Microbiology AUSTRALIA

OFFICIAL JOURNAL OF THE AUSTRALIAN SOCIETY FOR MICROBIOLOGY INC.

Volume 37 Number 2 May 2016

Education to enhance microbiology graduate employability

The Australian Society for Microbiology

Save the Dates

2016 Bi-State Conference, Victoria / Tasmania

Friday 25th / Saturday 26th November 2016

Peppers Seaport Hotel, Launceston TAS

Peppers Seaport Hotel, Launceston TAS
http://www.peppers.com.au/seaport/

What you can expect:

- A diverse and engaging scientific program provided at a picturesque location
- Great networking opportunities
- Catering, with an optional dinner opportunity on Friday night

Enquires:

Christine Seers (caseers@unimelb.edu.au), or
Karena Waller (klwaller@unimelb.edu.au)

The Australian Society for Microbiology Inc.

9/397 Smith Street
Fitzroy, Vic. 3065
Tel: 1300 656 423
Fax: 03 9329 1777
Email: admin@theasm.com.au
www.theasm.org.au
ABN 24 065 463 274

For *Microbiology Australia* correspondence, see address below.

Subscription rates
Current subscription rates are available from the ASM Melbourne office.

Editorial correspondence
Prof. Ian Macreadie/Mrs Jo Macreadie
Tel: 0402 564 308 (Ian)
Email: ian.macreadie@gmail.com

Published four times a year in print and open access online by

CSIRO

Unipark, Building 1, Level 1
195 Wellington Road, Clayton, Vic. 3168
http://microbiology.publish.csiro.au

Publishing enquiries
Jenny Foster
Email: publishing.ma@csiro.au

Production enquiries
Helen Pavlatos
Email: helen.pavlatos@csiro.au

Advertising enquiries
Doug Walters
Tel: 03 9545 8505
Mobile: 0419 357 779
Email: doug.walters@csiro.au

ISSN 1324-4272
eISSN 2201-9189

Microbiology AUSTRALIA

OFFICIAL JOURNAL OF THE AUSTRALIAN SOCIETY FOR MICROBIOLOGY INC.

Volume 37 Number 2 May 2016

Contents

Cover image: Students engaged in microbiology practical exercises at RMIT University (photo provided by Ian Macreadie).

Jonathan Iredell
President of ASM

The Australian Society for Microbiology has remained broad based for the many decades of its existence. In the absence of a publishing house to underwrite it, we continue to hold regular meetings and maintain a strong membership.

The executive (President, President-Elect or Immediate-Past, and the three Vice Presidents, Scientific, Corporate and Communications) therefore tend to run the national business of the Society, which is to a significant extent centred on the national scientific meeting.

The State branches drive the main activities in each state, which requires a large investment of time and energy, and these are a major part of the value of ASM to members.

One of the most important signs of health in a Society like ours is the level of participation in the democratic processes within it. The structure of our Society places most of the regular decision-making powers in the Council. Council meets only twice a year and has a lot of business to get through when it does, in a meeting that takes the whole day and is mostly driven by the national executive. The national executive makes a lot of key decisions in a consensus model but major decisions/structural changes are referred to national Council. Major changes such as constitutional reforms must be decided by the membership at an Annual General Meeting.

The Council has limited time and resources to develop strategic capacity. In recent years, we have brought together the state and national executives by bringing State Chairs in to Council, and more recently by introducing regular teleconferences between state and national executives. The Divisional Chairs are senior national discipline leaders that are essential for strategic management but are presently only in the National Scientific Advisory Council, with special responsibilities in scientific content and discipline balance. The national Chairs can attend Council and Executive by invitation but presently do not have a formal constitutionally defined role outside the NSAC.

In order to better manage the Society, you will notice we have focused on bringing our Associate Membership into full Membership (MASM) wherever possible. The cost of membership is no different but the Associate Membership has no voting rights and therefore cannot effectively participate in the national conversation. We urge all Associate Members to apply for MASM, a simple process through the Membership section of the website (http://www.theasm.org.au/membership/). This gives you a vote.

However, exercising your vote to effect or prevent major proposed changes requires attendance at the AGM, which is held at the Annual Scientific Meeting (Perth, 3 July: http://asm2015.asnevents.com.au/), which is not always practical.

At this year's ASM I will be asking the membership to consider moving to an online voting system, such as in many other comparable Societies, so that major changes do not need to wait for an AGM and so that every member can participate. We need to bring the Society back to the membership so that it can be responsive to change and reactive to needs.

Graduate employability: are we doing enough?

Danilla Grando
School of Science
RMIT University
Melbourne, Vic., Australia
Email: danilla.grando@rmit.edu.au

It is with great pleasure that I introduce this special issue of *Microbiology Australia* with its focus on the work currently being performed around Australia to help our microbiology graduates develop the skills and attributes required to become career ready and to secure employment. Preparing students for employment is a multi-faceted challenge. Modern education moves beyond classroom or online instruction to working with industry to provide student learning opportunities, as well as mentoring our students to engage in experiences that will expand their outlook and capabilities. This multi-faceted approach is important to give our students the best preparation for entering the new workforce, where innovation and creativity is key.

In this issue of *Microbiology Australia* Smith *et al*. look at the downward employment trends for life sciences, which is a sobering reminder of the many challenges to be faced by our life science graduates. Hidden in the data is the number of graduates that feel they are 'underemployed' – employed in jobs not related to their undergraduate degrees. What needs to be conveyed more clearly to students is that a science degree can prepare them for a wide range of jobs. Thus a science degree should encompass a wide range of learning opportunities, not just in skill and knowledge development but also in general skills and emotional intelligence. The article following this by Grando *et al*. looks at what employers and students are saying with respect to the skills and attributes that they need. The employer data was collected through a breakfast meeting held at a university, with the widespread support for the meeting showing us how willing employers are to engage with academia.

How work ready are university graduates? If you are an employer or if you are a university academic, your response to this question may vary. The Office of the Chief Scientist is looking closely at the issue of STEM-trained and job-ready graduates[1] and opens their argument for creating job-ready graduates by stating 'Australia is looking to universities to re-imagine what science education should be, and re-engineer for a future in which science is central'. To this end, members of the Education Special Interest Group (EdSIG) came together at last year's ASM Educators Conference – EduCon, to convene a working party to draft threshold learning outcomes for majors in microbiology. These guidelines have received the support of the national executive of ASM and are published in this issue. It is EdSIG's intention to create a resource within the ASM website that links learning outcomes to examples of curricula that can support learning. This issue of *Microbiology Australia* also has provided a valuable platform for microbiology educators to describe the excellent work they are doing to help students attain great learning outcomes.

I read with interest that *FEMS Microbiology Letters* now devotes a section of their journal to career development learning[2]. For those readers wishing to see what the UK is doing to enhance employability, Fahnert[3] has written an excellent review. The journal *Nature* has also for some time devoted a section of its journal to career development. Discussions with the editor of *Microbiology Australia*, Ian Macreadie, have led me to believe that it is possible to have a regular section devoted to Education and Careers in MA. This presents an excellent opportunity for networking of educators and industry to explore initiatives and report on outcomes. I wish to thank all the contributors to this current issue of *Microbiology Australia*. This issue would not be possible without their dedication to improved learning outcomes for their students and the willingness to disseminate good teaching practice through publication. I look forward to reading more examples of good practice in future issues of *Microbiology Australia*.

References

1. Prinsley, R. and Baranyai, K. (2015) Stem-trained and job-ready. Office of the Chief Scientist. http://www.chiefscientist.gov.au/wp-content/uploads/OPS12-WIL_web.pdf
2. Fahnert, B. and Verran, J. (2015) Editorial: Education is.... *FEMS Microbiol. Lett.* **362**, fnv190. doi:10.1093/femsle/fnv190
3. Fahnert, B. (2015) On your marks, get set, go! – lessons from the UK in enhancing employability of graduates and postgraduates. *FEMS Microbiol. Lett.* **362**, fnv150. doi:10.1093/femsle/fnv150

Biography

Danilla Grando is an Associate Professor in the School of Science. Her teaching interests are online education and program delivery to enhance employability. Her research interests are diagnostic microbiology.

 10.1071/MA16020

Graduate employment trends in the life sciences: implications for microbiology educators

John V Smith[A], *Danilla Grando*[B] *and Nina Fotinatos*[C]

[A]School of Engineering, RMIT University, Melbourne, Vic., Australia. Tel: +61 3 9925 1298, Fax: +61 3 96390138, Email: johnv.smith@rmit.edu.au

[B]School of Science, RMIT University, Melbourne, Vic., Australia. Tel: +61 3 9925 7135, Fax: +61 3 99257110, Email: danilla.grando@rmit.edu.au

[C]Centre of Learning Innovation Professional Practice, Federation University Australia. Tel: +61 3 5327 9145, Email: n.fotinatos@federation.edu.au

Graduates in the Life Sciences, including microbiology have experienced similar employment trends to graduates in other fields over the past 30 years. Recent downward trends in graduate employment levels have raised concerns among educators and the community in general. Awareness of the diverse opportunities for graduates of microbiology is needed. For many, explicit education in 'employability skills' is also considered to be needed to enable graduates to succeed in the competitive job market.

