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Good Practice Guide

(Science)

THRESHOLD LEARNING OUTCOME 4
Communication

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Background

This Good Practice Guide supports the implementation of Science Threshold Learning Outcome (TLO) 4: Communication, which states that:

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

4. be effective communicators of science by:

4.1 communicating scientific results, information, or arguments to a range of audiences, for a range of purposes, and using a variety of modes

(Jones, Yates & Kelder, 2011).

Aims of this Good Practice Guide

This Good Practice Guide aims to:

- explain what TLO 4: Communication entails by discussing each aspect of TLO 4.1 and elaborating on the meaning and implications of those aspects
- review the literature on scientific communication, from the perspective of both the curriculum designer and the professional science communicator
- compile an annotated bibliography of literature and resources for scientists and science communicators, which will include sources from a variety of media and exemplars of student work within each modality
- provide detailed examples from Australian undergraduate science programs of curriculum design, teaching and assessment tasks that exemplify good practice in promoting science communication skills.

The student cohort

Design of curricula for undergraduate science programs must acknowledge that the courses within these programs often serve a mixed cohort of students. Generally, the student body can be broadly classified into three groups:

1. Bachelor of Science[1] students aiming for a career in laboratory science (either in research or industry)
2. Bachelor of Science students completing a science degree with the intention of pursuing a non-laboratory career, possibly after completion of a second degree, e.g. science communication, medicine, teaching, science sales and marketing and government/public service

[1] *Note: Bachelor of Biomedical Science, Bachelor of Marine Science, and other specialist science and dual-degree programs are included under the Bachelor of Science umbrella.

3. students enrolled in a non-science program of study who are completing science courses out of interest or because their program of study mandates the inclusion of appropriate course credits.

Therefore, care must be taken to ensure the types of communication with which these students are engaging are appropriate to their future career plans. It is inappropriate to assume that all BSc students will become research scientists. Hence, the other types of communication skills these students will need during their working life should be considered and included in curricula as learning and assessment activities.

TLO 4: Communication

TLO 4: Ideas for exploration

The requirements for graduates encompassed within TLO 4 are broad and include many elements of communication. When communicating, one must consider multiple issues – the content being communicated, the purpose of that communication, the method of delivery, and the intended (and possible) audiences. All these factors feed into the design and completion of a communication event, and should also be considered in designing learning activities and assessment around the science communication TLO.

If students are to develop proficiency in communication and meet the breadth of requirements within TLO 4, they need opportunities to both develop the skills and to practise them in a variety of formats throughout their undergraduate degrees. Indeed, given that science communication is fundamental to many assessment tasks, students must rapidly develop the skills to recognise appropriate communication formats and become proficient in those methods to achieve successful assessment outcomes. Despite the central nature of communication to student success, many undergraduate courses do not explicitly teach scientific communication skills; instead, the skills are implicit within assessment design.

To meet the diverse needs of students in developing 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. By developing this Good Practice Guide, the authors hope to elucidate the skills needed to meet each of those elements, and to aid curriculum designers and academics in this task.

'Communicating scientific results, information, or arguments'

> This term implies more than just presenting information. Science graduates will engage with their audience and be able to convey their message in a clear and understandable manner. In particular, science graduates will be able to present quantitative data in a variety of ways, including charts, graphs and symbols, which show clearly the trends or conclusions from their analysis as well as the accuracy of the underlying data
> (Jones, Yates & Kelder, 2011).

Fundamentally, for science graduates to become effective communicators of science they need to explicitly recognise and understand the nature of scientific argument, and be able to present a reasoned and well-evidenced message. A scientific argument must be based on and supported by credible evidence, be balanced and comprehensive, be objective, be logical, and be open to challenge and verification (Abi-El-Mona & Abd-El-Khalick, 2011).

In 1958, Toulmin published *Uses of Argument* which developed a definition of effective argument that focused on the elements of claim, ground and warrant (Toulmin, 1958). This work has been advanced into a structure for the development of scientific argument by scientists (Dunbar, 1993). More recently, it has also led to a framework for assessing scientific reasoning by undergraduate science students (Sampson et al., 2009). In this latter work, Sampson et al. (2009) define claim as “a conjecture, conclusion, explanation, descriptive statement or an answer to a research question”; evidence (‘ground’) as the “measurement of observations that show trends over time, differences between groups, or relationships between variables”; and reason (‘warrant’) as “a statement that explains why the evidence and other reasons support the claim” (Sampson et al., 2009, p. 1541).

While this argument structure is easily recognisable in scientific communications such as conference presentations and research articles, scientific literature reviews, and laboratory reports (Good Practice Example 3), it is also evident in other forms of scientific communication, which may encompass a much broader range of purposes, modes and audiences. In these more diverse types of communication, the presentation styles may be diverse (Baram-Tsabari & Lewenstein, 2013), but, essentially, the nature of argument remains consistent.

While science graduates must have the ability to develop and communicate scientific arguments, they must also develop the ability to effectively convey scientific evidence. This will include ‘research’ results (whether novel to science or novel to the students), which may have been generated by the students themselves or by others (Good Practice Example 3). Conveying evidence is the mainstay of the research scientist, and graduates need to recognise that this represents a specific genre, with conventions of language, nomenclature and style that may be particular to disciplines or sub-disciplines. In order to be able to effectively convey evidence, students must also have an understanding of what constitutes evidence, and how evidence is used within scientific argument (Good Practice Examples 3 and 4). These aspects are addressed in TLO 1.1 “explaining why current scientific knowledge is both contestable and testable by further inquiry” and in TLO 3.4 “collecting, accurately recording, interpreting and drawing conclusions from scientific data”, which emphasises the need for science graduates to use reproducible evidence which is verifiable.

While communication of science results is important, there is also a growing body of research indicating that the process and methods of scientific research themselves can engage a wide range of audiences for science (including future science students). Graduates need to be both critically aware of scientific method and capable of communicating this to others. In addition, science graduates are increasingly called upon to assess the ‘impact’ of scientific results. To do this, they need skills in understanding and communicating probability and uncertainty, and even in communicating unclear results (Budescu et al., 2009). Finally, graduates are increasingly communicating science in a global context; this is vital for international diplomacy and communication around complex global issues. Graduates are poised to make serious advances in this area but, to do so, they need core skills in communication for an international context.

‘to a range of audiences’

> Science graduates will be able to communicate with their peers, scientific non-experts and the general community. Science graduates will have some familiarity with the use of different genres of communication, including formal scientific

communication modes and less formal modes that could be used to communicate to non-scientific audiences
(Jones, Yates & Kelder, 2011).

The measure of success of any science communication is the extent to which it engages and informs its target audience. The successful science communicator must be able to recognise their target audience, and then make the science accessible to them. While the extent to which any science graduate will engage with different audiences is largely dependent on their destination post-graduation, every graduate needs to have developed the abilities to recognise and engage with a variety of audiences, in a genre appropriate to those audiences, to meet the requirements of TLO 4.

One of the primary audiences for scientists is their peers – an audience with whom they share similar expertise. Within the research community, the communication of novel findings and the scientific reasoning that explains them are paramount. Scientists use formal modes of communication such as peer-reviewed research articles and literature reviews, conferences presentations (including written abstracts and posters), and oral presentations; however, they also use less formal modes such as individual or laboratory group discussions. These genres tend to be well represented within university science curricula, embedded through assessment tasks such as laboratory reports – both oral and written, posters, assignments in the form of literature reviews, and critiques of published literature (Good Practice Examples 3 and 5). Each of these genres has specific rules, which may be taught implicitly through completion of these tasks or may be explicitly articulated in assessment guidelines, criteria and discussions. In addition, disciplinary and sub-disciplinary rules may apply in the methods of presentation of evidence, style, language and nomenclature.

