard level highly dependent on the chemical itself, route of entry and level of exposure. Where hazardous chemicals are used in undergraduate laboratory sessions the use of Risk Assessment and safe work procedures provide a safe learning environment for students. It is important that students are aware of the hazards that exist and how to avoid/control them by following safe work procedures. Instruction in the use of Material Safety Data Sheets and the Risk Assessment process is desirable.
- ***Electrical safety:*** Along with electrical hazards and working safely with electrical equipment, student training should include what precautions will prevent exposure to electrical hazards.
- ***Fieldwork:*** A professional activity requiring professionalism in its planning, all fieldwork for students must be planned in advance, including assessment of the possible risks for students. In turn, students participating in fieldwork have an obligation to know the environmental risks; contingency and emergency plans; the measures for individual protection (for example, solid walking boots); procedures for safety and first aid, communication and survival in terrestrial or coastal and estuarine environs; and conditions for the use of vehicles, boats and specialised equipment such as GPS systems.
- ***Laboratory equipment safety**:* Misuse of common laboratory equipment (for example, electrical devices, glassware, fume hoods, extraction cabinets, bench top microfuges/centrifuges, lasers) can present hazards to users. Instruction in the safe procedural use of relevant equipment should be provided to students prior to laboratory activities occurring.
- ***Personal protective equipment***: Personal protective equipment (PPE) is used for protection from harm only after elimination, substitution, isolation, engineering and administrative controls have been implemented. Students may be required to use a variety of PPE depending on the hazards present in the laboratory. Common types of PPE include closed shoes, laboratory coats, safety glasses and vinyl gloves.
- ***Laser safety:*** Some undergraduate science learning activities may include the use of lasers or radiation sources. The principal laser hazard is unintended contact with the laser beam, either directly or indirectly through reflections. The greatest risk is to the eyes and the skin. Students need to be aware of how to use lasers safely.

Professional responsibility in a team and society context

During the development of discipline-specific TLOs, the importance of the role of science in society has emerged. Biology has identified the importance of an appreciation of and responsibility for the sustainability of life as a specific learning outcome for TLO 5 – “Demonstrate an appreciation of the biodiversity on the planet and/or sustainability of life”. Chemistry has included “understanding and being able to articulate aspects of the place and importance of chemistry in the local and global community” as an element of TLO 5. Physics has identified that “it is important that physics graduates have some understanding of their social and cultural responsibilities as they investigate the physical world”. Development of social awareness in science students should be achieved in the context of science curricula through embedded case studies which explore the science behind topics and examine the broader impacts in society.

Good Practice Example 4

Workplace Health and Safety

Subject: Chemistry A

University: Griffith University

Author: Peter Healy (p.healy@griffith.edu.au)

Year level: Year 1, Semester 1 (open to science and non-science students)

Description: This course introduces the fundamental concepts and methods of general chemistry. This course presented through weekly lectures (three hours), workshops (one hour) and laboratory practicals (four hours fortnightly).

Teaching Workplace Health and Safety (WH&S) principles: The application of workplace health and safety practices in the chemical laboratory is one of the three learning objectives for Chemistry A. A compulsory safety induction lecture during orientation week is given to students, along with a follow-up safety talk in the first laboratory for each student. All risk assessments and safety data sheets relating to the conduct of undergraduate laboratory activities are kept up-to-date by technical staff and are available on request.

Practice and assessment of WH&S principles in the laboratory: From 2011, assessment for the laboratory component of Chemistry A was changed to focus on WH&S. Students were advised that they would achieve full marks for each laboratory assessment if they adhered to WH&S and professional standards. The requirements, such as wearing lab coats and safety glasses at all times, were made clear to students. Students were required to arrive at the lab on time, follow the directions of the demonstrators and the procedures outlined in the lab manuals, and work diligently for the entire four hours of the laboratory session. Marks were deducted by the demonstrators if, after warnings, students failed to adhere to these professional principles. Laboratory demonstrators modelled good WH&S practice, provided students with feedback on WH&S and professional behaviour, as well as helping with standard operating procedures and theory for laboratory techniques. One hundred per cent of students adhered to the safety practice throughout the lab class.

