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Vision and Innovation in Biology Education (VIBEnet)

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VIBEnet VISION & INNOVATION IN BIOLOGY EDUCATION

THE UNIVERSITY OF SYDNEY

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LA TROBE UNIVERSITY

UTAS

<www.vibenet.edu.au>

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Network summary

The network was established to:

- develop a national identity and network (VIBEnet) for university biology teachers to build on the Australian Learning and Teaching Council Learning (ALTC) and the Learning and Teaching Academic Standards (LTAS) project on the Science Threshold Learning Outcomes (STLOs) and develop Biology Threshold Learning Outcomes
- mentor the next generation of Biology teachers to enhance active/inquiry learning in biology, particularly at the first year level, and to build teams of academics, at the institutional level in each state and region
- create a 'Vision and Innovation' statement which reflects the collective understandings about the direction of the future of biological curriculum, especially at first year level.

The outcomes are as follows:

- An established network of over 160 academics who have met in national workshops on three occasions to share and disseminate good practice.
- A set of Biology Standards Statement and Biology Threshold Learning Outcomes (BTLOs) modelled on the Science Standards Statement[1], and a 'Vision and Innovation' Statement that articulates the future direction of the biology curriculum in Australian universities to be released in November 2015, both form the basis of curriculum change and an improved student learning experience.
- A sub-group of early to mid-career academics, who have been supported in the scholarship of teaching and learning by publishing in a special edition "Biology Education Futures" of the International Journal of Innovation in Science and Mathematics (IJISME) and to take leading roles in their organisations.
- A resource (http://www.vibenet.edu.au) for documents with links to other initiatives in institutions involved in curriculum reform in biology education.
- A narrowing of the gap between biology education and research. Perspectives of leading Australian biology researchers are available at
    - What is Biology? http://www.youtube.com/watch?v=kvBQv0cs0Sw.
    - What skills should tertiary biology graduates have? http://www.youtube.com/watch?v=Wur9tzJIA1c.
    - What are the most effective strategies for teaching tertiary biology? http://www.youtube.com/watch?v=gXjoAzWXdA4.
    - What content knowledge should tertiary biology graduates learn? http://www.youtube.com/watch?v=tJqjdIidW2w
    - How should students' understanding of biology be assessed? http://www.youtube.com/watch?v=97kf_Odn8Lo

[1] Jones S, Yates B and J Kelder (2011) Science Learning and Teaching Academic Standards Statement. Learning and Teaching Academic Standards Project. Strawberry Hills, NSW: Australian Learning and Teaching Council. Accessed 17th November 2013 http://www.olt.gov.au/resources.

Contribution to learning and teaching

Summary

The Biology discipline network, VIBEnet, is the first national network of university biology educators. Through a consultative and collegial process, the network has developed the first nationally agreed Biology Threshold Learning Outcomes (BTLOs). The Biology Standards Statement and the Vision and Change document provide a vision for a core biology curriculum and priorities for re-energising biology undergraduate education in Australia. Early and mid-career academics have been mentored in the scholarship of teaching and learning to prepare them to take their places as the future leaders in biology education.

The need for VIBEnet

Biology is a diverse discipline. It spans the scale of life from biomolecules to ecosystems and includes many sub-disciplines such as: biochemistry, ecology, genetics, microbiology, plant and animal science and physiology. Unlike the disciplines of physics and chemistry which have professional associations, such as the Royal Australian Chemistry Institute (RACI) and the Australian Institute of Physics (AIP) with substantial resources devoted to education, there is no active overarching professional association in Australia which represents the whole discipline of biology. Instead of one professional body for biology, there are a large number of disparate societies which are aligned with the sub-disciplines of biology. The Australian Institute of Biology (AIB) http://www.aibiol.org.au is currently inactive.

VIBEnet was inspired by *Vision and Change in Undergraduate Biology Education: A Call to Action* led by the American Association for the Advancement of Science (AAAS) with support from the National Science Foundation (NSF). Prior to VIBEnet's inception, the highest profile biology education activities in Australia were the annual education symposium at ComBio (incorporating the annual meetings of the Australian Society for Biochemistry and Molecular Biology, the Australian Society of Plant Scientists and the Australia and New Zealand Society for Cell and Developmental Biology) and the Biology Discipline Day at the Australian Conference for Science and Mathematics Education (ACSME). These conferences have not succeeded in cementing a core group of biology educators, and, as a consequence, biology education in Australia remains peripheral to biology research. The creation of VIBEnet has filled a critical niche for a formal network of biology academics in Australia that is inclusive of the breadth of the biology discipline, biology educators and researchers.

Contribution Aim 1: Developing a national identity and network including biology

The first aim of VIBE was to develop a national identity and network (VIBEnet) for university biology teachers and to develop Biology Threshold Learning Outcomes (BTLOs). VIBEnet brought together biology educators from Australian universities who had already actively participated in previous ALTC biology education projects including Bioassess: *Enhancing the Assessment of Learning in Australian Higher Education: Biological Science* (www.bioassess.edu.au/) and Threshold Concepts in Biology (http://sydney.edu.au/science/biology/learning/threshold/). Other biology educators who had not been part of these projects also joined VIBEnet, resulting in a total membership of 166 academics from 26 universities. The first VIBEnet national conference was held at the University of Sydney in July 2012 and was followed by the second VIBE national conference held at the University of Melbourne in July 2013. 56 biologists from 26 universities attended the 2012 VIBEnet conference while 75 biologists from 21 universities attended the 2013 VIBEnet conference. In order to bridge the gap between biology education and biology researchers, leading Australian biology researchers were invited to provide keynote presentations at national conferences (for reports from conference one and two, see Appendix 1 and 2). A further third national conference occurred where VIBEnet combined with the biomedical discipline network, Collaborative Universities in Biomedical Education (CUBEnet) and the Quantitative Skills in Science (QS) project. This conference held at the University of Sydney was attended by 100 delegates. A book of Proceedings was published for that conference[2].