Graduate scientists also communicate with audiences who may be scientifically literate, but may not necessarily have expertise in the same field. The content of these forms of communication may include novel findings and reasoning, but may also include more fundamental scientific principles, scientific processes, and explanations of methods. The audience for these forms of communications includes reviewers of grants or ethics applications; readers of science editorials and generalist science literature; recipients of scientific reports; and lecture attendees, be they students or conference participants. As with communication among peers, these forms of communication have specific genre rules, but are likely to include a broader range of communication techniques, such the use of narratives, analogies and metaphors, and should contain less specific jargon (Baram-Tsabari & Lewenstein, 2013). Examples of undergraduate tasks that mimic these styles of communication are less well represented in the science curriculum, although some outstanding examples exist (Good Practice Examples 1, 2 and 6).

The other major audience with whom science graduates need to communicate is the general public. This audience will include a broad cross section of the community, with highly variable educational backgrounds and scientific understanding. The information presented to the general public may include novel findings, but may have a greater focus on the implications and impact of science, with discussions on the nature of science and the controversy that surrounds it. Climate change, biological engineering, and even 'Big Science' projects involving physics and astronomy have been considered 'controversial' in various media (Friedman, 2012). To effectively communicate in this environment, students need to both understand and possess basic skills in assessing and addressing controversies. Communication with this audience has very different genre requirements, with a much greater need for readability, through the very limited use of jargon, and a demand for communication techniques which are highly engaging and express the relevance of science to the individual (Baram-Tsabari & Lewenstein, 2013). Forms of communication with the general public are likely to include media presentations, live or online discussion forums, and information presented as podcasts or on science blogs. This type of communication may also include more formal formats such as the 'lay language' sections of grants and ethics applications. However, in general, these modes tend to be much more personalised than the formal modes of communication between scientists, and the extent to which graduates will engage with this audience may vary according to graduate destination and attitudes (Poliakoff & Webb, 2007; Bentley & Kyvik, 2011). While examples of good practice in these modes exist (Good Practice Example 7), science undergraduates are rarely exposed to these communication formats as assessment tasks, but may participate in them as extracurricular activities.

'for a range of purposes'

> Science graduates will be able to present their findings in both a technical and non-technical manner. They will use scientific language correctly and appropriately and follow the conventions of discipline-specific nomenclature. This might include the use of standard symbols, units, names or key terms. Science graduates will be aware of the need to communicate the details of their investigations according to conventions that are usually specific to their sub-discipline, and which may be defined by publishers, editors or professional associations (Jones, Yates & Kelder, 2011).

As with the range of audiences, science graduates also need to be able to communicate science for a range of purposes. These purposes are not (and should not be) limited to the most familiar goals of science communication, such as obtaining grant money, publishing research papers, and reporting laboratory results.

Given the generalist nature of Australian undergraduate science degree programs, the destinations of science graduates can be particularly diverse, and the reasons why they need to communicate science are also varied. Indeed, many science graduates (30-50 per cent) continue on to further study, while only a relatively small proportion of working science graduates (approximately 20 per cent) are employed as science professionals (University of Sydney, 2008; Graduate Careers Australia, 2011).

The authors suggest that curriculum designers consider what their students need to know about science in the context of why and when they need to communicate it. A science graduate may be called upon to engage a class of primary school children in a discussion about global warming, to convince parliament not to cut research spending, or to pitch an idea to a venture capital group. Many science students continue into the health professions – they may need to convince a recalcitrant patient that they should lose weight, or to design an advertising campaign to improve public health. The capacity of a scientist to make an impact outside the laboratory is important; however, this requirement is rarely stressed in current science curricula.

Clearly, different communication purposes require genre-specific approaches that may stray from the comfort zone inhabited by most science academics. The authors acknowledge that some of the skills modern science graduates will need are not within the usual skill set of the science curriculum designer. One elegant solution to this problem is cross-disciplinary collaboration. Scientists can (and do) work with non-science colleagues to enrich their course offerings (Poronnik & Moni, 2006).

Curriculum designers are encouraged to regularly consider that students may have non-science professional careers in mind. If possible, curricula should include elements that build student awareness of these alternative uses for science understandings, while also giving students an opportunity to communicate their learning with a purpose that is relevant to their career goals.

'using a variety of modes'

> Science graduates will communicate using a range of media, including both written and oral, and a variety of other techniques. Such communication could include a range of formats (such as technical report, newspaper or journal article, and poster presentation) and new media (such as wikis, blogs and podcasts)
> (Jones, Yates & Kelder, 2011).

The modes of communication that science graduates use will vary widely, and will be dependent upon the purpose of the communication, the information conveyed and the audience for which it is intended. As mentioned previously, the modes of science communication range from the very formal modes of research articles, conference presentations and grant applications, to more informal modes such as media presentations, live or online discussion forums, and blogs.

The use of new media within both the formal or informal modes of communication is increasing, with the uptake of emerging media likely to be high amongst science graduates. To become proficient in recognising both the genre rules and the disciplinary and sub-disciplinary norms within these modes and media, and to enhance their uptake of emerging media, science undergraduates need to be introduced to core skills across media and have opportunities to develop these skills through exposure to multiple communication modes within their degree program. This is a central pillar of the Inspiring Australia policy (DIISRT) and key resources to be expanded are available at the Australian Science Media Centre (<www.smc.org.au>).

While written examinations and assignments, often in the form of literature reviews and laboratory reports, remain common assessment methodologies, interest in developing more innovative assessment practices which take advantage of emerging technologies (Good Practice Examples 1, 2, 6 and 8) is increasing. In addition, the core skills developed in the more traditional modes of communication are being better clarified and articulated so that examples of those modes retained within the curriculum can be used to greatest advantage (Good Practice Examples 3, 4, 5 and 7; TLO 3 Good Practice Guide: Example 11).

Approaches to teaching TLO 4 in Australian universities

As with each of the TLOs, the approach taken to teaching skills in science communication varies both across and within universities. Fundamentally, three curriculum models are used to include science communication in programs; examples of each model exist:

1. Fully integrated and embedded within the science curricula – science communication is taught in the context of the discipline, with skill development either horizontally-integrated (across a year level), vertically-integrated (between year levels) or both. This allows students to develop skills in a coordinated manner, but requires broader involvement of academic staff. The development of communication skills may also be linked to other skills such as the research skills developed in a series of inquiry-based laboratory classes (TLO 3 Good Practice Guide: Example 11).
2. Embedded within existing science course, but not necessarily well integrated – explicit teaching of communication skills, often by individuals with particular expertise (for example, the inclusion of specific lectures or a communication module within a course) but may suffer a 'disconnect' from the remainder of the course or program.
3. Separate communication course/unit –separate courses within the BSc program, for example, that explicitly focus on science communication. These may take the form of introductory courses at the first level, often combining science communication with understanding science as a field (TLO 1 Good Practice Guide: Example 5), or may be at higher levels (TLO 1 Good Practice Guide: Example 3).

Science communication: A professional future

An interest and passion for science may lead to diverse future careers for students as well as researchers. In Australia, science communication has emerged as a field of professional practice where those with a scientific background and excellent communication skills can find rewarding employment. For more information about the professional field of science communication, refer to the Australian Science Communicators website <www.asc.asn.au>. The effective diffusion of expert scientific knowledge is critical in today's increasingly commercialised and knowledge-intensive environment. Science communication may appeal to science students who wish to communicate effectively with scientists and professionals in business, industry, government and the media.

Professional qualifications in science communication

While science communication is an essential component of all undergraduate science degrees, it is unusual amongst the TLOs in also being a profession, with specialised qualifications in science communication or related topics available at both undergraduate and postgraduate level, and it represents a potential destination for BSc graduates. A number of Australian universities currently offer programs in science communication, with The Australian National University[2], The University of New South Wales and The University of Western Australia all offering both undergraduate and postgraduate programs, and The University of Queensland offering postgraduate programs.

Undergraduate programs consist primarily of Bachelor of Science programs with either a major or a minor in science communication. In contrast, postgraduate offerings are more diverse, ranging from Graduate Certificate, Diploma or Master of Science Communication by coursework, Masters programs combining coursework and research, to MPhil and PhD research programs.

[2] ANU hosts the Centre for Public Awareness of Science, which is the longest-running science communication academic centre. Its first graduate diploma was offered in 1986.