Graduate employment in Australia, as measured by annual surveys approximately four months after graduation show a dramatic

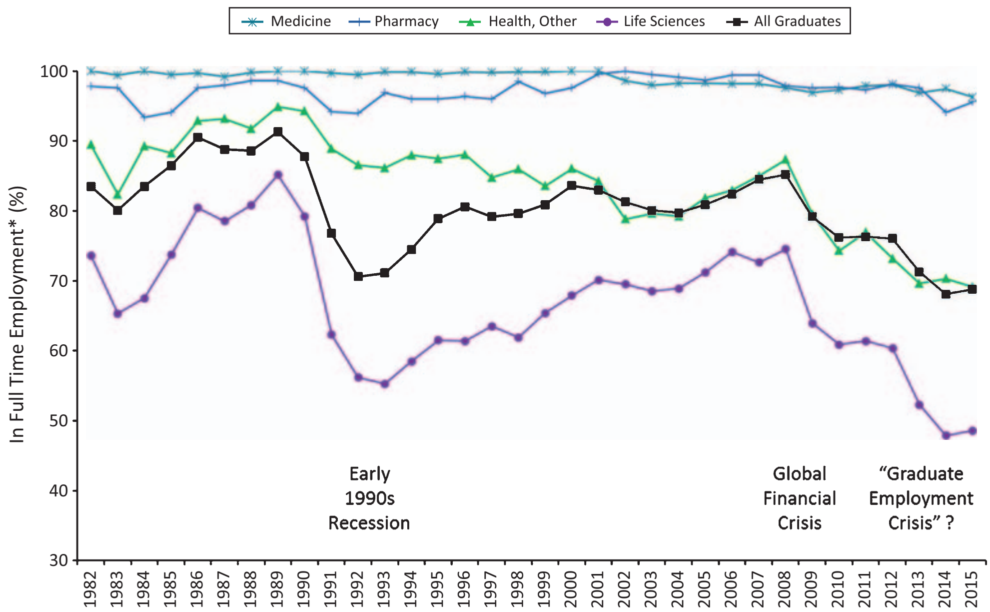


Figure 1. Fields of education graphed according to rate of full time (FT) employment from 1982 to 2014. *Employment is relative to respondents available for full-time work (Graduate Careers Australia data).

deterioration from 2009 to present. This deterioration occurred in two stages, the initial impact of the Global Financial Crisis followed by relatively little change in 2011 and 2012 then further drops in 2013 and 2014. The most recent data (2015) shows little change from 2014 (Figure 1).

While medicine and pharmacy appear immune from the impacts, close viewing of the data indicate that even those fields have been impacted negatively in recent years. The category 'Health, Other' has tracked the trend of 'All Graduates' since around year 2000. The category of 'Life Science' has ranged between 10% to 20% below the 'All Graduates' trend, over most of the 30 years of data available. The 10% difference is evident in times of better employment and the 20% more evident in times of poor employment (Figure 1).

Table 1. Fields of study as classified in the Graduate Destination Survey (Graduate Careers Australia).

Life sciences	Health, other
Biochemistry and cell biology	Acupuncture
Biological sciences	Community health
Botany	Complementary therapies
Ecology and evolution	Environmental health
Environmental studies	Epidemiology
Family and consumer studies	First aid
Food and beverage service	Health promotion
Food and hospitality	Indigenous health
Food hygiene	Medical science
Food processing technology	Naturopathy
Food science and biotechnology	Nutrition and dietetics
Forensic science	Occupational health and safety
Genetics	Optical science
Health not elsewhere classified	Optical technology
Human biology	Optometry
Human movement	Other health
Laboratory technology	Paramedical studies
Marine science	Podiatry
Microbiology	Public and health care administration
Natural and physical sciences	Public health
Pharmacology	Radiography
Zoology	Sport and recreation
	Sports coaching, officiating and instruction
	Traditional Chinese medicine

Microbiology is classified as part of the Life Science category (Table 1). It is however unknown how many graduates who are employed by pathology companies self-identify in the category of Health Other as medical scientists rather than the category of Life Sciences. When the employment data for the fields within Life Science are separated it can be seen that there is a wide variety of results (Figure 2). In 2012, microbiology had higher employment outcomes within the Life Sciences but fell to the lower part of the group as the lowest overall results were recorded in 2013 and 2014 (Figure 2). This may be a reflection that Microbiology is becoming a more inter-disciplinary science, with students graduating with Molecular Biology, Biotechnology and Biomedical degrees. Concerns have been expressed that 'microbiology is becoming a less distinct discipline within universities'[1]. This article reviews the recent data and briefly identifies some issues for education practices.

Entry-level microbiology jobs

Graduate employment data indicates that gaining employment is more difficult for graduates at the current time than it has been over the past 30 years. Nevertheless, the field of microbiology employs graduates in many diverse roles[1]. A brief survey of advertised

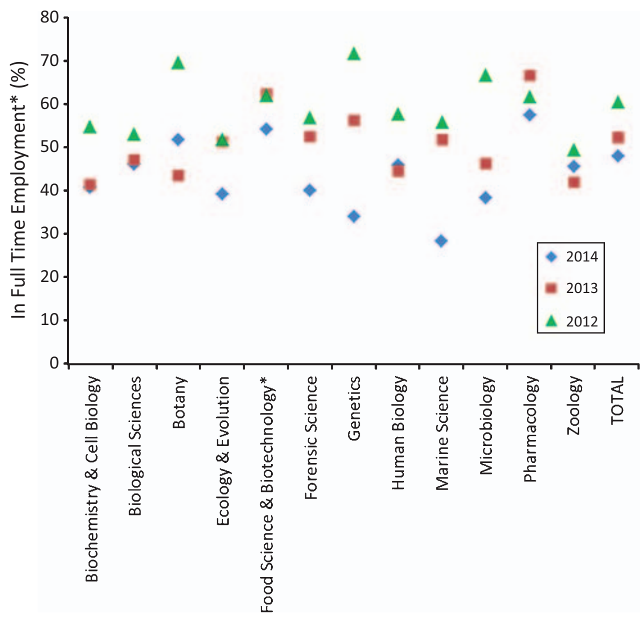


Figure 2. Full time employment data for selected life science fields. Not all fields of study shown due to small sample size in some cases. *Food processing technology has been included with food science and biotechnology. Graduate Careers Australia data. Breakdown for 2015 not available at the time of this investigation.

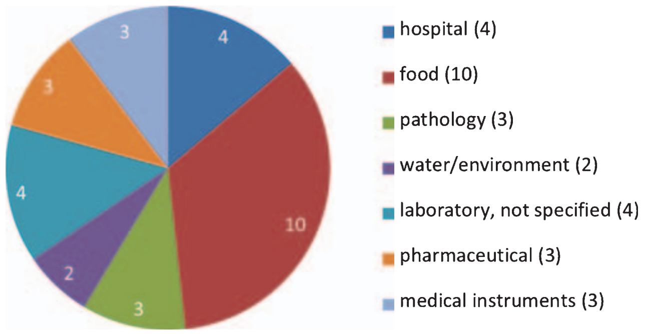


Figure 3. A non-exhaustive survey of 29 positions for graduate/junior employees on Seek searching for 'microbiology' (online career website December 2015). The category 'Food' includes food processing and food service roles.

positions, conducted by the authors for the purpose of this review, showed many varied roles where a degree in microbiology was a prerequisite or seen as desirable (Figure 3). The key requirements tend to be similar and three of these positions are summarised in Table 2. The advertised prerequisites, include a wide range of personal attributes such as 'attention to detail' and 'willingness to learn'.

Implications for microbiology education

Graduates of microbiology degrees have been affected, along with most other graduates, by a prolonged downturn in the level of employment in the field soon after graduation. The competition they face to obtain employment in the field is great. It is likely that the expectations of the graduate, and those who may have supported them through their studies, is also great[2].

If this is the case then educators in microbiology, and Life Sciences more broadly, need to ensure that they are preparing their students for greater success in transitioning to a career. Prinsley and Baranyai[3] found that employers in Australia rate graduates of STEM (Science, Technology, Engineering and Maths) as poor in intercommunication skills and time management. A key challenge for discipline educators is dealing with the divergent views on how these skills could and should be acquired. It also begs the question to what extent and in what ways should university education prepare students to compete for the limited number of jobs available in the field and is it their role?

A review of what employers are looking for (such as Table 2) shows that the desired attributes of graduates is broad. Many of these attributes such as 'professionalism', 'ability to work in a team' or 'ability to communicate' are likely to correspond with the aspirations of many university learning and teaching charters. However, the extent to which these attributes or skills are explicitly taught or assessed is likely to be highly variable. The style of teaching that underpins microbiology in a university context is heavily influenced by the experience of the educator and the academic freedom within the program/degree structure[4]. Where the educator lacks previous industry experience, this may also have an impact on the style and focus of the teaching curriculum, pedagogy, chosen learning and teaching strategies and establishment of an appropriate learning environment suitable to the field of microbiology.

Table 2. Examples of requirements from a survey of 29 positions for graduate/junior employees on Seek searching for 'microbiology' (online career website December 2015).

Title	Requirements
Scientist Grade 1	• To perform microbiology testing according to documented laboratory protocols within acceptable time frames
	• Professional approach to patient care, patient and pathology service's confidentiality, provision of pathology services, self-education and the teaching of others
	• Ability to organise own work and to relate well to fellow staff, other hospital staff and patients
	• Personal conduct that reflects, at all times, the highest professionalism required by <organisation>
Microbiology Assistant	• Applicants will be motivated, reliable and flexible with excellent time management and communication skills
	• The successful person will possess a high level of attention to detail with the ability to positively contribute to the team and be willing to learn
Laboratory Aid – Microbiology Department	• A Science degree obtained from a recognised Australian institution
	• Permanent residency
	• <State> drivers licence and own car is necessary
	• Ability to demonstrate sound organisation skills
	• Ability to work within a team
	• Ability to communicate effectively both verbal and written
	• Ability to work under pressure
	• Ability to understand and ensure compliance with WH&S [Workplace Health and Safety] policies and guidelines
	• Sharing the company's vision, cultures and values

It is also essential to acknowledge that while the university degree or diploma qualifications and practical experiences (within formal classes or otherwise) are valuable in gaining employment in the field other factors also influence opportunities in the market. The number of positions in the field are also influenced by the varying rates of retirements in both the public and private industries, the inevitable increased use and impact of automation, centralisation of microbiological services, value of networking within the industry related events and alignment between the skills and knowledge to vacant positions.

Previous contributions to microbiology education include engagement of learning and work[5,6] and use of game-based learning[7]. Contributions have also been made toward specifically addressing employability skills within curriculum[8–11]. There is need for further research and debate on how the field of microbiology can best educate graduates and improve their interpersonal communication skills and time management. Students need to be able to describe their 'microbiologist identity' and curriculum should ensure that there are plenty of opportunities to experience, develop and ultimately communicate the importance of a microbiology career[12]. Within the university context, educators can also be guided by information easily accessible in reliable textbooks/e-textbooks and the Australian Learning and Teaching Council (ALTC) Science Standards[13].

Conclusion

The record of graduate employment suggests that the Life Sciences including Microbiology has experienced the same general trends as other fields of study in Australia over the previous 30 years. That includes the recent 'graduate employment crisis' which appears to be a residual effect of the global financial crisis. The general trend appears to be toward lower rates of graduate employment – at least within the 4 months after graduation. Many educators including in the Life Sciences and Microbiology see incorporation of 'Employability' into curriculum to be one approach to improving outcomes – or at least enabling some graduates to outcompete others in a limited job market. That job market may also be artificially limited by not recognising the diverse range of employment opportunities for graduates with microbiological training. The opportunities are not only health-related and include diverse roles in environmental and biosecurity protection, food manufacturing and service and pharmaceutical development and manufacture.