In parallel with the VIBE conferences, VIBEnet members met and discussed the BTLOs and curriculum design in biology on the Biology Discipline Day at the Australian Conference for Science and Mathematics Education (ACSME) formerly UniServe, on three consecutive occasions in 2011, 2012 and 2013. VIBEnet members also connected with the other bioscience discipline network, CUBEnet, at national meetings at the Shine Dome in Canberra in December 2011 and in 2013.

The Biology Threshold Learning Outcomes (BTLOs)

The BTLOs were modelled on the Science Standards Statement and describe what biology graduates should *know, understand, and be able to do* (see Appendix 3). The BTLOs were developed through consultation at national conferences and workshops, and via an online national survey of VIBEnet members and biology researchers. They represent nationally agreed standards of attainment for biology graduates. The BTLOs describe outcomes for graduates who may have studied a general degree in biology or a specific sub-discipline of biology i.e. zoology or ecology, as a major within a generalist degree such as a Bachelor of Science (BSc). The many students that study biology only at first year introductory level will not be expected to meet the BTLOs (which are defined at graduate level), but the BTLOs do provide a framework for relevant foundational learning experiences at introductory level.

Ross PM, Hodgson Y and Tzioumis V (2012*) Game On: Preparing our Biology and Biomedical Graduates for the Future*. Proceedings of the CUBEnet/VIBEnet/QS Forum. Edited Proceedings, The University of Sydney 10-11 December 2012, pp. 33.

Views on what should be included in a core biology curriculum were collected from leading biology researchers through recorded interviews. These research leaders were asked what biology graduates should *know and be able to do*, and, from their point of view, what strategies would create effective tertiary biology education (Appendix 4). These videos have received collectively more than 1000 hits.

Contribution Aim 2: Mentoring biology learning and teaching leaders

The second aim of VIBE was to mentor the next generation of Biology teachers and curriculum designers (i.e. current sessional staff) to enhance active/inquiry learning in biology, particularly at the first year level, and to build teams of academics, at the institutional level in each state and region.

VIBEnet identified early-mid career academics within VIBEnet and then provided opportunities for them to develop leadership skills. These opportunities included: VIBEnet sponsorship of Drs Gerry Rayner (Monash University) and Ashley Edwards (University of Tasmania) to attend an LH Martin symposium on leadership in the tertiary sector. Titled 'Introducing Academic Leadership and Management' this was a two day meeting held on 28-29 August, 2012 at the LH Martin Institute (http://www.lhmartininstitute.edu.au/). VIBEnet members were also supported to participate in assessment workshops from the Australian Council for Educational Research (ACER). Mid to early career academics interested in biology education were also invited to a full day workshop titled 'Strategies for Academic Life in the Biological Sciences' prior to the 2nd VIBEnet annual conference at the University of Melbourne in July 2013. Topics included: applying for education grants, network and mentoring for an academic career and writing and being published in the Scholarship of Teaching and Learning (SoTL). The workshop was attended by 42 early-mid career academics from 21 institutions (Appendix 2). In response to the lack of a journal where biology academics can communicate and discuss issues in education, a two volume issue 'Biology Education Futures' of the International Journal of Innovation in Science and Mathematics Education (IJISME), http://openjournals.library.usyd.edu.au/index.php/CAL) will be published in September 2015. The editorial team includes early-career biology academic, Dr Michelle Coulson and many early-mid career academics are lead authors.

Contribution Aim 3: A vision for the future of biology education

The VIBEnet leadership team has constructed a draft 'Vision and Innovation' statement about the direction of the future of biological curriculum. This document reflects the collective understandings of 57 academics representing 25 universities nationally, three international universities and leading biological researchers. Core concepts identified include evolution, cell theory, and how living things in all their diversity are systematically classified, as well as an understanding of how biological knowledge is acquired through proposing and testing hypotheses. The final "Vision and Innovation" statement will be available on the VIBEnet web site by November 2015.

Factors contributing to productive networking

The VIBEnet approach to networking has been to create communities of practice[3] (or learning communities) characterised by mutual engagement with the discipline context of biology[4][5][6]. To network productively meant creating a shared vision, leveraging and aligning VIBEnet activities with other networks and rewarding individual contributions. The complex issues of identifying core skills and knowledge and effective curriculum, teaching and assessment strategies unites academics working in biology education and research. By linking across the sub-disciplines of undergraduate biology education and biology research, VIBEnet has captured a shared vision for biology education at the tertiary level in Australia. Academics work in a complex environment with competing demands on their time and attention[7]. VIBEnet addressed the geographic isolation of biology academics and the limited funding for travel which create barriers to networking through maximising face-to-face interactions. Key networking activities were:

Annual VIBEnet conferences

At each of these conferences, contributions from VIBEnet members were sought and sessions were devoted to debate key issues in biology education.

[3] Wenger E (2000) Communities of practice and social learning systems. *Organization,* 7(2) 225-246.
[4] Fincher, S., and Tenenberg, J. (2006) Using Theory to Inform Capacity-Building: Bootstrapping Communities of Practice in Computer Science Education Research. *Journal of Engineering Education* 95(4), 265-277.
[5] Jones A (2009). Re-disciplining generic attributes: the disciplinary context in focus. *Studies in Higher Education* 34(1), 85-100.
[6] Brewer, C. A., and Smith D. (2011) "Vision and change in undergraduate biology education: a call to action." *American Association for the Advancement of Science, Washington, DC* (2011).
[7] Bexley E, James R & Arkoudis S. (2011) *The Australian academic profession in transition.* Canberra: Department of Education, Employment and Workplace Relations, Commonwealth of Australia.