Specific skills

Communicating science to disciplinary peers

The supporting literature on how to communicate well in science is vast and many students and lecturers have access to guides, handbooks, videos, podcasts and other online resources to encourage improvement in communication. However, if student development in communication is to improve steadily, a piecemeal approach needs to give way to systematic curriculum design. Such a design would include the scaffolding of communication skills and concepts that complement the growing knowledge students possess.

A concrete example of a core science communication skill in most disciplines is scientific explanation. Sevian and Gonsalves (2008) have created a rubric for evaluating scientific explanation. They consider this task into five parts:

1. engaging the audience
2. connecting to prior understanding
3. structuring the explanation
4. forming images
5. presentation style.

Their rubric further demarcates the qualities each of these parts contributes to scientific explanation. Samples of scientific explanations with comments using the rubric are included.

Scientific explanation is, however, only one of the skills undergraduate science students are expected to master. Below is a non-exhaustive list of communication skills and concepts curriculum designers can incorporate into their teaching and assessment activities.

Basic skills:
Clarity – using disciplinary-appropriate language; giving background explanations and context while acknowledging disciplinary norms and existing knowledge; expressing probability and error clearly

Content – selecting appropriate disciplinary content; including appropriate methodologies; including well-presented data; including meaningful discussion of results

Organisation – following disciplinary norms for organising scientific writing or presentation; including appropriate citation and indexing; organising data presentation logically and effectively.

Intermediate skills:
Style – mastery of disciplinary style for written and oral presentations

Explanation – see above for five parts of the rubric for evaluating scientific explanation.

Advanced skills:
Answering and anticipating questions – demonstrating listening skills; organising communication to accommodate, encourage and answer audience questions

Communicating limits – articulating the boundaries or limits of the research; discussion of error, probability and/or uncertainty in relation to the claims of the research

Recognising global context – referencing the global aspects of research, which may include acknowledging international contributions or context.

Communicating science to non-scientists

Recently (in 2013), Baram-Tsabari and Lewenstein began the task of articulating the skills needed by scientists to communicate to those outside the scientific community. They identified a range of written skills that can be measured and evaluated at a basic, intermediate and advanced level. These measures could be adapted to other communication modes (presentation, digital media, etc.). Usefully, they have also validated their framework and instrument: an appropriate place to begin for course designers who wish to integrate these skills into their classrooms. Their framework is summarised below as a resource for generating assignments and assessments of how well students are prepared to communicate science to lay audiences. The published description of their approach includes sample assignment items. For example, students might be asked to identify core concepts to be explained to a nontechnical audience and attempt a 200-word explanation of these concepts (for example, mitochondria, pulsar, quantum, meiosis, dark matter, polymer, epigenetic, kinetic energy, the standard model, etc.). This work can be scaffolded to later assignments including research on these concepts, the incorporation of stylistic elements, and the development of analogy and narratives to engage audiences with these concepts.

Basic skills:
Clarity – using appropriate language, basic explanations, avoiding jargon, and acknowledging that an audience has prior knowledge or specific information needs

Content – selecting appropriate content which is engaging, interesting and relevant to a particular audience; including scientific information; including information about the nature of science, scientific method and the implications of science

Knowledge organisation – organising a presentation well using sound pedagogical and communication techniques, main theme, framing, scaffolding and repetition.

Intermediate skills:
Style – using aspects of style creatively; humour, emotions, anecdotes and local references

Analogy – developing analogic strategies for explaining complex topics

Narrative – using complex narrative tools including character development, conflict and resolution.

Advanced skills:
Dialogue – acknowledging and respecting multiple world views.

Resources for TLO 4

The published resources on science communication generally aim at two distinct audiences. Very practical resources fulfil the needs of scientists who are, or who wish to become, engaged with science communication. Resources of a more theoretical nature are directed at professional science communicators. A smaller number of resources service both groups.

While few resources are aimed specifically at curriculum designers, all of the resources listed below may have value through adaptation for student use. Many give instructive examples of science communication at work in many different formats – videos, news articles, blogs, images and more. These examples are often created by science students and could be used as the basis of designs for student tasks to be incorporated in curricula. Recently available, the website of the 'Inspiring Australia' project at <www.inspiringaustralia.net.au> is designed as a toolbox of resources for science communicators, and is also a great resource to support teaching. Finally, one of the greatest resources is people, both professional science communicators and the academics involved in science communication programs, who represent a valuable resource for scientists and curriculum designers. Contact can be made through the Australian Science Communicators website at <www.asc.asn.au/> or through university websites.

Print resources

For scientists

Baram-Tsabari, A. & Lewenstein, B.V. (2013). An instrument for assessing scientists' written skills in public communication of science. *Science Communication*, *35*(1), 56–85.

> This article describes the development of the first tool for measuring scientists' written skills in public communication of science. It includes the rationale for establishing learning goals in seven areas: clarity and language, content, knowledge organisation, style, analogy, narrative and dialogue, as well as the questions designed to assess these goals. The article provides detailed criteria for analysing the results of the instrument as well as findings from baseline data collected from science graduate and undergraduate students.

Bowater, L. & Yeoman, K. (2012). *Science communication: A practical guide for scientists*: Wiley-Blackwell.

> This guide is designed to help the novice scientist get started with science communication. It contains numerous case studies that discuss how to approach face-to-face science communication and engagement activities with the public while providing tips to avoid potential pitfalls.

Harmon, J.E. & Gross, A.G. (2010). *The craft of scientific communication*: University of Chicago Press.

> This guide teaches scientists how best to convey their research to general and professional audiences. The authors analyse published examples of how the best scientists communicate. Organised topically with information on the structural elements and the style of scientific communications, each chapter draws on models of past

successes and failures to show students and practitioners how best to negotiate the world of print, online publication and oral presentation.

Davis, M., Davis, K.J. & Dunagan, M. (2012). *Scientific papers and presentations: Navigating scientific communication in today's world* (3rd edn): Academic Press.

This very practical 'how to' book addresses the changing communication needs of academics. Topics include designing visual aids, writing drafts, reviewing, revising, communicating clearly and concisely, adhering to stylistic principles, presenting data in tables and figures, dealing with ethical and legal issues, and relating science to the lay audience.

Montgomery, S.L. (2003). *The Chicago guide to communicating science*: University of Chicago Press.

This straightforward book offers practical advice on crafting every sort of scientific communication, from research papers and conference talks to review articles, interviews with the media, email messages and more. The book avoids rules and warnings and, instead, focuses on how skilled writers and speakers learn their trade by imitating and adapting good models of expression.

Alley, M. (2013). *The craft of scientific presentations: Critical steps to succeed and critical errors to avoid* (2nd edn): Springer.

A new version of the Alley's 2002 classic of the same name, this text identifies what makes excellent presenters (for example, Brian Cox, Jane Goodall and Richard Feynman) so effective. In addition, the book explains what causes many scientific presentations to flounder. The text teaches the assertion-evidence approach to scientific presentations. Most engineers and scientists build presentations on the foundation of topic phrases and bulleted lists. The assertion-evidence approach encourages the use of succinct message assertions supported by visual evidence. The author is Associate Professor of Engineering Communication at Pennsylvania State University and is a leading researcher on the effectiveness of different designs for presentation slides.

Weigold, M.F. (2001). Communicating science: A review of the literature. *Science Communication*, *23*(2), 164–193.

This article, although now a bit dated, provides a good overview of science communication scholarship. The review is organised around the key players in any communication event, including news organisations, reporters, science information professionals, scientists and audiences. This article provides a good starting point when considering a wide-ranging literature search about science communication.

For science communicators

Stocklmayer, S.M., Gore, M.M. & Bryant, C. (2001). *Science communication in theory and practice*: *Contemporary trends and issues in science education*, Vol. 14: Springer.

This book provides an overview of the theory and practice of science communication. It deals with modes of informal communication – science centres, television programs and journalism – and the research that informs practitioners about the effectiveness of their programs. It aims to meet the needs of science communication students.

Bucchi, M. & Trench, B. (2008). *Handbook of public communication of science and technology*: Routledge Londres.

This work provides a useful introduction to the study of research trends in the public communication of science and technology. It is particularly focused on showing the evolution of this field. The contributors are drawn from multiple countries and contexts, so the book is useful on international issues and the perspectives of people from different geographical, disciplinary and cultural contexts.