It was noted that all students, irrespective of their chemistry knowledge at entry level, intuitively understood and accepted the need for WH&S and professional behaviour (familiar to most from part-time work experiences) and understood the need for these skills in their future laboratory classes and employment. It was observed that students spontaneously focused on developing safe work practices, developing team work (including peer help) and overcoming learning obstacles. This resulted in significant improvement in the confidence and ability of the students to complete and understand the technical requirements and achieve the academic learning outcomes of the laboratory.

Good Practice Example 5

Working effectively in teams using Process-Oriented Guided Inquiry (POGIL)

Subject: Foundations of Chemistry (FoC) IA and IB

University: University of Adelaide

Authors: Natalie Williamson (natalie.williamson@adelaide.edu.au)
Greg Metha (greg.metha@adelaide.edu.au)
John Willison (john.willison@adelaide.edu.au)
Simon Pyke (simon.pyke@adelaide.edu.au)

Year level: Year 1, semester 1 (FoC IA) and semester 2 (FoC IB) (open to science and non-science students; no prior knowledge assumed)

Description: The courses presenting introductory Chemistry to first year students with little or no prior Chemistry background are undertaken by students from extremely diverse academic backgrounds enrolled in a degree program such as Animal Science, Viticulture and Oenology, and Health Science. The courses are presented using three one-hour classes per week, one one-hour tutorial per week, and one three-hour laboratory class per fortnight. Process-Oriented Guided Inquiry Learning (POGIL)-style activities are incorporated into instructional classes.

Students spend part of each class working on these activities in small groups of three–four, enabling them to develop teamwork skills through discussion and presentation of answers to the questions within the activities. This teamwork aspect also allows students to develop self-directed learning skills within their groups, as using the POGIL inquiry method encourages students to make their own connections and draw their own conclusions from the information presented. Group work is continued within tutorial periods, further developing students' skills in this area. Laboratory work involves students investigating a particular chemical concept or procedure in each session, requiring them, in conjunction with one of their peers, to carry out measurements, collect data and use equipment appropriately to achieve the desired result.

Assessment: Assessment items for both Foundations of Chemistry courses include a written examination at the end of the semester (worth up to 60 per cent of the overall course grade), laboratory work (20 per cent) and online tutorial assignments (20 per cent). The skills developed by students within teamwork activities are assessed as follows. A written report is submitted for assessment at the end of each laboratory session containing aims, observations, conclusions and answers to questions posed in the practical script. The examination and online tutorial assignments are designed to test students' problem-solving skills as developed in classes and tutorials by including questions that require application of concepts rather than simple recall.

Good Practice Example 6

Professional Practice in Chemistry

Subjects: Professional Practice in Chemistry

University: University of Technology Sydney

Author: Alison Beavis (Alison.Beavis@uts.edu.au)

Year Level: Year 2 (open to science students; first year chemistry knowledge required)

Description: This subject provides an introduction to the professional skills required by practising chemists. Topics include an extensive coverage of safety and legislation, communication skills and academic writing, project management, teamwork, ethics, creativity thinking and innovative approaches to the solving of problems. Students will also develop skills in researching and referencing of literature sources.

Assessment: Students are assessed on an extensive chemical incident assignment which is completed in groups of four students. The groups undertake extensive research of the allocated topic, prepare a written report (using an exemplar report to guide them) and also present an oral presentation to the class. Criteria for assessment of the written report include the quality and coherence of the report, evidence of a thorough literature review, and correct referencing. The oral presentation is a peer-assessed activity, with students providing valuable feedback to their peers on criteria such as the quality of the slides, content, structure and general presentation skills.

Student Outcomes: Student learning is well supported throughout with numerous workshops designed to develop research skills and confidence in both written and oral communication. Additional activities are incorporated to assist students in understanding how to provide constructive feedback. Students are also provided with guidance on effective strategies for group work and project management, essential for the successful completion of this assignment.

TLO 5.3: Demonstrating knowledge of the regulatory frameworks relevant to their disciplinary area and personally practising ethical conduct

Regulatory frameworks relevant to their disciplinary area: Science graduates will have an awareness of the regulatory frameworks that apply to their disciplinary area. These might be the legal frameworks for experimentation and data collection, quality control procedures, or the necessity to obtain government permits for certain types of activity. They will be prepared to abide by these regulatory frameworks as they move into professional employment, and understand the consequences if they do not.