Collaborations with partner networks and leveraging of parallel activities and projects

VIBEnet actively collaborated with partner networks, conferences and projects. These partner networks included the Collaborative University Biomedical Education Network (CUBEnet) discipline network, AMSLaT (mathematics), Chemnet (chemistry) and the Physics education Network. Conferences included the Australian Conference for Science and Mathematics Education (ACSME) and the First Year Biology Educators Colloquium (FYBEC) in New Zealand. Major projects included the Quantitative Skills in Science (http://www.qsinscience.com.au/), Inquiry-oriented learning in Science (http://www.iolinscience.com.au/) and the Science and Mathematics network of Australian university educators (http://samnetaustralia.blogspot.com.au/). VIBEnet members contributed to the SaMnet leadership project, both on the Steering Committee and as project participants. The VIBEnet team leader presented at the First Year Biology Educators Colloquium (FYBEC) meeting in Wellington in 2011 and Auckland in November 2012. A reciprocal visit of Dr Amanda Harper from the University of Auckland occurred in December 2012. VIBEnet also collaborated with CUBEnet on assessment design with the Australian Council for Educational Research (ACER) workshops and raising the status of tertiary bioscience education with the Australian Academy of Science.

Collaboration with discipline peak bodies

Along with other science discipline networks, VIBEnet contributed to the Australian Council of Deans of Science (ACDS) National Workshop: Advancing the Science TLOs (Feb 22, 2013) and the ensuing publications on the development of discipline TLOs. The biology TLOs are also published on the ACDS Teaching and Learning Centre (www.acds.edu.au/tlcentre) website to foster cross-disciplinary collaboration on curriculum development. VIBEnet has presented at consecutive national teaching and learning conferences at the Australian Council of Deans of Science (ACDS) in July 2012-13.

CUBEnet

VIBEnet developed a collaborative relationship with CUBEnet (Collaborative University Biomedical Education Network), the biomedical discipline network. The close collaboration between these two networks ensured that the activities of the discipline networks were aligned.

Incentive for engagement by individuals

VIBEnet delivered professional development activities, individual mentoring and leadership opportunities to early and mid-career biologists. The popularity of the career development workshop held July 2013 (participants = 42) attests to the thirst for professional development opportunities.

Barriers to productive networking

Summary

The lack of an existing peak body for Biology education posed an immediate challenge to this network.

The barriers

Distance, time and finances pose barriers to productive networking. For academics in Australia, the physical separation of Australian universities is an ongoing challenge for all discipline networks[8] as is the constant tension between teaching and research which perpetuates barriers to pedagogical change[9]. For the VIBEnet project team, the first issue was ameliorated by creating a network of networks. Throughout the VIBEnet project, the VIBEnet team liaised closely with the project management teams of CUBEnet, SaMnet and ACSME. We met as a group, when VIBEnet project team members attended meetings of these other groups. When critical conversations within the VIBEnet team were needed, we held meetings at Melbourne airport, a central location. We also linked into existing conferences both nationally i.e. ACSME and ComBio and internationally i.e. First Year Biology Educators Colloquium (FYBEC) held at the Victoria University of Wellington (2011) and the University of Auckland (2012) in New Zealand and the Higher Education Research and Development Society of Australasia (HERDSA) at the University of Tasmania in 2012. We worked closely on CUBEnet initiatives with the Australian Academy of Science and the Australian Council of Deans of Science, Teaching and Learning Centre. The members of VIBEnet provide a group of like-minded colleagues interested in biology education and create peer recognition at the national level. In addition to the barrier of distance, a further barrier is created by an academic culture which values biology research more than biology education[10]. This issue was directly addressed by actively seeking commentary from leading biology researchers.

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[8] Bexley, E., James, R., & Arkoudis, S. (2011). *The Australian academic profession in transition.* Canberra: Department of Education, Employment and Workplace Relations, Commonwealth of Australia. 85 pages Accessed 18th November 2013. http://www.cshe.unimelb.edu.au/people/bexley_docs/The_Academic_Profession_in_Transition_Sept2011.pdf

[9] Brownell SE and Tanner KD (2012) Barriers to faculty pedagogical change: Lack of training, time, incentives, and --- tensions with professional identity? CBE – Life Sciences 11, 339-346.

[10] Savkar, V and Lokere, J. 2010. *Time to Decide: The Ambivalence of the World of Science Toward Education. Nature Education*: Cambridge Massachusetts. Pp1-14.

What the network offers

Summary

Prior to this project, there was no peak body or organisation concerned with tertiary level Biology education in Australia. VIBEnet has established the first national network of biology educators in higher education in Australia. This network is integrated across the many and diverse sub-disciplines of Biology, and inclusive of biology researchers. It provides a national identity for biology education and offers new opportunities for co-operation and collaboration to foster curriculum change in tertiary biology education. It will continue to represent a network of biology educators who will drive innovation within and between institutions.

Professional identity

VIBEnet offers a professional identity for academics interested in tertiary biology education. This is important in the academic context, where identity and admission into the professional practice of higher education has historically been informal and ad hoc[11].

Peer interaction and learning

VIBEnet addresses these challenges by providing a peer-to-peer professional community with opportunities for biology educators to come together in a collegiate atmosphere and discuss effective approaches to learning and teaching in biology. Disciplinary networks such as VIBEnet are particularly important in establishing common ground between biology educators and biology researchers.

Mechanism for curriculum change

VIBEnet has also provided an impetus for curriculum reform and change in tertiary biology education. The lack of teacher qualifications of many academics and the limited resources for professional development in curriculum design are impediments to change in tertiary biology education. VIBEnet avoided the failure of a 'development and dissemination change model'[12] and brought together academics to share resources in biology education who will act as mentors for their colleagues within and among universities in Australia. VIBEnet thus creates an 'ideal' missing in the Australian tertiary landscape, with an integrated conception of academic professionalism, marrying disciplinary and teaching expertise in tertiary biology.