Cheng, D., Claessens, M., Gascoigne, N.R.J., Metcalfe, J., Schiele, B. & Shi, S. (2008). *Communicating science in social contexts: New models, new practices*: Springer.

This broad volume covers the history, theory and practical application of science communication while also charting the changes in the field. The work is the product of long-term collaboration between the editors and members of the Public Communication of Science and Technology (PCST) Network. It provides a wealth of knowledge from 20 years of practice.

Bodmer, W., Bennett, D.J. & Jennings, R.C. (2011). *Successful science communication: Telling it like it is*: Cambridge University Press.

An applied 'how to' guide for science communication and engagement, this text brings together experienced and successful science communicators from across the academic, commercial and media worlds. The chapters provide background knowledge and inspiring ideas about how to deal with different situations and interest groups. Personal accounts of projects ranging from podcasts to science festivals and student-run societies give working examples of how scientists can engage with their audiences and demonstrate the key ingredients in successful science communication.

Cribb, J. & Hartomo, T.S. (2002). *Sharing knowledge: A guide to effective science communication*: CSIRO Publications.

This book is a guide for scientific managers, researchers, communicators and policy makers on practical, low-cost ways to add value to science by assisting its adoption or commercialisation. It is also a valuable text for the teaching of public awareness of science and science communication at the higher education level.

Academic journals

While research related to science communication can be found in a considerable number of science education and discipline journals, a small number of journals have a specific focus on science communication. These include:

Science Communication

Publisher/website: Sage Journals </scx.sagepub.com/>

This peer-reviewed, quarterly social science journal covers aspects of the communication of science and technology within research communities and to the public, and addresses issues of science communication policy.

Impact factor: 2.077

Journal of Science Communication

Publisher/website: SISSA Medialab <jcom.sissa.it/>

This is an online, peer-reviewed and open access journal that has been published quarterly since 2002. It has the stated aim of providing theoretical guidelines for both scholars and practitioners in the field of public communication of science and technology.

Impact factor: 0.255

Public Understanding of Science

Publisher/website: Sage Journals <pus.sagepub.com/>

This peer-reviewed, quarterly journal with a broad scope covers all aspects of the inter-relationships between science and the public, including topics ranging from popular representations of science, science fiction, science in schools, through to science and the media. While this journal is not specifically focused on science communication, it contains a large number of articles that discuss this topic.

Impact factor: 1.866

Video resources

NSF IGERT Video and Poster Competition

<posterhall.org/igert2013>

The website of the annual video competition for NSF Graduate students has links to previous years' competitions. While the competition entry is restricted, the resultant videos are all published online and are freely accessible. They are excellent examples of three-minute videos that explain scientific research and may be useful as exemplars for more advanced students.

Chemistry Vignettes

<www.chemistryvignettes.net/>

The website of the Chemistry Vignettes Project (Example 2) both describes the project and hosts numerous examples of the vignettes which have been created by students. The vignettes are short, annotated and interactive highlights from chemistry screencasts, and are useful both as chemistry education resources and as an example of science communication assessment task.

Blogs

A discussion of science communication and blogs takes two major forms; firstly, there are many great examples of science communication taking place; and secondly, there are discussions of science communication *per se*. Although few, if any, blogs appear to be entirely devoted to the discussion of science communication, the topic is well represented on science blogs in a variety of sites.

PLOS Blogs: MIT SciWrite

<blogs.plos.org/mitsciwrite/>

Contributions on this blog are created by students of the MIT Graduate Program in Science Writing, with some contributions from alumni and staff. The articles within it are valuable both as highly accessible discussions about scientific research and findings, and as examples of what students can achieve.

Scientific American Blog Network
<blogs.scientificamerican.com/>

This network, hosted on the Scientific American website, contains multiple blogs on a variety of scientific topics. While a blog devoted entirely to science communication does not exist, examples and commentary on science communication regularly appear within many of the blogs, and these are easily searched from the network website.

Websites

For scientists

<www.bbsrc.ac.uk/web/FILES/Guidelines/media_guide.pdf#search>

This very practical downloadable guide compiled by the Biotechnology and Biological Sciences Research Council covers the basics of news and the media (and how to deal with them) for scientists. It gives a brief overview of how the media works, how to engage with journalists and meet their needs, and the role of the scientist in communicating science to the public. The guide contains useful introductory resources for both scientists and science students.

<www.nature.com/scitable/topic/scientific-communication-14121566>

This website contains a series of practical guides on scientific writing and communication for graduate scientists and science students compiled by Nature Education. The website contains guides on the fundamentals of many forms of scientific communication: resources which would be suitable as guides for students undertaking communication tasks.

<theconversation.com/au/technology>

'The conversation' is not a source of communication resources as such, but a science news website which contains impressive examples of science communication on a wide variety of topics from an Australian perspective, as well as discussions and opinion pieces on science policy and the 'big picture' implications of science and technology.

For science communicators

<www.britishcouncil.org/talkingscience-organisations-resources-2.htm>

This link connects to the 'Talking science' section of the British Council website, which hosts a collection of resources for science communicators. The site has information incorporating the types and nature of various media, public engagement, education and development, and science communication organisations. It also has links to centres, other resources and networks, as well as promotion for specific events.

<www.facebook.com/EuroscienceWorkgroupScienceCommunication>

The facebook page of the Euroscience Workgroup on science communication posts newsworthy links and items on science communication, primarily directed at science communicators.

<ec.europa.eu/research/science-society/science-communication/index_en.htm>

The European Commission, Research and Innovation site on science communication has very practical pages covering topics such as communication strategies, media relations and a wide variety of different communication modes. It also provides links to the guides and brochures produced by the EU on science communication and related policy.

<www.britishscienceassociation.org/science-society/public-engagement-resources>

This site is the central hub for public engagement resources from the British Science Association. It contains a list of resources and organisations that support public engagement, and also has numerous tips, 'how to' guides and handy contacts for working with the media and graphic design resources.

<nationalscience.org/>

The National Science Communication Institute's stated aim is to help improve science collaboration, discovery, education and public policy by reforming the communication culture inside science. Its website contains both theoretical and newsworthy articles, with extensive links to other science communication outlets.

For both scientists and science communicators

<www.inspiringaustralia.net.au>

The website showcases the 'Inspiring Australia' strategy, which aims to inspire Australians to value scientific endeavour; to increase national and international interest in Australian science; to critically engage Australians with key scientific issues; and to encourage young Australians to pursue scientific studies and careers. This site was designed to host a toolbox of resources for science communicators, but is also a valuable resource to support teaching.

<www.asc.asn.au/>

This contact and information page of the Australian Science Communicators Network, a national association of more than 500 members, contains links to current events in science communication and other newsworthy items.

<www.aaas.org/programs/centers/pe/>

The Center for Public Engagement with Science and Technology website, which is a program of the American Association for the Advancement of Science, an international non-profit organisation dedicated to advancing science and publisher of the journal *Science*, contains a comprehensive set of applied resources for engaging with the media and the public.

<www.scidev.net/en/science-communication/practical-guides/>

This website contains a series of practical guides on science journalism created by the Science and Development Network. The SciDev.Net website is a source of news, views and analysis on information about science and technology for global development.

Good practice examples

Scientific communication is intrinsic to all Australian undergraduate science degrees. However, support for the development of undergraduate science students' communication skills is often implicit rather than overtly stated, and activities which promote that development in a variety of modes, to varying audiences and for differing purposes across the curriculum are often not well documented. Activities which will aid the progression of communication skills may vary widely and will include many of the assessment tasks completed by science students, ranging from oral presentations of laboratory reports to the building of 'wiki' pages describing specific phenomena. Examples of good practice may include specific tasks within subjects but may extend to tasks which are vertically and horizontally linked across the curriculum.