References

1. Redfern, J. *et al*. (2015) What is a microbiologist? A survey exploring the microbiology workforce. *FEMS Microbiol. Lett.* **362**, fnv208. doi:10.1093/femsle/fnv208
2. http://www.theglobeandmail.com/news/national/education/the-expectation-gap-students-and-universities-roles-in-preparing-for-life-after-grad/article21187004/?page=all
3. Prinsley, R. and Baranyai, K. (2015) STEM skills in the workforce: what do employers want? Office of the Chief Scientist, Canberra.
4. Åkerlind, G.S. (2007) Constraints on academics' potential for developing as a teacher. *Stud. High. Educ.* **32**, 21–37. doi:10.1080/03075070601099416
5. Hills, J.M. *et al*. (2003) Bridging the gap between degree programme curricula and employability through implementation of work-related learning. *Teach. High. Educ.* **8**, 211–231. doi:10.1080/1356251032000052456
6. Schliephake, K. and Mosse, J. (2010) Practicum and work experience in microbiology and related disciplines. *Micro. Aus.* **31**, 29–31.
7. Beylefeld, A.A. and Struwig, M.C. (2007) A gaming approach to learning medical microbiology: students' experiences of flow. *Med. Teach.* **29**, 933–940. doi:10.1080/01421590701601550
8. Rees, C. *et al*. (2006) Student employability profiles. The Higher Education Academy, York.
9. Verran, J. (2010) Encouraging creativity and employability skills in undergraduate microbiologists. *Trends Microbiol.* **18**, 56–58. doi:10.1016/j.tim.2009.12.006
10. Dong, T.T. *et al*. (2012) The Training Experiment of Independent Thinking in the Teaching of Food Microbiology. *Acad. Period. Farm Prod. Process.* **1**, 50.
11. Merkel, S. (2012) The development of curricular guidelines for introductory microbiology that focus on understanding. *J. Microbiol. Biol. Educ.* **13**, 32–38. doi:10.1128/jmbe.v13i1.363
12. Gavaghan, H. (1999) Career choices for scientists: an introduction. *Nature* **402**, 3. doi:10.1038/47094
13. Australian Learning Teaching Council (ALTC) (2011) Learning and Teaching Academic Science Standard Statement, September 2011. Australian Government Department of Education, Employment and Workplace Relations.

Biographies

Associate Professor John Smith is an earth scientist and engineer with 25 years experience in secondary and tertiary teaching in Australia and Japan. He was a research team member of the OLT Commissioned Project: Developing graduate employability through partnerships with industry and professional organisations.

Danilla Grando is an Associate Professor in the School of Applied Sciences. Her teaching interests are online education and program delivery to enhance employability. Her research interests are diagnostic microbiology.

Associate Professor Nina Fotinatos has a PhD in the field of Biomedical Science and Public Health and 10 years industry experience in both private and public diagnostic pathology organisations. Nina has been in a number of leadership roles during her academic career and has also been involved with a number of research projects in science, health and education.

What do Life Science employers look for in graduates?

Danilla Grando[A,E], *Catherine Pocknee*[B], *Bronwyn Clarke*[C] and *Margaret Jollands*[D]

[A]School of Science, RMIT University, Melbourne, Vic., Australia

[B]College of Science, Engineering and Health, RMIT University, Melbourne, Vic., Australia

[C]School of Media and Communications, RMIT University, Melbourne, Vic., Australia

[D]School of Engineering, RMIT University, Melbourne, Vic., Australia

[E]Corresponding author. Email: danilla.grando@rmit.edu.au

As part of an Australian Government Office for Learning and Teaching (OLT) grant to develop graduate employability through partnerships with industry and professional associations[1], RMIT University invited industry representatives from Life Science (microbiology focused) professions to a focus group to discuss their views on desirable graduate traits and attitudes. Subsequently current Life Science students at RMIT were also invited to focus groups. Using an expanded framework for graduate employability[2], their responses were coded and analysed and compared with responses from similar focus groups from other RMIT programs.

The analysis presented in Table 1 highlights some interesting comparisons between focus groups representing the School of Civil, Environmental and Chemical Engineering, the School of Media and Communications and the School of Applied Sciences. Although there were many similarities in the views expressed across these three schools, there are some notable differences that impact upon the employability of Life Science graduates. Looking at the data for Engineering and Media and Communications, there appears to be a congruence of themes expressed by students and employers. In contrast employers of Life Science graduates were more focused on considering the experience of graduates rather than their career development learning. Given this response it appears desirable to increase the opportunities that students have to engage in work relevant learning opportunities. Instituting a requirement to enable students to gain relevant work experience throughout their undergraduate degree has been recognised by the Office of the Chief Scientist[3]. Jollands[2] also noted that the observed discipline differences 'may reflect the homogeneity of career paths for Life Science graduates: typically, 'laboratory technician' is the first graduate position, with a narrow position description focused on repetitive experimental work.'

In the category of emotional intelligence, life science employers spent considerable time in the focus group discussing issues pertaining to self-awareness. Employers had experienced graduates who were overconfident and not willing to take the time to start at the bottom of the career ladder. One employer commented:

> *they think they can do anything. . ..so think they [can] expect executive management type roles. . .and they don't have the skills so they also don't recognise that they don't have the skills. . .*

The self-awareness issue is particularly problematic in diagnostic laboratories with one employer commenting'

> *the other thing I've found is problematic is . . . not having the confidence to ask a question or admit you don't know how to do something and therefore covering up.*

Table 1. Employability skills and attributes identified by students (x) and employers (■).[2]

Category	Sub-category	Engineering	Life sciences	Media and communications
Career development learning	Business acumen		x	x■
	Career planning	x■	x	x
	Knowledge of industry and job market	x■	x	x■
	Networking	x■	x	x
	Passions and interests	x■	x	x■
	Professionalism	■	x	x
	Recruitment processes preparation	x■	x	x■
Experience		x■	x■	x■
Degree subject knowledge, understanding and skills		x■	x■	x■
Generic skills	Adaptability	x	x■	x■
	Communication	x■	x■	x
	Critical thinking	■	■	x■
	Entrepreneurship	x		■
	Ethics	x■	x	x
	Innovation and creativity	■	x	x
	Leadership	x	x	
	Lifelong learning	x■	x■	x■
	Numeracy			
	Problem solving	x		x■
	Teamwork	x■	x■	x■
	Time management	x	x	x■
	Work ethic	x■	x	x
	Working under pressure	■	x■	x
Emotional intelligence	Self-awareness	x■	■	x■
	Self-management	x■	x■	x■
	Awareness of others	x	x■	■
	Managing others	x■	x	x■
	Motivation	x■		x

Interestingly both engineering students and life science students did not talk about critical thinking skills, although these were both mentioned by employers as being important. In contrast the students in Media and Communications did discuss this theme. The project leader commented that overall the students from the School of Media Communications gave more sophisticated and reflective views on the nature of employability (Margaret Jollands). It is notable that students from Media and Communications at the participating university have comparatively high employment rates compared to students from other universities studying similar degrees (Bronwyn Clarke). This is likely to be in response to the high number of focused employability projects conducted within this school[4] that have resulted from an explicit school directive, that aims to 'foster the development of graduates as critical and creative thinkers, multi-skilled and collaborative practitioners'[4]. It would be insightful for all disciplines to do further research in this area to investigate the possible linkages between focused programs and graduate employability outcomes.

Given the current government's imperative to become an innovation nation (www.innovation.gov.au), it is incumbent upon academics employed in life sciences to investigate and develop strategies that enable their graduates to become critical and creative thinkers. Capstone projects can often promote this type of learning, however, is the learning environment sufficiently scaffolded to ensure learning progresses throughout the capstone project? In many instances projects undertaken by students may have little relevant formative assessment specifically targeted to students' development of critical and creative thinking. One strategy for addressing this aspect of student learning in capstone projects is to adopt a three phases approach to ensure students receive appropriate and scaffolded feedback on their critical and creative thinking development. Preliminary analysis of a model described by MacKinnon[5] shows that scaffolding the learning in Capstone projects using a 3 phase model helps to explicitly develop judgement and critical thinking in complex contexts. The first phase should involve the supervisor exploring synchronously with the student the scope of the project to introduce and establish a culture of critical and creative thinking. In the second phase (mid-way) of the project the supervisor should provide examples of how critical reflection promotes a synthesis of current knowledge and informs the creative development of new ideas. Finally the student must receive constructive and targeted feedback about their critical and creative thinking development in the penultimate version of their final submission before summative assessment. Providing students with the opportunity to give a three minute oral 'thesis' (or similar activity) can help students to critically reflect on and articulate their achievements which in turn prepares them to perform orally in future interviews. When this approach was used with students there was a dramatic increase in grades ($n = 3$, all students scored >95% on summative assessment, D. Grando).

As part of the OLT funded project we interviewed life science employers who were employing graduates to perform microbiology jobs such as laboratory assistants, food quality assurance scientists, medical scientists and regulatory officers. However, there are many other types of jobs suitable for graduates majoring in microbiology[6]. The Chief Scientist in his 2014 report[7] on the future of STEM education states 'International research indicates that 75% of the fastest growing occupations now require STEM (Science, Technology, Engineering and Mathematics) skills and knowledge'. It may be difficult for us to envisage the jobs of the future but designing programs that result in enhanced employability for graduates can also promote entrepreneurship. When the successful employment outcomes in the School of Media and Communications at RMIT University are considered it is found that as well as high employability rates, there are a high number of students who establish their own companies through the embedded projects in the curriculum and then have the confidence to grow these quickly as graduates (Bronwyn Clarke).

It is important that every Life Science program ensures that their students are able to articulate their professional identity as a science graduate. Students often feel that they are being trained for research positions. A student commented:

> *It definitely feels like they were just setting us up for research though, it's like the job options that they . . . teach you about it's all just research, there's no . . . sales or teaching or like anything focused otherwise . . . If research isn't your cup of tea there are other things but they never told us anything, they assumed we're all here for research and that's not the case I don't think.*

Industry and students are both challenging our current curriculum/program design. Capstone projects focusing on research may not be enough preparation for the diverse employment opportunities on offer.