Ethical conduct: Science graduates will have demonstrated that they learned to behave in an ethical manner during their period of undergraduate study and are equipped to do so into the future. This might include accurate data recording and storage, proper referencing and avoidance of plagiarism, intellectual integrity, [knowledge of] animal ethics or human ethics. It is important that science graduates have some understanding of their social and cultural responsibilities as they investigate the natural world (Jones & Yates, 2011).

A knowledge of the disciplinary area regulatory frameworks

Science graduates must have an awareness of relevant regulatory frameworks, and an understanding of why these frameworks are in place and the consequences of not abiding by the 'rules'. Broadly, this might include awareness of legal frameworks for experimentation and data collection, quality control procedures, appropriate safety procedures, or the necessity to obtain government permits for certain types of activity. Specific cases are given below.

Science students and scientists must identify, assess and appropriately control risks to the health and safety of all persons conducting and participating in scientific work including the teaching environs, in accordance with the *Workplace Health and Safety Act 2011* (the Act). Implementation of the Act through a local university/workplace health and safety policy provides a manageable and interpretable form of WH&S. In the case of science students, laboratory experimental procedures and field work provide ideal opportunities to embed knowledge of WH&S into assessment tasks such as laboratory reports or questions relating to safety in pre-laboratory reports. Regulations, acts, standards and codes of practice that relate to specific science disciplines are listed in the resources section. A science student needs to have an awareness of the impact of their activities on the environment (for example, an understanding of the need for safe disposal of biological and chemical waste and what that might involve).

Science students involved in biomedical science and similar areas must respect human research participants and comply with ethical principles of integrity, respect for persons, justice and beneficence. These principles are elaborated in the *National Statement on*

Ethical Conduct in Human Research (2007) incorporating all updates as at September 2009. This statement is intended for use by potential research participants and researchers conducting research with human participants.

Science students undertaking research with Aboriginal and Torres Strait Islander peoples must consult *Values and Ethics: Guidelines for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research* (NHRMC 2003) and *Guidelines for Ethical Research in Indigenous Studies* (Australian Institute of Aboriginal and Torres Strait Islander Studies 2011*)*. Increasingly, areas such as biomedical, chemical and environmental science are inclusive of Aboriginal and Torres Strait Islander considerations. Science students involved in these discipline areas should have an awareness of any Aboriginal and Torres Strait Islander cultural sensitivities related to their studies.

Science students must respect the animals they use in science studies. The *Australian Code of Practice for the care and use of animals for scientific purposes 7th edition* 2004 covers all aspects of the care and use of, or interaction with, animals for scientific purposes in biology, agriculture and other animal sciences, industry and teaching. This Code of Practice addresses the use of animals in teaching, field trials, diagnosis and environmental studies.

Practising personal and professional ethical conduct

Most disciplines in science have an accrediting body (Royal Australian Chemical Institute; Australian Institute of Physics; Australian Society for Biochemistry and Molecular Biology; Australian Mathematical Society; Australian Society for Microbiology; Australian Society for Medical Research; Australia and New Zealand Society for Cell and Developmental Biology; Australian Society of Plant Scientists; Australian Institute of Food Science and Technology; Environment Institute of Australia; Australian Institute of Biology) and a set of standards which all science graduates must demonstrate on graduation for the purposes of membership of their accrediting body and throughout their careers as practising scientists. To this end, ethical awareness (both professional and personal), academic and intellectual integrity, and scientific accuracy are essential components in the education of a science student.

Universities typically have self-help web resources for referencing conventions (inclusive of reference style, media type and format), avoidance of plagiarism (for example, use of SafeAssign or TurnitIn for report and assignment submission), and policies relating to ethics issues. Proactively advising students of the need for academic integrity and providing them with guidance on best practice in studying and learning, particularly in the first year of a science degree, facilitates the development of professional responsibility in students. Thus, it is important that science students are formally educated (scaffolded by year level) in topics such as referencing, accurate data collection, secure data storage, transparent records of methodology and ethics. There are many opportunities within curricula to embed these topics. Some approaches include:

Professional practice resources: Educational resources embedded within subjects or specialist forums or seminars on topical issues can be used to help Science students learn about the standards of the relevant accrediting body and the importance of maintaining the quality and relevance of their skills throughout their working life.