The examples of good practice highlighted here are intended to illustrate the variety of good practice currently offered in Australian undergraduate science degrees. The selection includes well-documented examples of 'common' practices and some more unusual examples to demonstrate the innovative approaches possible; each includes a description of its purpose and effect on student outcomes. There are many exceptional examples of good practices occurring throughout Australian universities and this guide cannot hope to encompass them all. The authors acknowledge the passion and dedication of the many academics who have risen to the challenge of developing tasks to enhance their students communication skills.

To ensure consistency, all examples below are referred to as subjects even though they may be known as units or courses at the institutions where they are offered.

Please note also that the examples of good practice included in this Guide and their attributions were correct to the best of the knowledge of the authors at the time of writing. Rubrics, guidelines and task descriptions from many of the examples are available on request.

Example 1: Memes in biochemistry

Subject: Human Biochemistry (Current: Semester 2, 2013)

University: The University of Sydney

Author: Gareth Denyer (gareth.denyer@sydney.edu.au)

Year level: Second year

Subject and task context: This document provides a description of the use of memes in Human Biochemistry (BHCM2072). This intermediate Biochemistry course provides a grounding in intermediary metabolism with an emphasis on whole body integration.

Educational aims and outcomes: The major aim of the unit is to help students appreciate metabolic regulatory mechanisms. The major desired outcome is that students should have the ability to predict what will happen to metabolic systems when change occurs. Rote learning of the metabolic pathways is *not* expected.

Description of the task: Students create two captioned pictures (memes) to illustrate two separate concepts. These pictures are submitted to a Blackboard Blog so that all students can see their peers' work. Each picture has a sentence or two to explain the underlying concept. The extent to which this explanation is likely to assist other students' understanding and learning forms a part of the mark. Exemplars and the marking rubric are available on request.

The final collection of some 300 separate mini-concepts serves as excellent resource for all students, both in terms of illustrating unusual ways of communicating scientific concepts and also by allowing students to reveal personal insights and, sometimes, misconceptions that can be deconstructed by tutor feedback. It is important that the postings be monitored to identify and remove (or annotate) these incorrect submissions, as students may use them for study purposes.

To construct captioned pictures, students need to reflect on material taught in lectures and identify what they think are key concepts or 'light bulb' learning moments. Designing abstract ways to repackage the course content reinforces the concepts for the students.

Assessment: The institution's standards-based assessment guidelines were used. The rubric is shown in Appendix 1. Essentially, novelty, imagination and humour are sought in the submissions; the criterion that the submission should also demonstrate correct understanding of the material is maintained.

Other relevant/helpful comments: Despite initial concern that this task might favour students from the Anglo-Gen Y culture, discussions with international students, octogenarians, and conservative academics revealed that the use of a captioned cartoon or picture is not the preserve of one culture or age group. To foster inclusivity, students were not limited to standard online 'meme' pictures to convey their concepts; students could base their memes on pictures from non-Anglo cultures. This was refreshing, but sometimes these alternative expressions required supplementary explanation. Students could assume that the marking team was familiar with mainstream meme characters.

Some students use meme-generator websites to make their image (e.g. quickmeme.com), but the material on these sites is generally un-moderated and can be offensive. Students do not need to use a meme-generator to make their captioned pictures, PowerPoint is sufficient.

Students make their submissions to a Blackboard Blog. Since this carries their institutional login as identification, students must think carefully about what they post. They are held accountable for anything inappropriate. The ability of students to see the submissions of others was both positive and negative. It encouraged students to ‘raise the bar’ and also discouraged ‘recycling’ of concepts. However, students with poor communication abilities and/or low understanding of key concepts were ‘exposed’ to their peers.

What worked from an implementer’s perspective? Students generally enjoy this assessment task. They revealed their interpretations of the lecture materials in ways that would not have been possible using more formal assessment tools. In formal writing they tend to regurgitate content or to use language that masks their true understanding. In this informal setting they extrapolate, repackage and explain, effectively revealing their understanding and feelings. Memes also allow the assessor to see how the material impacts on the students’ conceptual framework and how it relates to their appreciation of the system as a whole.

In order to minimise marking discrepancies, it is helpful if grading is conducted by one person. This is not an onerous task; the memes are interesting and quick to mark.

What was difficult from an implementer's perspective? Despite all efforts to make the task equitable, it appeared to be less well done by the non-native-English-speaking students. Although the course feedback contained almost unanimous approval for the task, students who were awarded low marks found it convenient to dismiss the assessment as ‘rewarding style over substance’. This reaction was irritating for the task developers as tremendous effort went into (i) articulating what was required and (ii) designing a marking scheme that would provide some reward to students with little imagination or poor communication skills.

Example 2: Student authored video vignettes

Subject: Chemistry

University: University of East Anglia, England

Author: Simon Lancaster (S.Lancaster@uea.ac.uk)

Year level: Fourth year (this task is appropriate for earlier years)

Subject and task context: This document describes the production and use of student-generated vignettes in a masters-level chemistry cohort. A vignette is a short segment of a screencast covering a critical concept; it may be augmented by an interactive component introduced during the editing process. This approach has the potential to add value to any activity where students are asked to present their work.

Educational aims and outcomes: The aim of this activity is to have students combine material from the first and second year of their degree programs into a coherent framework.

The act of preparing and delivering a presentation requires the students to evaluate and synthesise their knowledge and teaching resources, and to consider the most effective way to convey the selected topic to their peers. In so doing, they gain experience in the transferable skills associated with presenting.

The process of critically evaluating, editing and annotating the recording are transferable skills rarely practised during a chemistry degree. Composing questions for the vignette requires creativity and pedagogical consideration rarely integrated into programs of study.

Description of the task: In this task students are required to produce short online interactive learning objects (vignettes). The vignettes feature embedded multiple-choice questions (MCQ) to enhance interactivity.

The vignettes are the end-product of a series of student-led revision seminars. Pairs of students are charged with preparing a presentation and revision notes on one of a series of topics from the early part of the degree. This provides a revision strategy and a platform for practising presentation skills.

These short classroom presentations are recorded using Camtasia Studio; students then convert these recordings into short interactive videos using the Camtasia software.
The communication task can be considered as follows:

1. The students are paired and allocated a revision topic.
2. Each student pair prepares a presentation to be critiqued by their peers and instructors.
3. Each pair delivers a presentation to their peers. The session is captured using Camtasia Studio.
4. Each student pair creates a vignette from their screencast. Students may also use additional recorded material.
5. The vignettes are published to Blackboard for use as a revision tool.

Assessment Criteria: The presentation and the vignette production were formative assessment (no marks awarded). The incentive for students to engage was the belief that they were working together to prepare for the final examination. Detailed feedback was provided to students on (i) the draft slides made before the presentation and (ii) the content and delivery of the presentation before vignette production.

Other relevant/helpful comments: Student permission was gained to publish some vignettes of exemplary technical standard at <www.chemistryvignettes.net>.

Figure 1 below indicates the average number of student accesses of the Blackboard posting of a typical vignette in the run up to the exam on 22 April (the day following the largest spike on the graph). The class comprised 30 students.

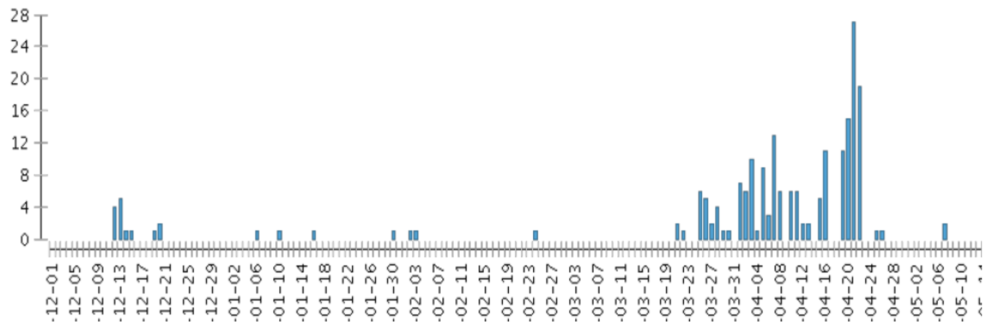

Figure 1: Blackboard accesses of "Electronegativity" a student-authored vignette

What worked from an implementer's perspective? Qualitative student evaluation was conducted through an independently convened focus group, where students were very frank. Pointedly, the focus group took place before the examination but while many students were beginning to prepare. Students were very positive about viewing the screencasts and vignettes.