In order for program leaders to determine the degree to which their program enhances graduate employability, we have developed a quiz to help assess a program's approach to developing employability in students (Figure 1). Program leaders should periodically check a sample group of graduating students' opening letters and CV. It may come as quite a shock to see the gap between employer expectations and student preparation for employment.

In conclusion, both academics and people employed in industry all share a desire to improve student employability. Many of the readers of this issue will have had a rewarding and fulfilling career

AREA	To what extent:	LOW				HIGH
CAREER DEVELOPMENT LEARNING	Is developing a professional identity a part of every course (subject) (learnt and assessed)?	1	2	3	4	5
EXPERIENCE (WORK AND LIFE)	Does every graduate have at least 12 weeks/400 hours of relevant work experience?	1	2	3	4	5
DEGREE SUBJECT KNOWLEDGE, UNDERSTANDING AND SKILLS	Does every graduate have a sound set of degree subject knowledge, skills and attitutes (learnt and assessed)?	1	2	3	4	5
GENERIC SKILLS	Does every graduate have a well-developed set of generic skills (demonstrated and assessed)	1	2	3	4	5
EMOTIONAL INTELLIGENCE	Does every graduate have a well-developed emotional intelligence (demonstrated and assessed)?	1	2	3	4	5

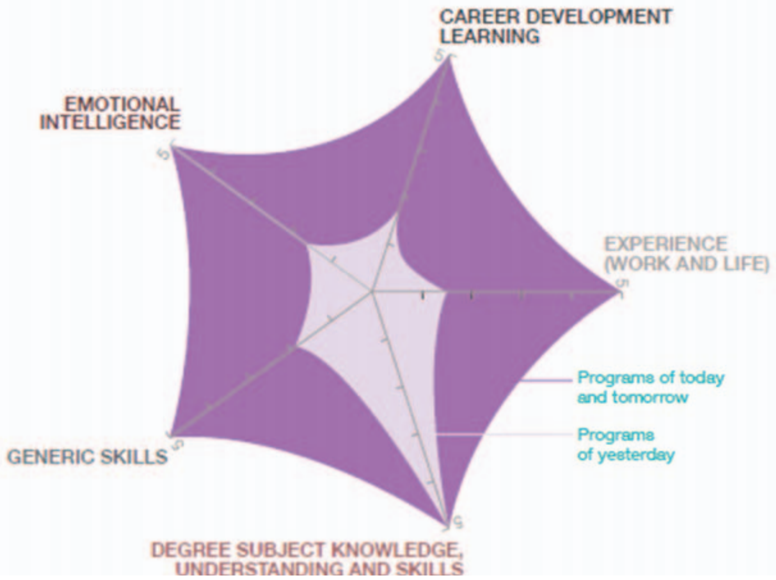


Figure 1. A quiz to assess your program's approach to developing employability in students.

and would want to help students achieve the same. There is much that academia can do to help students prepare for a working life; however, we need industry to offer work placement to students so that students can graduate with relevant work experience. The OLT grant has given RMIT academics an opportunity to spend time with employers and deepen the relationship between industry and academia. It is important that such discussions continue so that academia and industry are able to help students graduate with realistic expectations, a practiced eye for science's possibilities and the confidence to step into the world of graduate careers.

References

1. Jollands, M. *et al*. (2015) Developing graduate employability through partnerships with industry and professional associations. Strawberry Hills: Office for Learning and Teaching.
2. Jollands, M. (2015) A framework for graduate employability adapted for discipline differences. In *Proceedings of the Higher Education Research and Development Society of Australia Conference (HERSA, 2015)*, Melbourne, 6–9 July.
3. Prinsley, R. and Baranyai, K. (2015) Stem-trained and job-ready. *Office of the Chief Scientist, Occasional Paper Series* **12**, 1–4.
4. Arujo, N. *et al*. (2015) Student engagement for employability: a Belonging Project case study. In *Proceedings of the Higher Education Research and Development Society of Australia Conference (HERSA, 2015)*, Melbourne, 6–9 July.

5. MacKinnon, P. (2015) Engineering communication. In *Short stories: innovative approaches to developing employability in our students* (Eds M. Jollands and C. Pocknee). Strawberry Hills: Office for Learning and Teaching.
6. Rodrigues, S. *et al*. (2007) The usefulness of a science degree: The 'lost voices' of science trained professionals. *Int. J. Sci. Educ.* **29**, 1411–1433. doi:10.1080/09500690601071909
7. Office of the Chief Scientist (2014) *Science, Technology, Engineering and Mathematics: Australia's Future*. Australian Government, Canberra.

Biographies

Danilla Grando is an Associate Professor in the School of Applied Sciences. Her teaching interests are online education and program delivery to enhance employability. Her research interests are diagnostic microbiology.

Catherine Pocknee is currently a senior Academic Development Advisor at RMIT and has a strong educational research background. In 2007 she was a leader of the OLT grant; The Work Integrated Learning (WIL) Report: A national scoping study, and in 2014 she was senior project officer for the OLT grant: Developing graduate employability through partnerships with industry and professional associations at RMIT University.

Bronwyn Clarke is the Director of Programs for the School of Media and Communications. Her teaching practice and research interests focus on Belonging and Student Engagement for graduate employability within the Creative Industries.

Margaret Jollands is an Associate Professor in the School of Engineering. She is also Director of the SHEER (Science, Health and Engineering Educational Research) Centre at RMIT University.

Curriculum design for research-led teaching: Molecule to Malady



Helen Cain[A,C], *Richard Strugnell*[A] *and Frederic Hollande*[B]

[A]Department of Microbiology and Immunology, The University of Melbourne at the Peter Doherty Institute for Infection and Immunity, 792 Elizabeth Street, Parkville, Vic. 3010, Australia

[B]Department of Pathology, The University of Melbourne, Parkville, Vic. 3010, Australia

[C]Corresponding author. Tel: +61 3 8344 9944, Email: hmcain@unimelb.edu.au

Modern medicine is increasingly characterised by a personalised approach to treatment through producing therapies that target specific biological processes. When planning the new Bachelor of Biomedicine (BBiomed) degree, one of two completely new undergraduate courses crafted as part of the 'Melbourne Curriculum' introduced by The University of Melbourne in 2008, the paradigm that medical interventions should be evidence-based and driven by a molecular understanding of the cause of disease was a key design parameter. Our intention in developing the curriculum for *Biomedicine: Molecule to Malady* (M2M), a third-year compulsory capstone subject of this new BBiomed degree, was to enhance the ability of students to apply their core cross-disciplinary knowledge to unfamiliar problems in translational medicine by having expert clinicians/researchers explain the scientific reasoning applied to the development of disease interventions in their specialist areas.

Curriculum design at higher education institutions should be driven by the development of graduate attributes, described as 'knowledge, skills and values that students develop during their time at the university, and which shape their future contributions to their profession and as citizens'[1]. Throughout their undergraduate studies, students are led through a learning experience that is intended to prepare them for their postgraduate pathway, be it entry into the workforce or into postgraduate study and/or research.

The Melbourne Curriculum, launched at The University of Melbourne in 2008, 'featured six broad, three-year undergraduate degrees characterised by both disciplinary depth and academic breadth'[2]. In the Melbourne Curriculum, each major area of study culminates with 'a 'capstone' experience in the third year (understood as offering both disciplinary and cohort coherence and a bridge between the undergraduate experience and what lies beyond)'[3]. These capstone subjects are an integral part of the final year of each course, and are intended to 'enhance students' capacity to apply their theoretical knowledge to applied real world issues and demonstrate their ability to provide coherent solutions'[4].

In addition, it was intended that 'undergraduate education at a research-intensive university should be characterised by student encounters with teachers who are also researchers. . . (who provide) an introduction to the methodologies and ethics of research'[4].

The Molecule to Malady (M2M) story

The designers of the subject BIOM30002 Biomedicine: Molecule to Malady were in a unique position to develop a curriculum for a compulsory subject in the BBiomed degree that sat outside the 'major', the necessarily focussed and deep study stream in a particular area or discipline(s), and could thus focus on giving students an opportunity to examine scientific problem-solving,

 10.1071/MA16022

demonstrated by eminent researchers in their various fields as authentic 'research-led' teaching.

Influenced by clinician-scientists like Graham Brown and Steven Collins, the M2M designers were blessed with a myriad of topic options but chose to highlight diseases in which world-class clinical and scientific expertise was held within The University of Melbourne, and/or one of its allied medical research institutes – the Burnet Institute, the Murdoch Children's Research Institute (MCRI), the Walter and Eliza Hall Institute of Medical Research (WEHI) and St Vincent's Institute (SVI). The chosen topics were pandemics (HIV and malaria), B-cells and diseases, cystic fibrosis, rheumatoid arthritis (RA), muscular dystrophies and neurodegeneration (Alzheimer's disease and Parkinson's disease).

A defining feature of the BBiomed degree is that, each year, students complete a number of compulsory cross-disciplinary core subjects that provide them with an extensive and common base of scientific knowledge – this prior learning is extended by the content of the M2M subject, giving students a much-valued context for their core studies. It is expected that students will utilise their core knowledge in microbiology and immunology, genetics, and anatomy and physiology of the brain, bone and muscle as they progress through the six modules of M2M.

In designing the M2M subject we asked our teachers to demonstrate that a better understanding of the molecular basis of disease leads to better diagnosis and prognosis, and especially treatment with drugs and other interventions that specifically target the disease and/or pathogen; i.e. by understanding the specific molecules that are key to the pathology, treatment of the malady becomes much more targeted and likely to work, with fewer side-effects.

Our aim was to develop two of the key graduate attributes specifically desired by employers in the health sector: *knowledge of industry* (through explicit teaching about diseases and related current medical research), and *critical reasoning and analytical skills/problem-solving* (through explanations of the scientific reasoning applied to the development of interventions in the diseases studied)[5].

M2M: the how

M2M seeks to deconvolute the students' understanding of selected maladies (diseases) to develop a way of thinking about any disease. Students are led through an exploration of the key molecules associated with diseases, where the module champions (leaders) and their fellow lecturers describe the development of current treatments and look at the possibilities for future treatments that target relevant molecules, allowing students to develop a thought process that aims to be applicable to any treatment (i.e. what molecule, process or cell does it target?).

The M2M subject touches on elements of many of the majors that students are undertaking, while remaining relevant to the class as a whole in its holistic approach to the understanding of disease. The topics and methods of presentation, e.g. patient interviews, were selected to complement rather than overlap the teaching and learning provided in the BBiomed majors.