Curriculum design: Learning activities in the degree programs can be designed in a manner that requires the integration of disciplinary and workplace-relevant knowledge and skills deployed in the workplace. For example, the fast moving advancements in modern science require specialised scientific knowledge as well as the ability to recognise ethical dilemmas and design a response to these. Dual-use dilemmas and role-play involving real scientific case studies have been presented (Johnson in Rappert, 2010) as an ideal vehicle for effectively engaging science students (particularly in the biosciences areas) in ethics education, and in helping to develop the necessary skills for their professional development.

Work-integrated learning: When students experience work-integrated learning environments, typically in their final year of study, extra issues and educational experiences arise. These include maintaining appropriate confidentiality, intellectual property, pre-placement briefings including workplace health and safety, compliance with dress code and other special prerequisites, efficient management and effective monitoring of students' progress or reporting by students during placement. Exposure to these issues and processes provides students with a heightened awareness of professional issues thus preparing them for employment after graduation. Assessment which requires a student to reflect on their competency during a practicum or feedback to students on compliance help to raise professional standards and student awareness of these issues.

Good Practice Example 7

Vertical integration of animal ethics in the tertiary curriculum for Zoology students

Subject: Biology – Zoology

University: University of Tasmania

Authors: Susan Jones (S.M.Jones@utas.edu.au)
Ashley Edwards (Edwards@utas.edu.au)

Year level: Zoology units at first, second and third year levels in a Bachelor of Science

Description: A vertically integrated approach was used to develop students' appreciation of animal ethics across the three years of the Zoology major. In first year, students are briefly introduced to the ethical framework that guides the use of animals in teaching and research. In second year, students are given their first opportunity to work with vertebrates and cephalopod molluscs in the field and the laboratory. Their personal roles and responsibilities under *The Australian code of practice for the care and use of animals for scientific purposes* are emphasised, and each student signs the Student Declaration, as required by the University's Animal Ethics reporting requirements. In third year, students take greater personal responsibility for the care and use of animals in practical classes, and are required to demonstrate an understanding of the regulatory frameworks within which animal-related science is practised.

Assessment: Instruction in animal ethics is incorporated into units at all year levels, and students are encouraged to develop their thinking as they move through the undergraduate levels. A significant proportion of that development takes place within a didactic information delivery mode with no assessment of student learning. However, two units (at Level 1, Semester 2 and Level 3) include assessment tasks that require students to provide overt evidence that they can construct a scientific research question within an ethical framework. The tasks are structured exercises in which participants are assigned roles within a specific scenario; in both cases, in order to complete the written assignment, the students must role-play scientists designing and justifying their animal-based research to an ethics committee.

Outcomes: Students in all three levels (year groups) of the Zoology major were surveyed in a longitudinal study. They overwhelmingly agreed that ethics should be taught to undergraduates, and a majority thought that such instruction should be incorporated within subjects rather than be taught separately. After completing their first semester of study, students are highly likely to report consciously thinking about animal ethics issues relating to the use of animals, and they understand that this learning is directly relevant to their future professional work. The vertically integrated approach to exposing students to animal ethics is effective, but requires a more rigorous approach to embedding aligned assessment tasks within the curriculum.

Resources for TLO 5

Print resources

Australian Council of Deans of Sciences. (2001). *Why do a science degree?* (ACDS Occasional Paper No. 2). Accessible at <www.acds.edu.au>.

The findings of an Australian Council of Deans commissioned report, which investigated the employment profile of graduates of a science discipline three, five and ten years after their graduation. The skills valued by employers are identified and include problem-solving skills and the ability to work independently.

Harris, K-L. (2012). *A background in science: What science means for Australian society*. Accessible at <www.acds.edu.au>.

This study by the Centre for the Study of Higher Education examined the skills developed through science and the fundamentals for university-level science education to develop attributes of a scientist. Scientists were characterised as analytical, objective, evaluative, questioning, lifelong learners and confident in their problem-solving abilities.

Rice, R.W., Thomas, S. M. & O'Toole, P. (2009). *Tertiary science education in the 21st century*. Australian Learning and Teaching Council. Accessible at <www.olt.gov.au/resources>.

This report from the Australian Learning and Teaching Council Project includes a range of recommendations including the development of new approaches to the teaching and learning of generic skills such as the explicit identification, support and assessment of group work and problem-solving skills in the laboratory context.