What was difficult from an implementer's perspective? Students were less positive about producing vignettes themselves, largely because of the effort required and the difficulty of mastering the software at the last minute. Despite the developers believing that the Camtasia interface is very simple and their making available extensive online instruction, students did have some criticisms of the software. Workshops were given on Camtasia Studio but they were under-used by the students, who chose to teach themselves instead. In future, support will be provided through screencasts featuring example chemistry vignette production.

Example 3: Oral presentations in biomedical science

Subject: Integrative Cell and Tissue Biology (Current: Semester 1, 2013)

University: The University of Queensland

Authors: Andrea Bugarcic (a.bugarcic@uq.edu.au) and Kelly Jackson

Year level: Second year

Subject and task context: This is a practical-only course, restricted to Bachelor of Biomedical Science students, and focusing on the structure of cells and their functional importance within tissues. In particular, the topics covered include fundamental aspects of how cells respond to the extracellular environment by using highly specialised biochemical and fluorescent microscopy methodologies. The laboratory classes consist of an inquiry-based practical centred on a basic cellular uptake process called macropinocytosis.

Educational aims and outcomes: The major aims of the practical are: (i) to help students appreciate the molecular mechanisms underlying basic cellular processes; (ii) to develop students' understanding of methodologies for manipulating cellular processes; and (iii) to develop students' scientific reasoning and communication skills. The main desired outcome is the enhancement of students' hypothesis-development skills and their ability to predict what can occur within cellular processes when a simple treatment is implemented.

Description of the task: Students develop an experimental plan around the methodology and concepts taught in class and then perform the planned experiments. After completing the experiments students, give a 10-minute group oral presentation to their peers and an assessor about their experimental outcomes with particular emphasis on scientific reasoning.

At the beginning of the practical classes, the purpose of the task is explained and students receive task guidelines. The guidelines address the use of PowerPoint and include examples of good and poor scientific reasoning. The students also have access to the criteria sheet used for marking presentations. One week before the presentation, the teaching staff discuss the guidelines and criteria sheet with students in class.

Assessment: Hypothesis formulation, presentation of results, and handling of questions are specifically assessed. The greatest assessment weighting is on scientific reasoning (claim, evidence, reasoning, significance of research, and limitations of study). A standards-based rubric is used for this assessment. The rubric and associated guidelines are available on request. The development of the practical and its impact on student learning has been published and a manuscript on the oral presentation is in preparation.

Bugarcic, A., Zimbardi, K., Macaranas, J. & Thorn, P. (2012). An inquiry-based practical for a large, foundation-level undergraduate laboratory that enhances student understanding of basic cellular concepts and scientific experimental design. *Biochemistry and Molecular Biology Education*, *40*(3), 174–180.

Other relevant/helpful comments: This task was designed specifically to improve students' oral presentation and scientific reasoning skills; however, previous experience indicates that students prefer allocating presentation time to the introduction and methodology rather than the results. The developers assume this is because the introductory material is essentially a regurgitation of an ‘expert’ scientists’ work (and hence, it is not controversial) and the methods are something that the student has completed in the laboratory (so they understand them). Student comfort with these safer elements of the presentation meant that they spent more than half of their presentation explaining the introduction and methodology rather than engaging with their data or how their data agree with the hypothesis they proposed.

In response to this over-concentration of effort, the introduction and methodology requirements were removed and students were forced to (i) focus on formulating a question that can be answered with available methodology, (ii) describe the results they obtained, and (iii) explain these in the context of published work. This revised approach has been successful in encouraging students to develop a sound scientific reasoning based on their results.

What worked from an implementer’s perspective? Most science students have not been in contact with this type of assessment task in their Year 1 studies; they fear their inexperience in the art of public speaking will lead to low marks. To alleviate these fears, students were encouraged to talk to teaching staff about any problems they face early, so there is time to rectify them. The practical experiments are supported with a data analysis session so tutors can help students work with their data in advance of the presentation. The weight of this assessment task was offset by that of the individual final report (the task with the lowest mark receives the least weighting).

What was difficult from an implementer's perspective? The major difficulty with this assessment task is the requirement for group work during data collection, analysis and presentation. While most students are willing to contribute in every aspect of the task, a small percentage of students believe their peers can perform the bulk of the work and that they just need to ‘show up’. The groups usually self-regulate by assigning the smallest tasks to the least engaged students, but this also means that the least engaged students are poorly prepared for the second part of the practical (which is done individually). Making sure these students stay on track and engage with all tasks, including the oral presentation, is the main difficulty faced with this course.

Example 4: Data presentation – students select the good from the bad

Subject: Molecular Biology and Biochemistry (Current: Semester 2, 2013)

University: The University of Sydney

Authors: Jill Johnston and Gareth Denyer (gareth.denyer@sydney.edu.au)

Year level: Third year

Subject and task context: This document describes the use of a student-driven critical analysis of data presentation in Molecular Biology and Biochemistry – Genes (BCHM3071), a senior Biochemistry course that addresses how gene expression in regulated in higher organisms. It includes both a lecture and a laboratory component.

Educational aims and outcomes: The major aim of the unit is to guide students in appreciating both the structure of genes (and, hence, the nature of their encoded proteins) and how gene expression is regulated in response to different physiological stimuli. The major desired outcome is that students should have the ability to use contemporary molecular biology techniques and to appreciate how they can be used to study biological problems. There is a strong emphasis on analysis and communication of laboratory results.

Description of the task: In this task students are required to find and justify an example of published literature or popular science communication in which: (i) an inappropriate number of significant figures has been used and (ii) a graph or table has been presented in a confusing or sub-optimal way.

To guide the students in this task, students participate in a 'webinar' in which examples of results, graphs and tables are presented and students give their opinions. Presenting students with examples and the opportunity for them to articulate their opinions develops their critical analysis skills and their confidence in formulating their own opinions.

Assessment: Each response is marked in alignment with the institution's standards-based assessment guidelines. An abbreviated rubric is given here; more details are available on request from Jill Johnston.

Pass:	Suitable choice of number/figure; properly referenced; appropriate reflection on significant numbers
Credit:	As for pass, but showing more discrimination in selection of example
Distinction:	As for credit, but showing increased awareness, for example, of how the measurement was made and any associated limitations
High Distinction:	As for distinction, and the submission shows additional insight and furthermore is a brilliant choice of example.

Other relevant/helpful comments: There was concern that students might find this task simple and, indeed, trivial. However, the range of responses showed that many students have an implicit belief in the 'correctness' of published material and that requiring students to source relevant examples and to justify their choices forced them to be more critical and, hopefully, more thoughtful in presenting their own results.

What worked from an implementer's perspective? In general, students enjoyed this assessment task. Most importantly, they revealed their appreciation, (and lack of appreciation), of the principles of good data graphics.

In order to minimise marking discrepancies, it is helpful if one person does all the grading. This is not an onerous task. The responses are quick to mark, each one is interesting in its own right, and they usually fit neatly to one of the grade criteria.

What was difficult from an implementer's perspective? Despite all efforts to make the task outcome an embedding principle, it was disappointing to find that some students were not able to transfer the principles to presenting a supplied set of data in a task that formed another part of the total assignment. In the second part of the assessment activity, some students committed the same transgressions they had criticised in the item they had initially sourced and critiqued!

Example 5: Writing and peer appraisal of medical case studies

Subject: Biomedical Science (Current: Semester 2, 2013)

University: La Trobe University

Author: Fiona Carroll (F.Carroll@latrobe.edu.au)

Year Level: Third year

Subject and task context*:* This document describes the case study and peer evaluation component of two multidisciplinary courses covering a range of current topics in the biomedical sciences. The courses provide the students with a background in multiple biomedical science disciplines. Students also develop an understanding of areas of importance in health and medical research, including ethics and the interpretation of clinical data and systematic reviews.