The teaching team for M2M is wholly made up of clinician-researchers and research scientists who are leading and often world-experts in their fields. The current roster includes Professor Sharon Lewin (inaugural Director of the Doherty Institute for Infection and Immunity, co-convenor of the 2014 World AIDS Conference, and world-renowned HIV researcher and physician), Professor Brendan Crabb AC (Director and CEO of the Burnet Institute, and molecular biologist whose research focus is on the development of a malaria vaccine), and Professor David Tarlinton (Head of Department of Immunology and Pathology, Monash University). Our other module champions include Professor Sylvia Metcalfe, a medical genetics expert at the Royal Children's Hospital, and Professor Roberto Cappai, one of Australia's leading neuropathology researchers. Students are clearly engaged and inspired by the calibre of teachers with whom they interact in the M2M subject.

A key feature of the M2M curriculum is the inclusion of patient/parent interviews in each module to provide students with a personal perspective of diseases they are studying. Students have the opportunity to question these guest speakers to develop a deeper understanding of the diseases, and the effect of chronic illness on the lives of these generous and engaging people. The interviews have proven to be a powerful motivator for students to learn about diseases and possible treatments, giving them a glimpse of the impact of their potential future careers in medicine or research that would otherwise be difficult to convey.

The module champions and their fellow lecturers have been well-briefed on the core principles and aims of the subject and have worked with the academic coordinating team over the past six years to refine their lecture content, and to emphasise common themes between particular modules (e.g. the development of therapeutic monoclonal antibodies is discussed in the B Cells and Diseases module, while their use in rheumatoid arthritis therapy is presented in the RA module).

We believe we have developed authentic and pedagogically sound assessment tasks to evaluate student learning despite the large class

Table 1. Student experience survey data: Molecule to Malady.

Year	Class size (responses)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
2010	218 (130)[A]	4.1	N/A	N/A	3.4	N/A	N/A	3.0	N/A	N/A	N/A
2011	281 (245)[A]	4.4	4.1	3.7	3.6	4.4	4.0	3.9	3.9	3.5	3.7
2012	403 (216)[B]	4.3	4.3	3.9	3.9	4.6	3.6	3.6	4.0	3.5	3.9
2013	429 (154)[B]	4.4	4.0	3.7	3.8	4.7	3.1	3.2	3.9	3.5	3.8
2014	412 (166)[B]	4.6	4.6	4.3	4.3	4.7	4.3	4.2	4.2	4.0	4.0
2015	427 (167)[B]	4.6	4.7	4.2	4.2	4.7	4.0	4.2	4.3	3.9	4.2

Questions
(1) Overall, this subject has been intellectually stimulating
(2) Overall, this subject has been well co-ordinated
(3) Overall, this subject has been supported by useful learning resources
(4) Overall, this subject has been well-taught
(5) Focusing on my own learning in this subject, I have been required to work at a high standard
(6) Focusing on my own learning in this subject, I found the assessment tasks useful in guiding my study
(7) Focusing on my own learning in this subject, I received valuable feedback on my progress
(8) Focusing on my own learning in this subject, I learnt new ideas, approaches and/or skills
(9) Focusing on my own learning in this subject, I learnt to apply knowledge to practice
(10) Focusing on my own learning in this subject, I have been part of a group committed to learning

[A]2010–2011: paper-based survey (in lecture).
[B]2012–2015: voluntary online survey.
5 point Likert scale: 1 = strongly disagree → 5 = strongly agree. N/A, not available: change of question format in 2011.

size (427 students in 2015). The students complete three sets of multiple-choice questions (MCQs) examining key points in each pair of modules, as well as short answer questions (SAQs) that test the students' ability to integrate and apply their acquired knowledge in a final exam. Over the past six years questions used for assessment have been refined, with the introduction of innovative MCQs that require students to progress through a clinical scenario, answering questions for which they must apply their knowledge to the problem at hand. In the SAQs, students need to demonstrate both their grasp of the lecture content and their ability to apply this learning to a defined (new) situation.

Biomedical Science Threshold Learning Outcomes (TLOs) developed and ratified in 2013 by the Collaborative Universities Biomedical Education Network (CUBENET) using the Office of Teaching and Learning (OLT) Science and Biology TLOs[6] provide a benchmark for the M2M subject outcomes. The Molecule to Malady curriculum enhances the students' ability to 'demonstrate a coherent understanding of biomedical science' by giving them specific examples of the 'translation of biomedical science to clinical and medical outcomes' (TLO 1.2). Students who have successfully undertaken M2M will have exhibited 'depth and breadth of scientific knowledge by demonstrating integration of knowledge from across the disciplines contributing to biomedical sciences' (TLO 2) – this is a key driver of the M2M, and indeed the BBiomed, curriculum.

The Student Experience Surveys for the past six years represent the students' responses to the subject: the results from 2010 to 2015 are shown in Table 1.

It is particularly encouraging to see the excellent responses in Q1, Q4 and the improving responses in Q9. Given that this is a compulsory subject for an elite cohort (clearly-in ATAR usually >98.5), the survey responses are viewed as particularly strong testament to the excellent teaching within the modules and the very good 'back office' support.

More than 50% of the students in the M2M cohort seek admission to postgraduate medicine and allied health degrees, and a significant section of the cohort wish to pursue careers as research scientists. We believe that the exposure to leading clinical and research experts has been both motivating and enlightening for our students – providing them with a unique opportunity to understand the methodology behind the approaches to dealing with diseases in our society. This should allow them to apply these principles to unfamiliar problems they may face in the future.

We have included a portion of the video-taped interview of HIV-positive activist Paul Kidd by Professor Sharon Lewin (http://microbiology.publish.csiro.au/?acc=MA16022_AC.pptx). Sharon's concluding question and Paul Kidd's (unscripted) answer is, we believe, a powerful educational moment for the students in the class, and exemplifies the core principles of M2M.

Acknowledgements

The authors thank Professor Steven Collins, inaugural co-coordinator of M2M; the M2M Module champions and lecturers who presented the subject content and have worked with us to continually develop the M2M curriculum over the past six years; the patients/parent who have generously given their time to provide a real-life perspective of chronic disease for students; and the six cohorts of M2M students whose feedback has been invaluable in refining the subject.

References:

1. Bowden, J. *et al*. (2000). Generic capabilities of Australian Technology Network (ATN) university graduates. http://www.clt.uts.edu.au/ATN.grad.cap.project.index.html
2. Teaching, Learning and the Student Experience, Chancellery (Academic & International) web page. http://msl.unimelb.edu.au/teaching-learning
3. Holdsworth, A. *et al*. (2009) Developing capstone experiences. http://www.cshe.unimelb.edu.au/resources_teach/curriculum_design/docs/Capstone_Guide_09.pdf
4. The Melbourne Model: Report of the Curriculum Commission (2006) http://growingesteem.unimelb.edu.au/__data/assets/pdf_file/0003/86673/cc_report_on_the_melbourne_model.pdf
5. Graduate Careers Australia Pty Ltd (2013) Graduate Outlook 2013. The Report of the Graduate Outlook Survey: Employers' Perspectives on Graduate Recruitment. http://www.graduatecareers.com.au/wp-content/uploads/2014/03/Graduate_Outlook_2013.pdf
6. Biomedical Science Threshold Learning Outcomes CUBENET. (2013) http://www.cubenet.org.au/wp-content/uploads/2014/07/BIiomedical-Science-Threshold-learning-Outcomes-BiomedTLOs1.pdf

Biographies

Helen Cain is a lecturer (teaching specialist) in the Department of Microbiology and Immunology at The University of Melbourne. Her teaching research interests include the development of practical case studies to enhance students' ability to understand and apply key microbiological concepts. She is a co-coordinator and the academic convenor of the 'Biomedicine: Molecule to Malady' (M2M) subject.

Richard Strugnell is Pro-Vice-Chancellor Graduate and International Research and a Professor in the Department of Microbiology and Immunology at The University of Melbourne with research interests in bacterial pathogenesis. He is the designer and co-coordinator of the M2M subject.

Frederic Hollande is an Associate Professor in the Department of Pathology at The University of Melbourne. His research interests are focussed on mechanisms that underlie the plasticity of cancer cells during metastatic progression and in response to treatment. He is a co-coordinator of the M2M subject.

Applied Microbiology and Biotechnology teaching tailored towards regional needs and graduate employment

Dİ Kurtböke

Faculty of Science, Health, Education and Engineering
School of Science and Engineering
University of the Sunshine Coast
Maroochydore DC
Qld 4558, Australia
Email: ikurtbok@usc.edu.au

The University of the Sunshine Coast (USC) opened in 1996 and since 1999 held the full university status as well as being the first 'Greenfield' university to open in Australia since 1971 (http://www.usc.edu.au/). This status was in line with its mission to become an institution with strong emphasis on sustainability and environmentally friendly regional development while transforming a former cane farm into today's multi award-winning modern and distinctive sub-tropical architectural structure. Over the past 20 years the university has played a role as an 'urban catalyst' in one of the rapidly growing and transforming regions of Australia with a foundational mission statement: 'To be the major catalyst for the academic cultural and economic advancement of the region: by leadership; by pursuit of international standards in teaching and research; and by responsiveness to the needs of students, staff, community and the environment'.

Meanwhile simultaneously in the region the State Government of Queensland under the leadership of the former Premier Hon. Peter Beattie was placing emphasis into Biotechnology and the importance of the establishment of a knowledge-based economy for the regional advancement and transformation (http://www.alumni.uq.edu.au/queensland-the-smart-state). Again in the same years a discussion paper 'Developing Australia's Biotechnology Future' produced by Biotechnology Australia as a Federal Government Initiative was also highlighting the relevance of biotechnology for the sectors like: health, agriculture, forestry, mining, manufacturing, bioprocessing, environment, food processing and beverages and marine biotechnology and aquaculture[1]. Microbiology has always been one of the fundamental disciplines supporting the listed sectors in the discussion paper via the implementation of microbially mediated processes such as alternative energy generation, waste management, discovery of novel and effective therapeutic drugs and environmentally friendly agro-biologicals. Design and delivery of the courses within the Microbiology stream of the University of the Sunshine Coast related to applied, industrial and environmental aspects were thus implemented in parallel to these developments in the region since 2001[2].