O'Toole, P. (2012). *Tertiary demonstrator development: Preparing for the learning lab*. Australian Council of Deans of Sciences. Accessible at <www.acds.edu.au>.

The findings of an Australian Council of Deans commissioned report, which inquires into the professional development of demonstrators. It contains an excellent section (4.2.4) on inquiry-based teaching of laboratory.

Johnson, J (2010). Teaching Ethics to Science Students: Challenges and a Strategy in *Education and Ethics in the Life Sciences*, Rappert, B. (ed.) ISBN: 9781921666384 (pbk.) 9781921666391 (ebook) ANU E Press, 197–213.

This book chapter examines a number of ways in which the practice of science generates ethical issues and the form that science ethics education should take. It identifies what learning outcomes, skills and knowledge students should take from ethics classes and how the challenge of teaching ethics in science could be met.

Speight, J.G. & Foote, R. (2011). *Ethics in Science and Engineering*. Scrivener-Wiley Publishing: New York. ISBN: 978-0470626023

> This valuable reference book presents a wide-ranging discussion of ethics in science and engineering from a theoretical and applied perspective, and has close to 300 references.

Academic journals

The areas relevant to TLO 5.2 and TLO 5.3 tend to be covered by the codes of practice, acts, and regulations. This list of journals is focused towards research related to TLO 5: Personal and Professional Responsibility, predominately in the sub-areas of approaches to developing student learning through assessment and investigation; ethics in science education; and safety education. Some of these journals present primary, secondary and tertiary education projects.

American Journal of Physics <ajp.aapt.org/>

> The articles provide a deeper understanding of physics topics taught at the undergraduate and graduate levels, suggestions for instructional laboratory equipment and demonstrations, insight into and proven suggestions for better teaching methodologies, and insight into how university students learn physics. For example:
>
> Mason, A. & Singh, C. (2010). Helping students learn effective problem-solving strategies by reflecting with peers. *American Journal of Physics*, *78*, 748–754.
> A study of how introductory physics students engage in reflection with peers about problem-solving and the benefits to their learning of physics problems.
>
> Goldberg, F., Otero, V. & Robinson, S. (2010). Design principles for effective physics instruction: A case from physics and everyday thinking. *American Journal of Physics*, *78*, 1265–1277.
> Research-based design principles used in the development of an inquiry-based physics and physical science curriculum. Evaluation showed that the curriculum enhanced students' conceptual understanding.

Biochemistry and Molecular Biology Education
<www.sciencedirect.com/science/journal/14708175>

> This journal includes articles to enhance teacher preparation and student learning in biochemistry, molecular biology, and related sciences such as biophysics and cell biology. For example:
>
> Smith, K., Wueste, D. & Frugoli, J. (2007). Using 'ethics labs' to set a framework for ethical discussion in an undergraduate science course. *Biochemistry and Molecular Biology Education, 35*(5), 332–336.
> The concept of an 'ethics lab' was developed to attempt to integrate ethics education into a sophomore/junior level science course, Introduction to Genetics. Rapid positive outcomes for student learning are reported.

Brauner, A., Carey, J., Henriksson, M., Sunnerhagen, M. & Ehrenborg, E. (2007). Open-ended assignments and student responsibility. *Biochemistry and Molecular Biology Education, 35*(3), 187–192.
An inquiry-based protein biochemistry laboratory course was created in an effort to increase student responsibility in learning. An inquiry matrix was used to evaluate the degree of learning responsibility taken during the course. Students gained confidence in their ability to solve problems, formulate and test hypotheses, and collaborate with both clinical and non-clinical professionals.

International Journal of Innovation in Science and Mathematics Education (IJISME)
<ojs-prod.library.usyd.edu.au/index.php/CAL>

IJISME publishes innovative education research in the areas of science and mathematics. For example:

O'Malley, M. & Roberts, T.S. (2012). Plagiarism on the rise? Combating contract cheating in science courses. *International Journal of Innovation in Science and Mathematics Education*, *20*(4), 16–24.
The prevention and detection of plagiarism in the context of science education presents particular difficulties. The article suggests several innovative and possibly controversial methods to minimise the number of occurrences, ensuring that as few students as possible cheat, and describes various techniques to aid in the detection of those who do plagiarise.