Educational aims and outcomes: The aims of the case study exercise are: (i) to help students extend and examine applications of the theoretical content in the course; (ii) to increase student information literacy skills; and (iii) to improve student writing, reflection, and metacognition. The desired outcome of the exercise is that students are able to write a concise overview of a topic of biomedical interest that is appropriately sourced and referenced.

Description of the task: The case study exercise forms a central component of the communication activities in the Bachelor of Biomedical Science program. Students conduct three case studies in each of two final-year courses; two are written and one is an oral presentation. The case study operation is described below.

The theoretical content is provided to students in pre-readings for each of two class sessions per case study. During the class, the students form groups where they discuss and answer a series of reading-related questions. After the second session, the students are given a report topic and an accompanying assessment rubric. Each student writes a concise, individual report about the topic.

Following submission of the first case study, the students participate in peer review. Students read three of the case studies submitted by their classmates and assess them according to the rubric. There are guided questions to help them think about the report and the feedback required. Students then form groups of four where they discuss the case study and their assessments.

The sequence of classroom activity, report and peer review is then repeated with a different topic. This time the students independently assess and provide anonymous, constructive feedback to three of their classmates.

The case study sequence is followed by student talks on *one* of the case studies. More details on these can be obtained by contacting Fiona Carroll directly.

Assessment: The case study report is marked according to a rubric. Both case studies are marked based on the same rubric. This enables students to monitor changes in the quality of their work.

What worked from an implementer's perspective? This task works well. The students generally respond very positively to peer-reviewing and the opportunity to look at alternative ways of structuring information on the same topic. They clearly see the exercise as useful for developing their writing skills. Interestingly the peer review also seems to increase the care and proofreading capabilities of the students prior to submission! Generally an improvement (usually of a grade or more) is noted between the first and last written case.

The quality of the reports seemed to improve after attendance at the case study classes was made compulsory – probably largely due to a better student understanding of the content. While the developer is fortunate in having the ability to extend the task across two subjects to allow for the repetition and development of skills, the peer review element could easily be adapted to an individual task.

What was difficult from an implementer's perspective? The task has been developed over several years with a few changes along the way. It is marking-intensive, particularly in the earlier formative stages prior to the peer assessment. This is probably true for most traditional writing tasks. Initially, the ulterior motive for employing peer assessment was to lighten the marking load for later case studies, the idea being that, in the second course, only those where a discrepancy existed in the marks given by the three student reviewers would be marked. This approach, however, has received negative feedback from students who most commonly suggest that other students are not qualified to grade their work or that the students are unduly harsh in their assessment despite the task being heavily moderated. How easy (or time-consuming) the peer review elements are to implement depends on what software and/or LMS capabilities the instructor has to facilitate the task. Exploring your options is recommended.

Example 6: Collaborative wiki development

Subject: Developmental Biology (Current: Semester 2, 2013)

University: University of Queensland

Author: David Simmons (d.simmons@uq.edu.au)

Year level: Second year

Subject and task context: This document describes the use of student-generated wiki pages in an introductory developmental biology course. The course focuses on how a single cell becomes a complex multicellular organism. It deals with core concepts such as cell fate, differentiation, cell-cell communication, cell morphogenesis and cell signalling.

Educational aims and outcomes: The major aims of the wiki assignment are: (i) to develop skills in scientific communication and (ii) to promote an in-depth understanding of developmental biology concepts. The desired outcome is that students will learn to integrate concepts and scientific observations from multiple sources into a cohesive, concise teaching aid.

Description of the task: In this task, students design and post a wiki page that deals with an aspect of developmental biology for a model organism.

The wiki assignment is introduced to the students in a lecture and two tutorials. These classes allow students to see wiki pages from previous cohorts; they address (i) how to pick topics, (ii) what a good wiki 'looks like', (iii) how to use the MediaWiki software, and (iv) how to avoid copyright issues.

The students are formed into groups of 3–4 and tasked with using their wiki page to convey an important developmental biology 'concept' to their peers. First, students choose a particular developmental system and model organism in which to demonstrate and describe their concept. Instructors help students to get started by providing them with lists of appropriate subjects for each of the three 'pillars' they need to combine to create a wiki topic. An example of this 'pillar-based' topic formation might be: branching morphogenesis (concept); kidney formation (developmental system); mouse (model organism). This would result in a page entitled *Branching morphogenesis in the formation of the mouse kidney*. Students are also free to develop original ideas for their pages.

Each group's suggested topic/s are submitted for approval on a 'first come, first served' basis. This allows breadth of topics with minimal overlap each year. The students then produce and submit an outline of their wiki page for assessment and feedback before building and submitting their final page for marking. All students are able to see all groups' pages during the whole assignment, as well as selected previous years' pages, to obtain ideas and inspiration.

The key to student success in this assignment is the ability to locate, filter, edit and integrate material in order to tell a state-of-the-art story, in an interesting, engaging and effective manner. The assignment is purposely vague in its requirements to promote imagination and innovation. Often students delegate tasks, allowing artistically inclined students to work on visuals while more structured or cautious students code the page and compile written materials and references. Students are encouraged to provide fully-referenced external links and resources on their pages so they can focus their content and be concise. Figures and animations are encouraged to be summative, integrating several ideas or observations into a cohesive story.

Assessment: The marks are distributed between the Wiki Outline, (20 per cent of the wiki mark), for which students submit an outline of what they envision their page to be/look like, and the final Wiki Page (80 per cent of the wiki mark). Students can work on their pages until the deadline, at which time access to the pages is suspended and tutors mark the pages.

What worked from an implementer's perspective? The students typically enjoyed this assignment and the feedback has been mostly very positive. Initially, the students are concerned with the vague requirements and are hesitant about how to get started. However, students without strict rules and templates to fall back on, eventually engaged with their group members and often came up with creative 'out-of-the-box' thinking and ideas! When they have a defined template to follow, the level of creativity and innovation is typically low.

It has been difficult to determine which resources, templates and ideas to provide to the students at the beginning. As described above, a mix and match of 'pillar lists' that students can use to explore different combinations of concepts and developmental animal models are now provided. This provides enough structure to prevent panic among the students, but enough flexibility to enable and encourage the creation of totally original topics.

The use of MediaWiki, hosted on the University's Science server, rather than using the integrated Blackboard Wiki, enabled an ongoing resource that the students felt was more relevant (MediaWiki is the software that runs Wikipedia; in essence, students are also taught how to make Wikipedia pages).

What was difficult from an implementer's perspective? Perhaps not unique to this course, the most difficult factor to deal with is the group nature of the assignment. Some students felt they have done more than others, or that under-performing students were 'a drag' on their grades. To counteract this problem, the peer-review component to the assessment was used (10 per cent of their final page mark). The value of this component may be increased to better differentiate students who actively participated from those who did not. However, more than 90 per cent of groups usually get along and produce great work, with little conflict. Efforts to implement effective measures to deal with non-participation are ongoing.

Example 7: Planning, presenting, and evaluating the success of a health-promotion initiative

Subject: Health Promotion and Health Education (Current: Semester 2, 2012)

University: Zayed University, United Arab Emirates (UAE)

Author: Merryn McKinnon (merryn.mckinnon@anu.edu.au)

Year level: Third year

Subject and task context: This document describes an interdisciplinary subject that runs for third-year health-science students in Abu Dhabi in the UAE. The subject examines how sociocultural, economic, political and educational factors influence health in communities and how such knowledge is utilised to create intervention programs. Each student group identifies a particular health issue and then develops and implements a related health promotion initiative, creating a portfolio of the associated assessment tasks. The course emphasises 'hands on' experience to develop skills used in the work of a health promotion/education professional.

Educational aims and outcomes: Upon completion of this course, students should be able to: (i) understand the complex factors associated with health in communities; (ii) understand the roles and responsibilities of health educators; (iii) identify basic health needs of UAE society; and (iv) plan, implement and evaluate their own ethical health education program. In addition, the subject aims to develop the students' information literacy, critical thinking, quantitative reasoning and leadership skills.