[11] James R, Baik C, Krause KL, Hughes Warrington M, Sadler D & Booth S. Academic Workforce 2020: Reconceptualising the professional practice of teaching in higher education. A Strategic project commissioned by the Office for Learning and teaching

[12] Dancy MH, Henderson C (2008) Barriers and Promises in STEM Reform. http://homepages.wmich.edu/~chenders/Publications/Dancy_Henderson_CommissionedPaper2008.pdf

Appendix 1

1. Preamble and Aims of VIBE

The Vision and Innovation in Biology Education discipline Network (VIBEnet) was formed to address a recognised need in the tertiary biology community to:

- Create a Vision and Innovation Statement to reflect our collective understanding about the future of tertiary biology education
- Articulate the key concepts and competencies (knowledge and skills) of biology graduates in the form of Biology Threshold Learning Outcomes (BTLOs)
- Continue a conversation about effective learning and teaching practices which develop graduate conceptual understanding and competencies in biology and determine, through assessment, whether biology graduates have achieved these outcomes
- Support each other, including mentoring the next generation of academics, so that we collectively create institutional change in the learning, teaching and assessment of tertiary biology.

Unlike physics and chemistry, there is no single biological professional association in Australia that provides a forum for the discussion of learning and teaching undergraduate tertiary biology. The inaugural VIBEnet workshop, held at the University of Sydney on the 15 June 2012, provided a forum for the beginning of a collective conversation, between academic leaders in the learning and teaching of tertiary biology across Australia, to fill this "biology education" gap.

The American "Vision and Change in Undergraduate Biology Education: A Call to Action" project has already identified that it is time "to address the biology we teach so that it better represents the biology we do".[1] The goal of the VIBEnet workshop, similar to the Americans, is to create and sustain a network of biology discipline academics that will set an agenda of identified good practice for the future of learning and teaching tertiary biology.

At the inaugural VIBEnet workshop we commenced discussions on the core unifying themes in biology and the competencies or ways of "thinking and practising" or "habitats of the mind" that we expect our biology graduates to demonstrate on completion of their undergraduate degree. We also discussed pathways to transform undergraduate biology, approaches to implement and evaluate innovations and ways to support faculty to change institutional approaches. These discussions are the start of a series of conversations which will lead to a shared "Vision and Innovation" statement on the future and direction of the tertiary biological curriculum in Australia published by 2013.

[1] http://visionandchange.org/

2. Attendees

There were 56 participants from 26 institutions representing the leading tertiary academics focussed on research and teaching in biology. The keynote addresses were given by Professors John Mattick AO FAA FRCPA Executive Director of the Garvan Institute and Jenny Graves AO from the Australian Academy of Science. The workshop was facilitated by Dr Derek Muller (ABC Catalyst presenter) and the VIBEnet team Associate Professors Pauline Ross, Elizabeth Johnson, Professor Sue Jones, Drs Charlotte Taylor and Vicky Tzioumis.

3. Outcomes

There were two main workshop sessions on the day. The first involved discussions on the core unifying themes and competencies expected of biology graduates based on a summary of identified core concepts and competencies from a series of reports. During the second workshop participants discussed a draft set of Biology Threshold Learning Outcomes (BTLOs) which have now been edited (based on the feedback from this workshop) and will be circulated to the wider community of tertiary biology academics in the form of a survey).

Core unifying themes and competencies

The core unifying concepts and ways of thinking and practising in the discipline of biology have been identified in a series of reports and projects. In general, participants at our workshop also agreed that the core concepts of biology included life, evolution, energy, homeostasis and structure and function, while core competencies included the scientific process of inquiry and collection and evaluation of evidence as well as critical thinking and analysis, communication and collaboration. Participants also noted the increasing need for mathematics and quantitative skills and the increasing need for interdisciplinary perspectives of students.

4. Where to next?

There was general discussion on the need for a biology discipline network which would provide a place to discuss and share practice. The next stage for VIBEnet is to survey, more comprehensively, tertiary academics on the core unifying themes and competencies of biology graduates and the articulation of this through the Biology Threshold Learning Outcomes (BTLOs). Participants can complete this survey at https://www.surveymonkey.com/s/BTLOs.

Appendix 2

Report on the 2nd Vibe workshop

Biology Education Futures

University of Melbourne – 11-12 July 2013

At the inaugural VIBEnet workshop held at the University of Sydney on June 15th 2012, we discussed the core unifying themes in biology and the competencies or ways of "thinking and practising" that we expect our biology graduates to demonstrate on completion of their undergraduate degree. These discussions were used to create the Biology Threshold Learning Outcome statements (BTLOs) and are being embedded into the "Vision and Innovation" statement on the future and direction of the tertiary biological curriculum in Australia which will be published in late 2013. Our second workshop, held at the University of Melbourne on the 11-12 July 2013, was a two day workshop focussed on the future of biology, especially mentoring early to mid-career biology academics. The conference organising team included A/Profs Dawn Gleeson (Chair), Elizabeth Johnson (VIBEnet), Drs Gerry Rayner, Janet Macaulay, Heather Verkade (Monash), Ashley Edwards (UTAS), and Jan West (Deakin). The Collaborative Universities in Biomedical Education (CUBEnet) were proud sponsors of the workshop.

2. Attendees

Overall there were 66 participants from 20 institutions (plus 9 from 9 secondary institutions) representing the leading tertiary academics focussed on research and teaching in biology. On day one there were 42 participants, representing universities from 17 Australian and one New Zealand institutes and day two 66 participants, one New Zealand and 19 Australian universities. Proceedings were opened by Associate Professor Michelle Livett (Associate Dean, Teaching and Learning) from the University of Melbourne who welcomed delegates and spoke about the importance of supporting research in tertiary biology education. The keynote addresses were given by Professor David Vaux from the Walter and Eliza Hall institute (WEHI) and Professor Geoffrey Crisp (RMIT) who explored the future of biology research and the skills needed for biology graduates and the future of science education and Professor Philip Batterham who described methods to communicate science to the public. The VIBEnet team included Associate Professors Pauline Ross, Elizabeth Johnson, Professor Sue Jones, Drs Charlotte Taylor and Vicky Tzioumis.