Microbiology since the Pasteur days has been a discipline with a rich history of connecting research and teaching. Pasteur created pedagogics of the discipline by promoting the value of laboratory research for the individual and the society to grow and improve in harmony with the works of the nature. Since then microbiology continued to build on his 'use-inspired basic research' concept by incorporating it into the teaching practices[3,4].

One of the foundational pedagogies used for the design of the microbiology courses at the USC was the *Constructivism*[5–7], which:

- '*Advocates teaching as a process that guides students to construct their own knowledge by building connections from what they already know to the information the teacher intends them to acquire*'
- '*Students are more likely to learn and remember ideas that are reinforced by their own interests and experiences in the world around them*'
- '*Classroom science teaching is recommended to make explicit links between scientific knowledge and everyday experiences*'
- '*Microbiology is particularly well suited for these recommendations because the effects of microorganisms are more evident in the world around us (e.g. new infectious diseases, crop failures, food poisoning, antibiotic resistance...)*'[4].

Design pedagogies used during microbiology course development at the USC were targeted the encourage students to reflect on and utilise their own regional knowledge and experiences while transferring theory into design and application of innovative microbial technologies to provide solutions for the regional problems. Such encouragement has been in line with the strategic directions defined for the region by the state and regional governments and councils. In addition, the Pasteur's Quadrant (Figure 1) was also incorporated into the course design and delivery that was 'directly influenced in its course both by the quest of fundamental understanding and the quest of applied use'[8].

To be able to respond to regional problems at graduate level target-directed teaching was implemented to develop student's understanding about the needs of the rapidly growing region and local

QUEST FOR FUNDEMENTAL UNDERSTANDING?	HIGH	PURE BASIC RESEARCH (BOHR QUADRANT)	USE-INSPIRED BASIC RESEARCH (PASTEUR QUADRANT)
	LOW		APPLIED RESEARCH (EDISON QUADRANT)
		LOW	HIGH
	CONSIDERATION OF USE?		

Figure 1. Pasteur's Quadrant[8].

industries as well as gaining in-depth understanding in science and microbial biotechnology. Development of a graduate level understanding throughout student's learning was expected to be utilised towards the growth of sustainably advancing region. Examples might include the transformation of the traditional sugar cane industry into a biofuel generating one utilising the advancements in science and technology and opening new avenues for the farmers or converting excessively produced molasses in the region into value-added products such as acetone, butanol or glycerol.

Graduate qualities emphasised to students throughout their education in the University of the Sunshine Coast include:

- 'creative and critical thinking, generating original ideas and concepts, and appreciating innovation and entrepreneurship,
- empowered, having both the capacity and confidence to pursue the attainment of full potential,
- engaged, contributing positively to diverse communities through service and leadership,
- ethical, acting with integrity in intellectual, professional and community pursuits,
- knowledgeable, building disciplinary and interdisciplinary knowledge through a scholarly approach incorporating global and regional perspectives,
- sustainability-focussed, responding to ecological, social and economic imperatives'

Microbiology courses offered since the establishment of the University were thus constructed to embed these qualities.

The USC was also selected as the only university from Australia to be included in an OECD study in 2006 due to its engagement with the local regional community[9]. This recognition provided further impetus and drive for the implementation of microbially mediated processes in the region by empowered graduates via in-depth understanding in applied microbiology. At the graduate level it was expected that:

- the theoretical knowledge is translated by students into action learning by relating their previous regional and environmental knowledge to newly acquired knowledge (e.g. microbial biotechnology);
- students were able to relate the gained knowledge into the big picture as well as into their program of enrolment (e.g. interdisciplinary and holistic approach); and
- discipline-based educational self-development in line with global advancements in the field of microbiology while playing a major role as a graduate in the sustainable and environmentally friendly development of the region (e.g. regional waste management).

The current structure of the delivery of microbiology courses is given in Figure 2, which adapts cumulative learning in microbiology as well as leading to Honours level studies. Pathway from SRP, WIL courses leading to Honours and post-graduate studies also results in regionally relevant data generation and publication of research papers in partnership with local industries or government bodies[10–18]. USC's *Teaching-Research Nexus* (Figure 2) was also embedded into the microbiology stream that advocates 'mutually reinforcing connections between teaching and research that are central to the meaning of higher education and the idea of the university'. '*Teaching-Research Nexus* has traditionally driven both curriculum design and delivery, and the research efforts of many universities[19,20], and this tradition has also been pivotal at the University of the Sunshine Coast since its foundation. The dual pathway where research shapes and informs teaching, and teaching shapes and informs research defines the nexus' and is embedded in the operations of the University at several levels since its foundation. The significance of *Microbial Resource Centres* in microbiology education has been emphasised globally[21] and to foster student research activities a *Microbial Library* containing bioactive microorganisms was also established to provide support material for student research projects[22] conducted under the Special Research Project courses. Work Integrated Learning courses are offered through regional industries and government agencies to provide graduate level understanding of the regional needs for sustainable solutions.

The University of the Sunshine Coast, consistent with its strategic plan and 'Aboriginal and Torres Strait Islander education and employment initiatives, also connects with employer and industry/professional bodies to build and extend pathways into higher education for Aboriginal and Torres Strait Islander people. It also has an *Indigenous Advisory Committee* to advise the University on Aboriginal and Torres Strait Islander student matters including equitable access, participation, retention and success. *Indigenous Cadetship Support* (ICS) aims to improve the professional employment prospects of Aboriginal and Torres Strait Islander peoples. It links Aboriginal and Torres Strait Islander tertiary students with employers in a cadetship arrangement involving full-time study and work placements. Cadetships enable Aboriginal and Torres Strait Islander students to gain the professional qualifications and experience needed for a range of jobs in the private, public and community sectors and assists them to move into employment on completion of their studies' http://www.usc.edu.au/explore/structure/university-committees/vice-chancellors-indigenous-advi

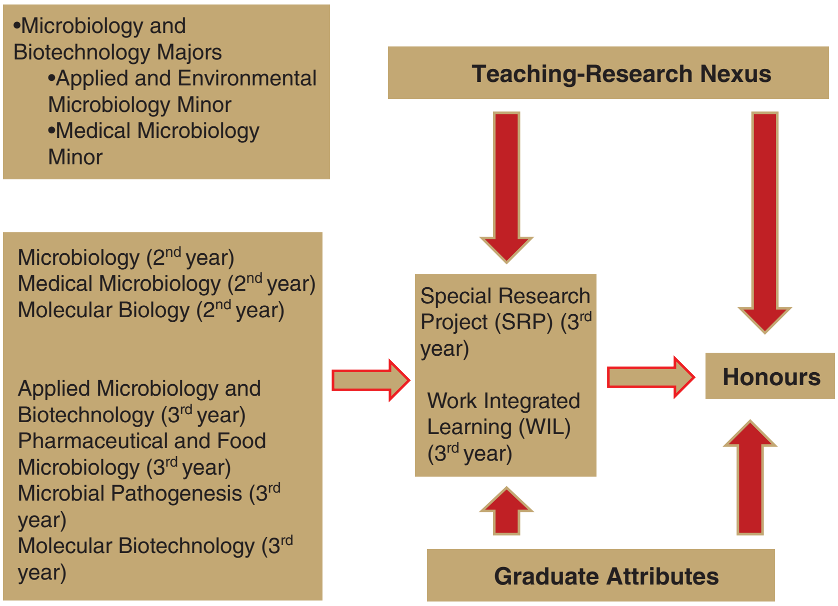


Figure 2. Target directed teaching structure of *Microbiology* and discipline based skills.

Figure 3. Delivery of Applied Microbiology and Biotechnology lecture series at the Perm State University, Russian Federation.

sory-committee. Indigenous communities lived for centuries in self-sustained ways and their increased immunities against microbial diseases are known due to traditional ways of nutrition and living. The discipline of microbiology and traditional knowledge can thus foster a valuable partnership in particular in the field of biomedicine for discovery of new and potent therapeutic compounds.

All above listed target-directed and constructed efforts in the microbiology major have also resulted in the development of international links. Relevance of applied microbiology and biotechnology in the development of sustainable solutions at the global context for different regions of the world was a point of exchange when a series of invited lectures were delivered in the Perm State University, Russia in October, 2015 (Figure 3).

USC will celebrate its 20th year of its establishment this year. Microbiology teaching has been an important part of the degree programs ranging from science to biomedical science and developed in line with the USC's efforts in empowering the regional students with internationally compatible skills and knowledge and ensuring employment at regional, state, national and international levels.

I would like to conclude with Pasteur's words: 'I beseech you to take interest in these sacred domains so expressively called laboratories. Ask that there be more and that they be adorned, for these are the temples of the future, wealth, and well-being. It is here that humanity will grow, strengthen and improve. Here, humanity will learn to read progress and individual harmony in the works of nature, while humanity's own works are all too often those of barbarism, fanaticism and destruction', and add that microbiology is one of the disciplines has profoundly impacted and will impact global peace and advancements via delivery of innovative designs stemming from innovative microbial engines. Future industrial revolution lies in the hands of microorganisms if we understand fully their purpose of existence and fascinating diversity and functions in the environment.

Acknowledgements

I acknowledge and thank all former and current students of the microbiology courses for their endless efforts to better-their-best. I would like to thank parents of the students who enthusiastically supported us all along. I also gratefully acknowledge regional councils, government institutions and industries who actively participated in the research, provided cash and in-kind contributions and employment to our students upon graduation. I acknowledge the traditional custodians of the land The Gubbi Gubbi People on which the University of the Sunshine Coast operates.