Description of the tasks: The course includes the development and assessment of communication skills in all of its classroom and assessment activities. These include: (i) a weekly journal of the ideas, thoughts and questions students have as they read about and work on health promotion and education; (ii) participation in class discussions; (iii) a critical literature review of a health issue in the UAE; and (iv) a behaviour change essay on a health education or promotion initiative in which they discuss the type and value of behaviour change models and/or theories relevant to the initiative. The course culminates in an assessment task where students work in groups to develop, execute and evaluate an ethical health promotion program. One lesson a week is devoted to program work; there are sessions on research and evaluation methods, practical exercises and troubleshooting, as well as opportunities for program presentation to an identified audience.

Assessment: Students are graded on their ability to work in a team, as well as their actual program. Students build a portfolio that reflects meetings, progress and allocation of tasks amongst the group members, as well as a dossier of communication materials specific to their program. Many science communication projects have multiple stakeholders, so the ability to work collaboratively is important. Specific aspects assessed include the suitability of their health promotion program for the target audience, the quality of program information, and the student's own evaluation of their program's quality and presentation.

Other relevant/helpful comments: After the project was completed, the students presented their promotion initiatives at a Zayed University science fair. This allowed the students to convey information to a range of audiences including non-science students at the University, and a visiting fifth grade from a local primary school. The science fair incorporated posters, ‘hands on’ experiences, experimental set up and students explaining scientific concepts and principles.

Throughout the subject, students relied heavily on each other to produce their health program. They allocated workloads and responsibilities, and learned how to manage others to achieve a common objective. They also learned the challenges of working in a group, and how to produce something successful if one group member is not contributing at expected levels. This is a valuable, ‘real world’ experience and skill to have!

What worked from an implementer’s perspective? The practical application of ‘hands on’ skills at a health fair was very useful in terms of their learning. Students experienced what health educators routinely face. Major outcomes included one group's stall helping a student realise she had an eating disorder, while another group's breast-feeding advocacy video was adopted by the major maternal health hospital in Abu Dhabi. A standout achievement by one group was catalysed by their healthy lunchbox campaign. They invited a celebrity chef to take part, and this culminated in the chef filming an entire episode of his TV show in and around the health fair, highlighting the students and their work. Anecdotal comments from students often indicated that this was the first time they had an opportunity to actually apply what they were learning in a ‘real world’ or ‘hands on’ context. They felt they had learned so much and could actually achieve a lot more than they thought. For most, although challenging and exhausting, it was also empowering, providing a sense of self-confidence and ability that may not have been felt (as strongly) before.

What was difficult from an implementer's perspective? The students universally *loathed* the reflective journal. Many did not see the point of it. Some did accurately reflect and encompass what they were learning within their broader context, but they were certainly in the minority. This could be indicative of ESL students not wanting to write in English, or a cultural preference for oral transmission of information as is typical of Arabic cultures. Certainly students’ spoken English was, on average, stronger than their written. The health fair (or science fair) is extraordinarily time-consuming to organise and requires considerable project management, liaison and negotiation skills for the lecturer. However, it becomes easier with each iteration and the benefits for the students, as well as the feedback from other students and faculty, do make it worthwhile!

Example 8: Creative Podcasting in Chemistry

Subject: Introductory Chemistry (CHEM1105)
University: University of Western Australia
Authors: Emma Bartle (e.bartle@uq.edu.au), Nancy Longnecker, Mark Pegrum
Year level: First year

Subject and task context: This document describes the use of creative podcasts in an introductory chemistry course.

Educational aims and outcomes: The course aims to provide students with a basic grounding in key chemical concepts covered in the Year 11 and 12 chemistry syllabi. The course is designed for students with little or no relevant chemistry background.

Description of the task: In this task, students were required to work in small groups to create a 3-minute podcast on a core chemistry concept. The topics of 'acids & bases' and 'oxidation & reduction' were assigned to students; these are two concepts in the course that students often find difficult (as shown by anecdotal evidence and past examination performance). They were encouraged to approach the task creatively, for example presenting analogies or practical applications of the concept.

To complete the assignment, students were placed into groups of three based on their assigned bench in the practical laboratory class. This ensured they had shared timeslots to work together on the task in the weeks when lab sessions weren't scheduled. Groups of three were chosen to ensure that if one person didn't carry their weight for the task there was still a team of two to work on it. The purpose of the task is explained to students during a lecture. Students were briefed about the task in a lecture and provided with an assessment handout via WebCT (UWA's online learning management system at the time). The handout contained the task instructions and marking criteria. An example podcast on the topic of 'atoms and chemical bonds' was created and placed on the unit WebCT site so that students could listen to it and get ideas. 'Atoms and chemical bonds' is the first topic taught in the unit.

Students submitted their completed podcasts through the WebCT learning management system. Each group was given a group name to help preserve the anonymity of the students. To give the students the perception that the assessment task was meant to be a bit of fun, group names were based on characters from a commercially available chemistry card game, Elementaurs™ (e.g. Princess Neo). The podcasts were uploaded to the class's WebCT discussion board during the final week of semester and were available for students to listen to during study week. Students were required to listen to and comment on a minimum of six podcasts (three about 'acids & bases' and three about 'oxidation & reduction', with their own included in the total of six) from their practical class group.

Assessment: The podcasts were assessed using a marking rubric with five criteria: 1) how well the introduction set the scene; 2) clarity, accuracy and relevance of content; 3) whether the conclusion provided a clear summary of the main points; 4) the structure and flow of the podcast and 5) technical sound quality (volume and clarity). Bonus marks were also awarded for creativity. The podcasts were marked by the course coordinator. Students were required to complete a teamwork assessment, evaluating individual contributors to the group assessment task. Students were asked to sign a digital publication authorisation from to allow the podcasts to be published on *iTunesU*.

Other relevant/helpful comments: Student feedback has been positive enough to recommend use of this type of podcast assignment in other large science classes. The assignment appears to have motivated students to develop an explanation of some aspect of a fundamental topic and to share their insights with their peers. As an engaging, learner-centred task, it fitted well with contemporary pedagogical approaches.

Descriptions of the assessment task and a case study have been published:

Bartle, E., Longnecker, N. and Pegrum, M. 2010. Can creating podcasts be a useful assignment in a large undergraduate chemistry class? In: M. Sharma (ed.) , Proceedings of the 16th Annual Uniserve Science Conference, *Uniserve Science Conference*, University of Sydney, Camperdown Campus, NSW, pp 104-107. 29 Sept – 1 Oct 2010.

Bartle, E., Longnecker, N. and Pegrum, M. 2011. Collaboration, Contextualisation and Communication using New Media: Introducing Podcasting into an Undergraduate Chemistry Class, *International Journal of Innovation in Science and Mathematics Education*, 19(1), 16-28.

The assessment task was also found to have a positive effect on learning outcomes; increasing students' understanding of content material by encouraging a deep learning approach. This paper is currently in press:

Pegrum, M., Bartle, E. and Longnecker, N. (in press). Can creative podcasting promote deep learning? *British Journal of Educational Technology.*

What worked from an implementer's perspective? The assignment required minimal effort on the part of the course coordinator and laboratory demonstrators and so was an efficient use of limited teaching resources to provide an engaging learning opportunity for students.

Future research opportunities

The field of science communication research is rapidly growing. The advent of professional programs in science communication and the subsequent creation of science communication professional bodies, such as the Australian Science Communicators, have created a highly engaged network of researchers and practitioners. With journals, books and websites specifically dedicated to furthering the research on effective approaches to science communication, the field is likely to continue to grow. There is considerable potential research in examining the various facets of science communication and public engagement with science.

However, despite the growth of science communication research, relatively few of the resources available are specifically designed to aid the curriculum designer in incorporating the explicit teaching of science communication into science programs. In addition, while there has been increasing research interest, what constitutes effective science communication practices, and research into curriculum models and pedagogical methodologies that enhance students' scientific communication skills remain somewhat limited. Nevertheless, there are many outstanding examples of good practice occurring within universities, both in Australia and abroad, a few of which have been highlighted in this guide. Given the central importance of science communication to both undergraduate science students and the scientific and general community, it is vital for academics and curriculum designers to have the opportunity to evaluate and then disseminate such examples of good practice beyond their immediate colleagues, to enhance the teaching of science communication across the university sector.

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