3. Outcomes

On the afternoon of the first day a series of workshops to support early-mid career academics in Biology or Biomedical Sciences with an interest in learning and teaching were organised by Heather Verkade (Monash) and Ashley Edwards (UTAS) with experts from across the country. There were several themes explored including:

1) **Applying for Education Grants** - Prof Richard James (OLT grants standing committee), and the Promoting Excellence Team (Monash University) provided insight into the system and strategies to improve success. Workshop participant Susan Rowlands (UQ) and guest Dragan Ilic (Monash) followed with some personal experiences of the process.
2) **Networking and Mentoring for an Academic Career** – Dr Maggie Evans-Galea discussed the importance of mentoring and making helpful and supportive contacts and included a period of small group discussion.
3) **Writing and getting published in SoTL** – Dr Charlotte Taylor (USyd) gave some friendly advice from her experiences of publishing in both discipline and SoTL sphere and Dr Paula Myatt (UQ) ran a writing workshop aimed at giving participants the tools to start thinking about publishing in the SoTL sphere.

On the 2nd day of the workshop**,** Professor Vaux spoke passionately about the importance of new technologies in the future of biology education and the key skills that biology and biomedical students need to master. Professor Crisp highlighted the changing focus of science and biology education with the emergence of online learning, Massive Online Open Course (MOOCs) ware and cutting edge technological tools available to students and teachers. In his vision for the future of biology education he stressed the importance of changing the learning and assessment environment and spoke about the role of game-based learning in designing assessment tasks 'without interrupting the flow'. After morning tea A/Prof Pauline Ross and Prof Susan Jones presented the final version of the Biology Threshold Learning Outcomes (BTLOs) and the VIBE vision for biology education and showcased the opinion of leading biology researchers on what biology graduates should know and be able to do.

1. What is Biology? http://www.youtube.com/watch?v=kvBQv0cs0Sw
2. What content knowledge should tertiary biology graduates learn? http://www.youtube.com/watch?v=tJqjdIidW2w
3. What skills should tertiary biology graduates have? http://www.youtube.com/watch?v=Wur9tzJIA1c

Following this, two sessions showcased good practice in biology education. We heard about the use of novel assessment strategies for large courses, peer teaching in laboratory classes, flipped lectures and reality-based learning approaches that engaged students and improved student marks. Professor Philip Batterham ended proceedings with an inspiring talk on his efforts to engage the public with events in science education and to also increase the opportunities available to Indigenous students through the Residential Indigenous Science Experience (R.I.S.E.)

Appendix 3 BTLOS and Standards statement

2013

Biology Standards Statement

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Elizabeth Johnson and Susan M. Jones

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Authorship: This Biology Standards Statement has been prepared by Pauline Ross, Charlotte Taylor, Elizabeth Johnson and Susan Jones, the VIBEnet Leadership Team, as part of the Discipline Network Project *Vision and Innovation in Biology Education.* Vicky Tzioumis was the Project Officer supporting this initiative.

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Learning and Teaching Academic Standards Statement for Biology

This Biology Standards Statement is modelled upon the Science Standards Statement (Jones, Yates and Kelder, 2011)[1]. It includes a description of the nature and extent of biology, a statement of the Biology Standards expressed as threshold learning outcomes (TLOs), and accompanying notes that provide a framework for understanding, interpreting and applying the Biology Threshold Learning Outcomes (BTLOs).

The BTLOs strongly reference the Science TLOs (Jones et al., 2011) that were the core output of the ALTC Learning and Teaching Standards project for science. The Science TLOS have been endorsed by the Australian Council of Deans of Science as "a generic high-level statement of Bachelor of Science threshold learning outcomes" (Jones et al., 2011: p. 2), and map to the Australian Qualifications Framework (AQF) specification for the bachelor degree.

The BTLOs represent a consensus view of the biology professionals consulted (via workshops and an online survey) during the Discipline Network Project *Vision and Innovation in Biology Education* (VIBE) funded by the Office for Learning and Teaching (OLT). The Biology TLOs therefore represent the current (2013) nationally agreed standards of attainment for biology graduates in science.

Biology graduates may have studied biology (or a specific component of biology: e.g. biomolecular science, zoology or ecology) as a major within a generalist degree such as the Bachelor of Science (BSc). However, many students of biology will study biology only at first year (introductory) level as a foundation for later more specialised studies in, for example, medical or paramedical fields. For all such students and for the academics designing curricula for them, the BTLOs and their accompanying notes provide an essential guide to the core knowledge and skills expected of any student who studies biology at tertiary level. These include an understanding of evolution, cell theory, and how living things, in all their diversity, are systematically classified. In particular, students will understand how biological knowledge is acquired through the scientific method. Although such students will not be expected to meet the BTLOs, which are defined at graduate level, they will have had relevant foundational learning experiences in biology at introductory level.

This Standards Statement for Biology therefore provides a foundation for the evaluation of current biology degree programs, and for future curriculum development.

[1] Jones, S. M., Yates, B. F. and J.-A.Kelder (2011). *Learning and Teaching Academic Standards Project: Science Learning and Teaching Academic Standards Statement*. Sydney: Australian Learning and Teaching Council (<www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011> or <disciplinestandards.pbworks.com/w/page/52657697/FrontPage>).

1. Nature and extent of biology

Biology is the study of living organisms, whether single-celled or multi-cellular, as individuals or in groups, and their interaction with their environment and with each other. Biologists seek to understand the structure and function of the living world. Biologists investigate how organisms, access and use energy and the processes by which they develop and replicate. Evolution provides an overarching framework for understanding changes that have occurred in groups of organisms over time.