International Journal of Science and Mathematics Education
<www.springer.com/education+%26+language/mathematics+education/journal/10763>

This journal contains articles on a variety of topics and research methods in both science and mathematics education that address common issues in mathematics and science education and cross-curricular dimensions more widely. For example:

Hewson, P.S. (2004). Resources for science learning: Tools, tasks, and environment. *International Journal of Science and Mathematics Education, 2*, 201–225.
This article addresses the question of how science learning can be improved by recognising that, while learners themselves are responsible for their own learning, the quality of this learning is greatly influenced when appropriate resources are available to learners. Three different types of resource are discussed.

Reid, A., Wood, L. N., Smith, G.H. & Petocz, P. (2005). Intention, approach and outcome: University mathematics students' conceptions of learning mathematics. *International Journal of Science and Mathematics Education*, *3*, 567–586.
The focus of this article is on the complex nature of the students' intentions for learning, approaches to learning and outcomes of learning of mathematics. A theoretical model based on research findings is presented, which aims to build on and expand earlier descriptions of students' learning approaches and develop professional skills.

Journal of Chemical Education <pubs.acs.org/journal/jceda8>

The *Journal of Chemical Education* typically addresses chemical content, activities, laboratory experiments, instructional methods, and pedagogies with the educator and instructors in mind. Examples include:

Di Raddo, P. (2006). Teaching Chemistry Lab Safety through Comics. *Journal of Chemical Education*, *83*(4), 571–3.
Comic book lab scenes were presented and discussed. The need to adhere to copyright regulations for the use of the images is discussed so as to increase students' awareness of academic honesty and copyright issues.

Alaimo, P.J., Langenhan, J.M., Tanner, M.J. & Ferrenberg, S.M. (2010). Safety teams: An approach to engage students in laboratory safety. *Journal of Chemical Education*, *87*(8), 856–861.
This active, collaborative program involved the use of student "safety teams" and includes 'hands on' safety training as well as student-led safety presentations, laboratory monitoring and post-lab inspections for each lab session. This approach could easily be appropriately modified and implemented in nearly any science laboratory course.

Wright, S.M. (2005). Introducing safety topics using a student-centred approach. *Journal of Chemical Education*, *82*(10), 1519–1520.
Activities that use constructivist teaching strategies to introduce aspects of chemical safety are described. Three student-centred, cooperative lessons that introduce students to material safety data sheets and hazardous chemical labelling systems are presented.

Journal of Medical Ethics <jme.bmj.com>

The journal seeks to promote ethical reflection and conduct in scientific research and medical practice. For example:

Jones, N.L., Peiffer, A.M., Lambros, A., Guthold, M., Johnson, A.D., Tytell, M., Ronca, A.E. & Eldridge, J.C. (2010). Developing a problem-based learning (PBL) curriculum for professionalism and scientific integrity training for biomedical graduate students. *Journal of Medical Ethics. 36*(10), 614–619.
Small-group sessions examined case scenarios which emphasised professional standards, obligations and underlying philosophies for the ethical practice of science, competing interests of stakeholders and the oversight of science (internal and external).

New Directions for Teaching and Learning
<onlinelibrary.wiley.com/journal/10.1002/(ISSN)1536-0768>

Articles include a comprehensive range of ideas and techniques for improving teaching based on the experience of instructors and the latest findings of educational and psychological researchers. For example:

O'Steen, B. & Rachel Spronken-Smith, R. (2012). Inquiry-Guided Learning in New Zealand: From an Appetizer to an Entrée. *New Directions for Teaching and Learning*, 129, 39–49.
This article discusses how inquiry-based learning can be included in a large first year sociology class, and, in the second case, how inquiry-based learning is successfully embedded throughout an ecology degree program.

Science and Engineering Ethics
<www.springer.com/social+sciences/applied+ethics/journal/11948>
Science and Engineering Ethics explores ethical issues of direct concern to scientists and engineers covering professional education, research and practice and provides material which will be useful for the education and training of scientists and engineers in the ethical issues encountered in the workplace.

McGowan, A.H. (2012). Teaching Science and Ethics to Undergraduates: A Multidisciplinary Approach. *Science and Engineering Ethics,* Published online: 3 January 2012.
The teaching of the ethical implications of scientific advances in science courses for undergraduates has significant advantages for both science and non-science majors. The author examines the disadvantages of the concept as well as the advantages of improving student's understanding of their science and its potential implications.