References

1. Biotechnology Australia (1999) Developing Australia's Biotechnology Future. Discussion Paper. Publication of Biotechnology Australia, A Federal Government Initiative. Commonwealth of Australia.
2. Kurtböke, D.I. (2008) Microbial biotechnology education from a regional perspective. *Microbiol. Aust.* **29**, 102–103.
3. Handelsman, J. *et al*. (1997) Biology brought to life: a guide to teaching students how to think like scientists. Wm. C. Brown Publishers, Inc., Dubuque, Iowa, 256 pp.
4. Handelsman, J. (2002) Microbiology as a change agent in science education. *ASM News* **68**, 163–167.
5. Brooks, J.G. and Brooks, M.G. (Eds) (2000) In Search of Understanding: The Case for Constructivist Classrooms. Allyn and Bacon.
6. Steffe, L. and Gale, J. (Eds) (1995) Constructivism in education. New Jersey: Lawrence Erlbaum Associates, Inc.
7. von Glasersfeld, E. (1995) A constructivist approach to teaching. In Steffe L. and Gale J. (Eds) Constructivism in education, pp. 3–16. New Jersey: Lawrence Erlbaum Associates, Inc.
8. Stokes, D.E. (1997) Pasteur's Quadrant Basic Science and Technological Innovation. Brookings Institution Press.
9. Thomas, P. (2006) OECD report recognises role of university. On Campus, *Sunshine Coast Daily*, Saturday, 1 July 2006, p. 46. http://www.sunshinecoastdaily.com.au/
10. Brinkmann, C.M. *et al*. (2014) Detection of *Thermoactinomyces* species in selected agricultural substrates from Queensland. *Microb. Ecol.* **67**, 804–809. doi:10.1007/s00248-013-0354-5
11. Eccleston, K.L. *et al*. (2010) Assessment of the role of local strawberry rhizosphere-associated streptomycetes on the bacterially-induced growth and *Botrytis cinerea* infection resistance of the fruit. *Sustainability* **2**, 3831–3845. doi:10.3390/su2123831
12. Shanahan, E.F. *et al*. (2010) Evaluation of pathogen removal in a solar sludge drying facility using microbial indicators. *Int. J. Environ. Res. Public Health* **7**, 565–582. doi:10.3390/ijerph7020565
13. Wasmund, K. *et al*. (2009) Novel alkane hydrolase gene (alkB) diversity in sediments associated with hydrocarbon seeps in the Timor Sea, Australia. *Appl. Environ. Microbiol.* **75**, 7391–7398. doi:10.1128/AEM.01370-09
14. Stephen, K. and Kurtböke, D.I. (2011) Screening of oomycete fungi for their potential role in reducing the biting midge (*Diptera: Ceratopogonidae*) larval populations in Hervey Bay, Queensland, Australia. *Int. J. Environ. Res. Public Health* **8**, 1560–1574. doi:10.3390/ijerph8051560
15. Rames, E. *et al*. (2009) Bacterially-induced growth promotion of micropropagated ginger. Proceedings of the VIth IS on *in vitro* Culture and Horticultural Breeding (R.J. Geijskes *et al*., Eds). *Acta Hocticultura*, 829, 155–160.
16. Eccleston, G.P. *et al*. (2008) The occurrence of bioactive micromonosporae in aquatic habitats of the Sunshine Coast, Australia. *Mar. Drugs* **6**, 243–261. doi:10.3390/md6020243
17. Harper, J. *et al*. (2008) The efficacy of vermicomposting on the population structure of Enterococci in domestic biosolids in a residential resort community. *Environ. Health* **8**, 11–21.
18. Pettett, L.M. and Kurtböke, D.I. (2004) Development of an environmentally-friendly biofertilizer from poultry manure using keratin degrading and antibiotic producing bacteria. *Actinomycetologica* **18**, 34–42. doi:10.3209/saj.18_34
19. Brown, M.R.W. (2007) Living with change: research-based scientific education is essential. *Pharm. J.* **278**, 425–426.
20. Carrick Institute Teaching Research Nexus Forum Report (2007) http://www.altc.edu.au/carrick/webdav/users/siteadmin/public/dbi_forum_trnexus_07_report.pdf
21. Şahin, N. (2006) Biosafety, biodiversity and significance of Microbial Resource Centers (MRCs) in microbiology education. *World J. Microbiol. Biotechnol.* **22**, 219–224. doi:10.1007/s11274-005-9024-1
22. Kurtböke, D.I. (2004) Actino-Rush on the Sunshine Coast: Prospects for Bioprospecting. In the *Proceedings of the 10th International Congress on Culture Collections*, Tsukuba, Japan, 2004 (Watanabe M.M., Suzuki, K. and Seki T., Eds), pp. 319–322.

Biography

Dr Kurtböke has been working in the field of biodiscovery and has been an active member of the international actinomycete research community since 1982. She currently conducts research and teaches in the field of applied microbiology and biotechnology and is senior lecturer at the University of the Sunshine Coast (USC), Queensland. She has been a member of the *Biodiscovery Industry Panel* established by the AusBiotech and DEHWA, which networks Australian biodiscovery operators. She has also established a bioactive actinomycete library used for research and teaching activities at the USC as well as in partnership with regional, national and international collaborators for discovery of new therapeutic agents, agrobiologicals, enzymes and environmentally friendly biotechnological innovations. She has also been an active member of the World Federation of Culture Collections (WFCC) including serving as the Vic-President of the Federation (2010–2013).

Training PhD students to bridge the Academia–Industry gap



Priscilla Johanesen[A,B], *Jose Garcia-Bustos*[A] *and Paul Wood*[A]

[A]Infection and Immunity Program, Monash Biomedicine Discovery Institute and Department of Microbiology, Monash University, Vic. 3800, Australia

[B]Corresponding author. Email: priscilla.johanesen@monash.edu

It is now well understood that the career paths of PhD students are diverse and not all PhD graduates strive for a career in academia[1]. Even if the opposite were true, the number of PhD graduates greatly exceeds the number of currently available and projected academic positions[2]. It is clear that the PhD as it is traditionally understood has to evolve. With the changing outcomes of the PhD has come the requirement to provide students with training that will equip them with marketable skills vital for success in real-life workplaces, extending them beyond their discipline-specific research and knowledge with skills applicable to industry, academia, government, the community and possibly entrepreneurial activities. This article describes a training module 'From Project to Product', which has been developed at Monash University to engage students with industry and introduce them to career pathways outside of academia.

Historically in Australia, academic and industrial career options have been seen as dichotomous pathways. The cultural divide between the two can be seen in figures, which indicate that 60% of all Australian researchers work in universities, compared with less than 30% of researchers employed in the business sector. This contrasts with other countries, where the majority of researchers are employed in the business sector: the United States (80%), Japan (70%) and Switzerland (64%)[3]. This divide is further emphasised by the Organisation for Economic Co-operation and Development (OECD) Science, Technology and Industry Scoreboard 2013 statistics on the level of collaboration between business and higher education or research institutions. These data showed that Australia was placed last of 33 countries with respect to collaboration with large firms, and second last for small to medium enterprises[4]. In the most recent OECD Science, Technology and Industry Scoreboard 2015 Australia was not even listed[5]. There is a clear and urgent requirement for Australian academic institutions and industry to work together to bridge this gap.

The training module 'From Project to Product', was developed at Monash University as a component of the Monash Doctoral Program[6], to prepare graduates for career options outside academia where the skills learned during a PhD such as project planning, flexibility in execution of a project, as well as problem solving, competition awareness and lateral thinking can give them a competitive advantage. The primary purpose of the module is to lead students through the steps involved in taking a basic research finding through to a translational outcome, such as a product or application that will contribute to human or animal health. The module is facilitated by two academics – Professor Paul Wood and Associate Professor Jose Garcia-Bustos – who have had extensive experience in industry, having had senior R&D roles in two of the world's leading pharmaceutical companies, Pfizer Animal Health and GlaxoSmithKline, respectively.

The module consists of six face-to-face, two-hour sessions in which students are guided through the initial stages of product planning, including crucial considerations required when implementing such a project. Students are also introduced to the development of key strategic documents, such as a target product profile. In the first session, Paul and Jose give an overview of their industry experience before introducing students to the training module and describing the purpose of a target product profile. Students then form teams of two to three, who work together to develop a target product profile for a product of their choice. Students are expected to collaborate in their own time outside of the face-to-face sessions and to seek guidance from the facilitators as needed. Initial drafts of the target product profiles are presented in week 4, where students obtain feedback from Paul and Jose and their peers. In the final session of the module in week 6, students pitch their product idea as a team to the remainder of the cohort, discuss the feasibility of the product in the market place and present an estimate of the funds they would need to progress their idea to the next milestone. They are advised to consider the audience as a source of venture capital and encouraged to immerse themselves in the simulation by wearing business attire during the presentation.

In addition to the guiding of students through the development of a target product profile, the module also includes a session on intellectual property fundamentals as well as interactive sessions with guest speakers from a wide variety of career backgrounds. These guest presenters tend to share the common thread of having had an initial academic career, which later evolved into careers in alternate areas, such as biotechnology, patent law, or successful entrepreneurism.

Student feedback indicates that these presentations are essential to the value of the module. When asked what students liked most about the training module, unsolicited comments included: 'Listening to different speakers the pathways were all different'; 'Listening to everyone's story to how they got to where they are'; and 'The guest lecturers – great insight into different areas of industry'.

In addition to providing feedback on guest lecturers, students have commented on what the training module has taught them with respect to industry exposure: 'Teaches you about an aspect that you don't really have exposure to'; and 'The fact that I can now understand the influence of industry in product development and commercialisation'.

Overall, we believe these comments indicate that the module is serving the purpose for which it is intended. Significantly and alongside providing industrial exposure, this module requires students to focus on skills that are valued highly by employers, such as communication and presentation skills, critical thinking, teamwork and networking, all of which will be advantageous in their future careers.

As discussed at the beginning of this article the training module from Project to Product is an instructor-led activity that was developed as a way to expose students to professional pursuits outside academia, and to modestly begin to address the divide between industry and academia. Alongside modules such as this, in 2015 PhD candidates at Monash University, as well as other universities across Victoria including The University of Melbourne, RMIT and La Trobe University were invited to take part in the pilot of the new Industry Mentoring Network in Stem (IMNIS)[7] program. Supported by the Australian Academy of Technological Science and Engineering (ATSE), and developed by a team, which includes Professor Paul Wood, Ms Ronnie Wood, Dr Tony Radford and Mr John Kirby, IMNIS aims to tackle the disconnect between academia and industry by enhancing the industry-university networks. This is achieved by linking experienced industry individuals as mentors with PhD students in the STEM discipline. The Victorian industry pilot in 2015 focused on biotechnology and was supported by AusBiotech, while a separate pilot in Western Australia focussed on energy and mineral resources with support from the Institute of Engineers. Importantly, all these initiatives aim to educate young Australian researchers in the foundation steps of their careers, exposing students to industry and opening up the potential for other career pathways. Ultimately, it is hoped that training modules such as these will play a part in bridging the academia-industry gap thus benefiting future collaborative research outcomes between academia and industry in Australia.