As a branch of science, biology is characterised by its complexity and diversity. The many sub-disciplines of biology are distinguished by:

- their subject matter
- the scale of the subject matter
- the suite of tools used for investigation.

Biology is a particularly dynamic discipline. Compared to the history of other areas of science, key areas of rigorous study in biology (e.g. genetics and molecular biology) have developed relatively recently. Biology is now moving into a phase of rapid expansion and discovery that places biologists at the forefront of current scientific research. Today's biologists face novel ethical challenges and need to develop innovative ways to work with living organisms. This requires them to develop, monitor, and practice ethical procedures, and to champion this approach in the public arena as the ethical questions facing society become increasingly more complex and challenging.

> *"…biology is poised to help answer many of the pressing problems of the 21st century as related to food, ecosystem sustainability, development of alternatives to fossil fuel, and health–related issues."*[2]

Biology sits within the philosophical and operational framework of science. Working as a biologist requires immersion in the basic concepts that underpin thinking and practising in all the sciences. The discipline of biology itself requires an understanding of all aspects of life and thus it encompasses an extraordinary range of sub-disciplines such as taxonomy, ecology, physiology, phylogenetics, cytology, microbiology and molecular biology. These areas are closely connected by a common intellectual approach that guides the ways of thinking and experimentation that advance our understanding of living organisms. Natural systems exhibit complexity and dynamism at scales from the global ecosystem, to individual organisms and to the cellular and molecular level. A commonality in structures and processes characterises all these systems, and an ability to move conceptually between these scales is a key requirement for biological thinking and reasoning.

Biologists work within an established framework of scientific methodologies, employing observation, measurement, and classification, to conduct experiments and test hypotheses. This structured approach is particularly pertinent to the dynamic nature of living systems, which are characterised by complexity, variability, and unpredictable outcomes. This

[2] Holm et al. (2011). Vision and change in biology undergraduate education. BaMBEd 39(2) 87-90.

provides a particularly challenging framework, and biologists must therefore acknowledge the role of probability in the interpretation and communication of their findings.

Biologists share a focus on making careful observations of phenomena in field or laboratory environments, a rigorous approach to asking questions and developing hypotheses, and the selection of appropriate experimental methods with which to test their predictions. Through the application of the scientific method, biology graduates will understand how biological knowledge is generated and that such knowledge is both testable and contestable.

2. Australian graduates in biology

The career destinations of Australian graduates with biology degrees are many and varied, reflecting the very broad scope of the discipline and the diversity of degree offerings at Australian institutions of higher education. A national survey of employment outcomes for science graduates over the period 1990-2000[3] found that graduates in the Life Sciences reported a much wider range of professional employment compared to other areas of science, encompassing technical, managerial and professional levels.

Depending on the nature of their degree studies, biology graduates may find employment with a range of organisations, including, for example, pathology or biotechnology laboratories, environmental agencies, state or federal government agencies, such as Parks and Wildlife Services. Some may also find employment in technical work in the laboratory or hands-on research in the field, and may be required to provide analysis, synthesis, recommendations or policy advice based on scientific knowledge generated by others. Biology graduates are needed as teachers in primary or secondary schools to improve the scientific and biological literacy of the community.

In all of these scenarios, biology graduates require good critical thinking and communication skills, and the ability to work independently and in teams in a disciplinary or interdisciplinary context.

> *"….. you are expected to read and write well, to talk coherently and intelligibly and to develop a sense of style. There is a tolerance of divergent values. A biological training also offers a grounding in manipulative skill, a capacity for reasoning and an ability to cope with complexity"* [4]

[3] What Did You Do With Your Science Degree? A national study of employment outcomes for Science degree holders 1990-2000, prepared for the Australian Council of Deans of Science (ACDS) by Craig McInnis, Robyn Hartley and Malcolm Anderson, Centre for the Study of Higher Education, University of Melbourne

[4] Becher and Trowler (2001). *Academic Tribes and Territories: intellectual enquiry and the cultures of disciplines*. Open University Press, Philadelphia, USA

3. Biology Threshold Learning Outcomes (BTLOs)

	Upon completion of a bachelor degree or major in biology, graduates will:
Understanding biology	1.1 Demonstrate a coherent understanding of biology by articulating the methods of biology, and explaining why current biological knowledge is both contestable and testable through further inquiry. 1.2 Demonstrate a coherent understanding of biology by explaining the role and relevance of biology in society. 1.3 Recognise that biological knowledge has been acquired by curiosity and creativity, and demonstrate creativity in thinking and problem solving. 1.4 Recognise and appreciate the significant role of biodiversity in sustaining life on our planet.
Biological knowledge	2.1 Exhibit depth and breadth of biological knowledge by demonstrating well-developed understanding of identified core concepts in biology. 2.2 Exhibit depth and breadth of biological knowledge by demonstrating that these 'core concepts' have interdisciplinary connections with other disciplines.
Inquiry and problem solving	3.1 Gather, synthesise and critically evaluate information about biological phenomena from a range of sources. 3.2 Critically analyse observations of biological phenomena by creating and developing models and/or proposing and testing hypotheses. 3.3 Design and conduct field, laboratory based, or virtual biological experiments. 3.4 Select and apply practical and/or theoretical techniques. 3.5 Collect, accurately record, interpret, analyse, and draw conclusions from biological data.
Communication	4. Effectively synthesise and communicate biological results using a range of modes (including oral, written, and visual) for a variety of purposes and audiences.
Personal and professional responsibility	5.1 Be accountable for their own learning and biological work by being independent and self-directed learners. 5.2 Work effectively, responsibly and safely in individual and peer or team contexts. 5.3 Demonstrate knowledge of the regulatory frameworks and ethical principles relevant to their sub-disciplinary area within biology, and apply these in practice.