Video resources

Independent Learning (2:46)
www.youtube.com/watch?v=ir8MZJkddIA
This video was produced by Nottingham Trent University and is a short summary of independent learning – what it is, how to do it, why it is important and what it means for a university student.

Khan Academy
www.khanacademy.org/
This resource contains an extensive video library for maths, biology, chemistry and physics available at the Khan Academy. The Khan Academy's materials are available free of charge and also include interactive challenges, assessments from any computer with access to the web, and a custom self-paced learning tool.

Official video of the International Year of Biodiversity 2010 (8.27)
www.youtube.com/watch?v=V1VYmpTikgw
This video was produced by the United Nations Environment Program and summarises and emphasises the factors, importance and benefits of biodiversity for the planet and sustainability of life. This video aligned with TLO 5.4 for Biology.

Websites

Australian Government Office for Learning and Teaching
<www.olt.gov.au/resources>

The Resource Library of the Office for Learning and Teaching contains a collection of higher education learning and teaching materials flowing from projects funded by the Commonwealth of Australia, including those from the Australian Learning and Teaching Council. Almost 100 resources relate to science.

Australian Mathematical Sciences Learning and Teaching Network
<amslat.edu.au/>
This website reports on the AMSLaTNet workshop to continue work around defining Threshold Learning Outcomes for the mathematical sciences. Forty mathematical sciences academics from around Australia took part.

Professions Australia
<www.professions.com.au/>
Professions Australia develops policy positions on issues of concern to professionals and provides resources on subjects such as higher education and ethics.

Chemistry Discipline Network
<chemnet.edu.au/>
The Chemistry Discipline Network was established in 2011 and includes as a key aim implementing the Chemistry Threshold Learning Outcomes.

CUBENET – Collaborative Universities Biomedical Education Network
<www.cubenet.org.au>
CUBENET aims to create a critical mass of active tertiary biomedical academics at the national level in Australia to provide a sustainable framework for a program-wide approach to the biomedical curriculum.

Science and Mathematics Network of Australian University educators
<samnetaustralia.blogspot.com.au/p/alp_10.html>
The SaMnet page provides details of other discipline networks (Physics Education Network, and regional networks SNUSE – Sydney Basin Network of University Science Educators; BUNSE – Brisbane University Network of Science Educators) as well as details of action learning projects in science and mathematics. Current action learning projects include some of the good practice examples listed here as well as:

Implementing enquiry-oriented experiences in the first-year physics laboratory.
Isoardi, G., Kirkup, L. (UTS), Beames, S. (UTS) & Savage, S. Queensland University of Technology. Physics.
This website discusses how to change the nature of practical experiments conducted in the first year physics lab away from cookbook-style experiments that are not sequenced with unit content and how to promote authentic scientific inquiry with exploratory labs, transforming the existing laboratory program.

Improve cohesion within subjects and introduce inquiry-based learning.
Beckman, J., Ferru, I., Beckmann, B. & van Leeuwen, B. Australian National University. Biology and Biomedical Science.

Inquiry-based learning activities (e.g. hypothesis testing, statistical analysis and elementary research – first year level) may be scaffolded to replace some student discussion and answer writing in order to enhance student engagement and learning of research and reporting skills.

Embedding change in Biochemistry teaching via knowledge transfer.
Fildes, K., Bedford, S., O'Brien, G., Keevers, L. & Carr, P. University of Wollongong. Biochemistry.
This site discusses increasing student engagement by moving some student activity away from the current passive lecture situation to a more active environment through using Process Oriented Guided Inquiry Learning (POGIL©) activities.

VIBEnet – Vision and Innovation in Biology Education
<sites.google.com/site/vibenet101/home/community>
VIBEnet have developed a set of draft Biology Threshold Learning Outcomes (BTLOs) and invite all tertiary biology educators to comment on these BTLOs.

Acts, regulations, guidelines and codes of practices

Agricultural and Veterinary Chemicals (Administration) Regulations 1995
<www.comlaw.gov.au/Details/F2012C00529>
These regulations provide a balanced and nationally consistent framework for the use of controlled and prescribed chemicals.

Australian code of practice for the care and use of animals for scientific purposes 7th edition 2004
<www.nhmrc.gov.au/guidelines/publications/ea16>
The Code provides principles for the guidance of teachers, investigators, and all people involved in the care and use of animals for scientific purposes. It provides guidelines for the humane conduct of scientific and teaching activities, and for the acquisition of animals.