4. Notes on the Biology Threshold Learning Outcomes (BTLOs)

These notes are intended to offer guidance on interpreting the Biology Threshold Learning Outcome (BTLO) statements. The notes and the BTLOs should be considered in the context of the statement of the 'nature and extent of biology' contained in this booklet, and the *Vision and Innovation Statement* produced by VIBEnet as a separate publication.

The BTLOs describe the threshold learning outcomes of a pass level graduate from a bachelor level degree program in biology or biology major within a bachelor degree. A *bachelor degree* is defined according to the Australian Qualifications Framework, within which it represents a level 7 qualification. A *threshold learning outcome* (TLO) is defined as the "minimum discipline knowledge, discipline-specific skills and professional capabilities including values and behaviours that are expected of a graduate of a specified level of program in a specified disciplinary area" (Jones et al., 2011: p. 3).

The BTLOs are not intended to be weighted equally across the major or degree program, nor does the numbering imply a hierarchical order of importance. However, the numbering may be used to provide easy reference to a specific BTLO.

The notes on the BTLOs presented here draw upon the notes on the Science TLOs provided in the Science Standards Statement, but are written in the context of the discipline of biology, with the intention of supporting biology teaching academics in curriculum review and renewal.

The **Good Practice Guides for the five Science Threshold Learning Outcomes** should be consulted for further elaborations of these notes. Each Good Practice Guide provides a succinct literature review of current research, exemplars of good practice, and a suite of web and print based resources relevant to that TLO. The theoretical concepts and practical ideas in the Science Good Practice Guides will be directly applicable to undergraduate teaching in biology.

BTLO 1 Understanding biology

BTLO 1.1

A coherent understanding: Graduates need an appreciation of biology as the study of all aspects of living things and their interactions with the environment. Biology is a broad and ever-expanding discipline with many sub-disciplines. It is too broad a discipline for biology graduates to understand all the sub-disciplines in detail, but graduates should understand how the sub-disciplines interact to describe living organisms and the processes of metabolism. The theory of evolution is a unifying principle for the discipline.

The methods of biology: Biology graduates will understand that biological knowledge is created through the process of research and inquiry. Creating new knowledge in biology involves observations of biological phenomena and design of hypotheses that are testable through systematic and logical inquiry. Biology graduates will be able to recognise the limitations of the methods of biology as well as their strengths, and understand that sometimes serendipity is involved in making new discoveries.

Contestable: A biology graduate will have an appreciation and understanding that biological knowledge and existing understandings are based on the best evidence at the time, but are open to uncertainty, contestability and further inquiry which may depend on the constraints of currently available technology.

Testable: All biological knowledge is, in principle, testable. A biology graduate will understand that many biological 'facts' have already been tested (and can be replicated), while other biological knowledge awaits testing and re-testing (i.e. is contestable) by experiment.

BTLO 1.2

Role and relevance: Biology graduates will understand that biological knowledge creates both challenges and opportunities for individuals and society at local and global levels. Biological knowledge allows decision making about individual and global human health, the maintenance of biodiversity and the sustainability of ecosystems.

Society: Biology graduates will understand that there are complex societal issues that have solutions in biology. These include improving human health, population growth, food sustainability and security, genetic and medical technologies and the sustainability of biodiversity and ecosystems.

BTLO 1.3

Curiosity and Creativity: Biology graduates will understand that the creation of biological knowledge is often the consequence of curiosity and innovation. Biology graduates need opportunities to be creative and curious in conducting experiments and research during their undergraduate studies. This means that undergraduate learning experiences should include opportunities for discovery, for exploration and for making novel connections.

BTLO 1.4

Sustainability of life: Biology graduates need to appreciate that biological knowledge has a significant role in ensuring sustainability of biodiversity and life on our planet.

BTLO 2 Biological knowledge

BTLO 2.1

Depth and breadth: Biology graduates will have depth of knowledge of the core concepts in biology, which are further articulated in the *Vision and Innovation Statement* for undergraduate biology education. Graduates will have gained a *depth* of knowledge through the study of a specific sub-discipline of biology at an advanced level. Their advanced level studies will build on the *breadth* of introductory and intermediate level studies.

Biological knowledge: This is the currently accepted body of facts, unifying theories and explanations from investigations of the natural world.

Core concepts: Biology graduates will understand the unifying theories, organising principles and core concepts of the biology discipline.

BTLO 2.2

Interdisciplinary connections: Biology graduates will understand how concepts in biology relate to other sub-disciplines in biology and disciplines of science. Solving 21st century biological problems will require the integration of biological knowledge with other disciplines. Biology graduates will need to think and contribute outside their immediate disciplinary boundaries, and be prepared to work in interdisciplinary teams to provide informed solutions about the complex problems facing the world.

*Sub-disciplines***:** This term is used in this document to describe a sub-discipline of biology, such as molecular biology, genetics, ecology, plant or animal science, or biochemistry.

BTLO 3 Inquiry and problem solving

BTLO 3.1

Critically evaluate information: Biology graduates should be able to assess the validity of information by reference to the author credentials, the publisher, intended audience, relevance and/or critical analysis that may include aspects of the experimental design and the conclusions reached.

Range of sources: Sources will include books, book chapters, academic and biological journals (refereed and non-refereed), government reports and other 'grey' (i.e. non-refereed) literature, and online or other electronic information. Biology graduates will be able to critically evaluate science-based material in the media and other public forums. They will be able to determine the credibility of the evidence, assumptions and potential fallacies in arguments.

BTLO 3.2

Critically analyse observations of biological phenomena: Biology is primarily an observational and experimental discipline. Using critical thinking skills, biology graduates will observe similarities and differences in phenomena, and detection of and departure from biological patterns. They will create explanations/models to account for these observations and identify implicit and explicit assumptions in these explanations/models, while understanding that multiple working hypotheses may be reasonable. Graduates will be able to critically analyse and explain the arguments underlying the creation of these explanations/models that support their understanding and explanations of biological phenomena.