Australian Radiation Protection and Nuclear Safety Act 1998
<www.arpansa.gov.au/regulation/legislation/index.cfm>
The object 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 such as a *Radiation Safety Act 1999* (Qld) and Radiation Regulation (2007) (Vic.).

Guidelines for Ethical Research in Australian Indigenous Studies 2011
<www.aiatsis.gov.au/research/docs/ethics.pdf>
The guidelines address ethical research and human rights, including intellectual property laws and rights in traditional knowledge and traditional cultural expressions, and the establishment of agreements and protocols between Indigenous people and researchers.

National Statement on Ethical Conduct in Human Research 2007 – updated 2009
<www.nhmrc/gov.au/guidelines/publications/e72>
The statement is a series of guidelines developed by the National Health and Medical Research Council, the Australian Research Council and Universities Australia in accordance with the *National Health and Medical Research Council Act 1992.* ISBN: 1864962755

Poisons Standard 2012
<www.comlaw.gov.au/Details/F2012L01200>
This schedule describes the classification and use of chemicals that are poisons and is regularly updated.

Values and Ethics – Guidelines for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research
<www.nhmrc.gov.au/guidelines/publications/e52>
These guidelines have been written around a framework of Aboriginal and Torres Strait Islander values and principles and provide guidance for ethical health research.

Workplace Health and Safety Act 2011
<www.comlaw.gov.au/Details/C2011A00137>
This Act provides a balanced and nationally consistent framework to help protect workers, including science students, against harm to their health, safety and welfare through the elimination or minimisation of risks arising from work.

Future directions and opportunities

The Good Practice Guide for TLO 5 aims to provide undergraduate educators with ideas, information and resources to gain a perspective of personal and professional responsibility in the education of tertiary science students. Examples continue to be reported as approaches that could be used to achieve improvements in curriculum and include:

- laboratory team activities
- use of technology for pre-lab preparation
- online forums to communicate with demonstrators
- introduction of assessment items such a reflective learning journal for a course/year of study.

The responsibility lies with undergraduate educators to engage in a commitment to continuous improvement and to disseminate their ideas and innovations in teaching science to undergraduate students. There are many opportunities for further work. Examples include:

(a) a mapping of learning outcomes for the key themes of TLO 5 throughout a science degree to assist in identifying themes or areas of TLO 5 in need of development or integration into the science curriculum

(b) self-directed learning in the context of the science discipline; a case study approach, where frequency and scaffolding of laboratory report writing will establish a minimum standard towards self-directed learning

(c) active integration of Workplace Health and Safety (WH&S) into laboratory curriculum, rather than through information sessions to students, would help students to develop responsibility for their own safety and the safety of others. Students should develop personal and professional responsibility early in their careers and be further prepared for workplace environments. Active integration of WH&S into student learning activities has the potential to develop in students a theoretical understanding in conjunction with practical experience in practical WH&S issues. When surveyed, employers have expressed the need for graduates with a greater understanding of WH&S.

The key themes of TLO 5 – self-directed learning; responsible, safe and effective work practices; knowledge of regulations; and ethical conduct – are all themes that cannot be considered outside the scientific context. Thus, the challenge is to contextualise and integrate these themes into a science undergraduate education without dilution of discipline knowledge. Knowledge in Science (which is a theme of TLO 2 and the Good Practice Guide for TLO 2) has undergone significant changes in the last decades and continues to do so, often with rapid speed. This has led to the significant impact of science on the world and society.

Upon graduation, science students need to have a context not only for science activities but also issues such as professional behaviour, ethics and Workplace Health and Safety. In addition, a recent and heightened awareness regarding the development of science education, considers the perspective of students, teachers, employers and government agendas. The context of these perspectives constitutes a challenge for the adoption of TLO 5 into undergraduate curriculum. Much can be learnt, however, through the cross-fertilisation of teaching exemplars; the sharing of solutions to student learning challenges through collaboration; and the application of learning and teaching approaches among science disciplines. The Good Practice Guide for TLO 5 has sought to clarify and expedite the adoption of the key underpinnings of self-directed learning – responsible, safe and effective work practices; knowledge of regulations; and ethical conduct – into the undergraduate science curriculum for Higher Education students within Australia.

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