*Proposing and testing hypotheses***:** Biology graduates will be able to construct testable hypotheses and null hypotheses from explanations/models. Biology graduates will understand that hypotheses cannot be 'proven', but that the null hypothesis can be rejected through statistical analysis and this provides a tool for justification to support the hypothesis and model.

BTLO 3.3

Design and conduct field, laboratory-based or virtual biological experiments: Biology graduates will be able to design and carry out an experiment that effectively tests a hypothesis. Biology graduates will be able to design an experiment identifying the main variables (which may interact), controls and replication.

BTLO 3.4

Select and apply practical and/or theoretical techniques: Biology graduates will have an understanding of a range of practical techniques in the laboratory or the field (as appropriate) including microscopy, molecular and cell biology techniques, whole organism experimentation, population and ecological analysis and modelling of biological data. Graduates will be able to use practical techniques appropriate to their chosen sub-discipline of biology and have an appreciation/basic understanding of techniques used in other areas of science that complement biological inquiry.

BTLO 3.5

Collect, accurately record, interpret and draw conclusions from quantitative data: Biology graduates will be able to collect, collate and organise data from experiments and other sources. Data in biology may be quantitative (numerical measurement) or qualitative such as images, video or sound recordings. Experimental results can be collected in a variety of forms, usually involving multiple measurements that are consolidated into datasets. Biology graduates will be able to recognise patterns and describe trends and relationships in the data using statistics as appropriate. They will have the capacity to develop arguments and draw valid conclusions based on their interpretation of the data and statistical analyses. Their conclusions may lead them to reject and re-cast a working hypothesis or explanation. Each of these steps requires the critical thinking processes of analysis, inference, interpretation and deductive reasoning. Biology graduates will be able to explain the significance of random sampling, reproducibility and uncertainty in experimental design and analysis. In addition, qualitative evidence, such as descriptive observation, may be used to inform scientific judgements.

BTLO 4 Communication

Effectively synthesise and communicate: Biology graduates will be able to synthesise complex biological information and/or data and present it in an accessible way appropriate to a specific audience.

A range of modes: Biology graduates will be able to communicate experimental outcomes and information effectively using a range of modes (written, oral, visual) and formats (e.g. written scientific research report, poster, new media, webpage) using a variety of techniques (e.g. graphs, statistical tables, models and simulations).

A variety of purposes and audiences: Biology graduates will be able to communicate their findings in ways which reach and are understood by audiences of their peers, decision makers, the general public, school students and future biologists; they will be able to present biological information in both technical and non-technical ways.

BTLO 5 Personal and professional responsibility

BTLO 5.1

Independent and self-directed: Biology graduates will have learned to work autonomously within certain professional contexts, and will be able take responsibility for their own development as learners. They will know how to seek required information and be able to apply that information in novel settings. They will understand the limits of their own current learning, and know when to seek assistance.

BTLO 5.2

Work effectively, responsibly and safely: Biology graduates will know the occupational health and safety requirements and risks of scientific work in the laboratory, field or office, as appropriate to their sub-discipline. They will take responsibility for themselves and for others working with them as team mates or volunteers. When working in teams, they will understand the need to negotiate and responsibly fulfil their role(s) in team projects.

BTLO 5.3

Regulatory frameworks: Biology graduates will know the regulatory frameworks that apply to their sub-disciplinary area. These might include animal ethics legislation and procedures, federal and state government permit systems, Australian Quarantine regulations, guidelines from the Office of the Gene Technology Regulator, food standards and/or medical/human ethical standards. They will be prepared to abide by these regulatory frameworks as they move into professional employment, and will understand the consequences for themselves and others.

Ethical principles: During their undergraduate study, biology graduates will have demonstrated ethical behaviours specific to their biological context (e.g. animal care and handling or patient confidentiality). At the broader level, they will understand and demonstrate intellectual and scientific integrity, including accurate data recording and appropriate storage, proper referencing and plagiarism.

Appendix 4 Interview with leading biology researchers

Leading biology researchers interviewed were:
Professor Maria Byrne (http://sydney.edu.au/medicine/anatomy/research/labs/byrne/),
Professor Stephen Simpson (http://sydney.edu.au/science/people/stephen.simpson.php)
Associate Professor Gareth Denyer
(http://sydney.edu.au/medicine/people/academics/profiles/gareth.php)
Professor Richard Kingsford (http://www.bees.unsw.edu.au/richard-kingsford)
Associate Professor Paul Adam (http://www.bees.unsw.edu.au/paul-adam)
Professor Emma Johnston (http://www.bees.unsw.edu.au/emma-johnston)
These videos were produced by Derek Muller and Andrew Bennett and are available on YouTube (see below).

Leading Australian biology academics share their thoughts on what skills are important for biology graduates to have. The videos were produced by Derek Muller and Andrew Bennett.

Video number	Question	Video location and Comments
1.	**What is Biology?**	http://www.youtube.com/watch?v=kvBQv0cs0Sw
2.	**What skills should tertiary biology graduates have?**	They all stress the importance of developing research skills and agree that these are best taught in practical classes – both in the laboratory and in the field. http://www.youtube.com/watch?v=Wur9tzJIA1c
3.	**What are the most effective strategies for teaching tertiary biology?**	They comment on the importance of innovation and communication with students. http://www.youtube.com/watch?v=gXjoAzWXdA4
4.	**What content knowledge should tertiary biology graduates learn?**	They all agree that understanding evolution and evolutionary processes is key to understanding biology and biological processes. http://www.youtube.com/watch?v=tJqjdIidW2w
5.	**How should students' understanding of biology be assessed?**	Are exams ever the best option? http://www.youtube.com/watch?v=97kf_Odn8Lo