Acknowledgements

The authors acknowledge the contribution and support of the following people who have generously given their time to guest lecture in this module: Ms Maria Harrison Smith, Dr Mark Heffernan, Associate Professor Jan Tennent, Dr Stuart Gribble, Professor David Jackson, Dr Tony Radford, Dr Jenny Petering and Associate Professor Tracey Brown. Ethics approval for data collected, including students comments, was granted from the Monash University Human Ethics Committee.

References

1. The Group of Eight. (2013) The Changing PhD – Discussion Paper. March. https://go8.edu.au/sites/default/files/docs/the-changing-phd_final.pdf
2. http://www.nature.com/news/how-to-build-a-better-phd-1.18905
3. Office of the Chief Scientist (2013) Science, Technology, Engineering and Mathematics in the National Interest: A Strategic Approach – A position paper. July.
4. OECD (2013) 'Collaboration on innovation', in OECD, OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth, OECD Publishing, Paris.
5. OECD (2015) 'Collaboration on innovation', in OECD, OECD Science, Technology and Industry Scoreboard 2015: Innovation for growth and society, OECD Publishing, Paris.

6. https://www.monash.edu/graduate-research/future-students/phd
7. http://www.atse.org.au/content/industry-mentoring-network-in-stem-imnis.aspx

Biographies

Professor Paul Wood obtained his PhD from the JCSMR, ANU, in 1982. After a post-doc at The University Melbourne he joined the CSIRO Division of Animal Health as Leader of the TB diagnostic and vaccine development program, where he patented the platform TB diagnostic technology, successfully commercialised by CSL, Prionics and the Australian company, Cellestis. Paul received a number of awards for this research including the CSIRO medal, ASM Diagnostic award and in 2013 The Clunies Ross award. Paul was also the Deputy-Director of the CRC for Vaccine Technology from 1993–2000 and has published over 100 scientific papers. In 1997, he became VP/Director, Global R&D in AH at CSL, and in 2004 joined Pfizer AH as Senior Director, A/NZ Biologicals R&D. In 2008, he left Australia to become Executive Director, Global Discovery, Pfizer AH, Kalamazoo, Michigan. He led the Global Discovery team for both pharmaceutical and biological products with 200 staff and a budget of US$60 million. Paul returned to Australia in 2012 and established his own consultancy company and accepted an Adjunct Professor position at Monash University. He was also a Director of a start-up AH company Nexvet Biopharma and is one of the Directors of the IMNIS Initiative. In 2015 he was elected as a Fellow of ATSE.

Associate Professor Jose Garcia-Bustos has a long record in anti-infective research in both academia and industry, having worked in bacteriocins for his PhD thesis and in the structure of the bacterial cell wall and the mode of action of beta-lactam antibiotics while a Fulbright fellow at The Rockefeller University in New York. While at GlaxoSmithKline and its legacy companies he coordinated groups at research sites in different countries and successively led the Molecular Microbiology Group, the Drug Discovery Biology Unit and the Malaria Unit in Tres Cantos (Spain), where at different times he supervised and managed biologists and medicinal chemist's working on drug discovery projects for antibacterials, antifungals, malaria and TB.

Associate Professor Priscilla Johanesen is Head of Teaching and Learning in the Department of Microbiology at Monash University and has 20 years experience in teaching microbiology in various modalities to undergraduate and graduate students across the disciplines of science, biomedical science and medicine in both Australia and the USA. In recognition of her dedication to teaching Priscilla was awarded the David White Excellence in Teaching Award at the Australian Society for Microbiology Annual Scientific Meeting in 2014. Priscilla's current role has involved the development and implementation of training programs for PhD students in the Faculty of Medicine, Nursing and Health Sciences, Monash University.

Embedding research ethics and integrity into undergraduate practical classes




Karena L Waller[A], *Daniel P Barr*[B], *Paul M Taylor*[C] *and Odilia L Wijburg*[D]

[A]Department of Microbiology and Immunology, The University of Melbourne, at The Peter Doherty Institute for Infection and Immunity, Melbourne, Vic. 3000, Australia. Tel: +61 3 8344 0045, Email: klwaller@unimelb.edu.au

[B]Office for Research Ethics and Integrity, Research Innovation and Commercialisation, The University of Melbourne, Melbourne, Vic. 3010, Australia. Tel: +61 3 9035 4170, Email: dpbarr@unimelb.edu.au

[C]Office for Research Ethics and Integrity, Research Innovation and Commercialisation, The University of Melbourne, Melbourne, Vic. 3010, Australia. Tel: +61 3 8344 2047, Email: pmt@unimelb.edu.au

[D]Department of Microbiology and Immunology, The University of Melbourne, at The Peter Doherty Institute for Infection and Immunity, Melbourne, Vic. 3000, Australia. Tel: +61 3 8344 9919, Email: odilia@unimelb.edu.au

The core principles of research ethics and integrity that underpin the responsible conduct of research are critical to the design and performance of high quality research that generates excellent research data and outcomes that can be confidently trusted. Although many senior researchers have gained an in-depth appreciation and understanding of the importance of research ethics and integrity in the responsible conduct of research, many undergraduate students in science and technology disciplines do not obtain a basic, working knowledge of relevant research ethics and integrity principles as part of their degree. Here, we describe the introduction of a research ethics and integrity curriculum component into our third year practical classes, and the beneficial outcomes that we observed.

Research ethics and integrity in the responsible conduct of research

The requirement for the responsible conduct of research (RCR) is increasingly gaining attention within the broader scientific community. Guidelines for RCR are provided by research institutes, universities and governments around the world. The 'Australian Code for the Responsible Conduct of Research' provides guidelines on key areas to promote scientific integrity and best practise in research and emphasizes the need for training in RCR[1]. Importantly, 'The Code' also addresses community expectations of researchers. Numerous scientific publications, some of which are published in high profile seminal journals like *Nature* and *Science*, have sought to bring greater awareness to the scientific community of what constitutes RCR, and what researchers and research institutes (including universities) can and should be doing to achieve it[2,3]. This increased attention, coupled with RCR being an integral component of all disciplines within the Science, Technology, Engineering and Mathematics (STEM) umbrella, has led to an increased awareness of the need for appropriate education in RCR[4–7] during tertiary education, and for research higher degree (RHD) students[8]. Yet despite this, the teaching and learning of the core principles of research ethics and integrity that underpin RCR for undergraduate university students is very often implicit rather than explicit. Indeed, many undergraduate students at the conclusion of their three year Degree possess a poor understanding of what constitutes RCR, or more bluntly, *why things need to be done a certain way* *in research*[8–10]. An earlier survey of American undergraduate Biology courses highlighted this issue, finding none of the 104 courses reviewed included a required (compulsory) curriculum component on ethics[11]. Thus, it is perhaps not surprising that many undergraduate students lack this knowledge at the conclusion of their three year undergraduate Degree.

To overcome this, many academics are now calling for earlier inclusion of some basic training on RCR in the undergraduate curricula of STEM disciplines[9,12–14] rather than its more usual introduction when undergraduate students undertake an intense research-based learning experience (such as an optional senior Honours year). Unfortunately, not all undergraduate students undertake such an intense research experience, and so many students graduate from their degrees and go on to seek future employment in STEM disciplines without a basic, requisite working knowledge of relevant research ethics and integrity. To directly redress this issue for graduates of Microbiology and Immunology majors at The University of Melbourne, we recently introduced into the curricula of our third year practical subjects a component on research ethics and integrity that directly links to the in-class critical dissection of a primary research article in journal club sessions.

The students and subjects

The students undertaking our third year practical subjects in Microbiology (MIIM30016 Techniques in Microbiology) and Immunology (MIIM30015 Techniques in Immunology) are drawn almost exclusively from the Bachelor of Science (BSc) and Bachelor of Biomedicine (BBiomed) Degrees. Each of these practical subjects consists of 1x 3 hours (h) of practical per week, plus 2x 1h of lecture or tutorial sessions per week. The practical topics in both subjects were specifically designed to provide a 'research-type' learning experience for the students focusing on different aspects of Microbiology and Immunology. Additionally, in each of these subjects the majority of the practical sessions were 'wet' practicals performed in a certified Physical Containment Level 2 (PC2) laboratory, while a minority were 'dry' practical sessions predominantly focusing on bioinformatics, analysis of flow cytometry data and Journal Club sessions (enabling the critical review of a recent discipline-specific primary research article). Both of these subjects were first deployed in 2014, and included a curriculum component devoted to research ethics and integrity. These sessions typically comprised a 1h general introduction to research ethics and integrity followed by a 1h interactive workshop. These sessions were prepared and delivered by Dr Daniel Barr (Associate Director) and Dr Paul Taylor (Director) from the Office for Research Ethics and Integrity (OREI) at The University of Melbourne and were facilitated by Dr Karena Waller and/or Dr Odilia Wijburg. The introductory session focused on the principles of research ethics and integrity most obviously connected to research in Microbiology and Immunology. The idea of the connectedness of one piece of research to another, and the iterative but sometimes paradigm-shifting nature of research, were explored with the analysis of case studies. Areas of research practice that are of immediate relevance to student researchers, such as: research data and records management and navigating authorship; the objectives of animal and human research ethics; and the impact of research misconduct, were explored in more detail. The latter interactive workshop was specifically designed to stimulate students to answer questions about research ethics and integrity and also required them to apply their newly acquired knowledge of RCR (gained from the introductory sessions) in the context of the Journal Club paper. Although students had previously dissected and evaluated the structure and scientific content of the Journal Club paper in a separate class, the workshop session required them to review the paper again, but this time from the perspective of research ethics and integrity by asking the question 'what is it about the paper that makes you trust the findings?' At the end of each teaching semester in each subject, we administered a voluntary, anonymous questionnaire (Table 1) to students requesting responses to Likert-items (on a scale of strongly disagree to strongly agree) and written comment to open-ended questions regarding their thoughts on the utility of the research ethics and integrity sessions. Although the questionnaire used in 2014 contained just two questions regarding research ethics and integrity (Table 1), in 2015 to probe what the students thought about the utility of these sessions in greater detail, we expanded the number of questions in the questionnaire to six.

Quantitative analysis of the Likert-item responses and the qualitative analysis of the open-ended responses revealed some interesting trends. Across both years and both subjects, students overwhelmingly agreed (including the cumulative agreed and strongly agreed responses) that they found the research ethics and integrity sessions useful (2014: 47.9% agreed compared with 39.7% neutral and 12.3% disagreed and strongly disagreed; 2015: 52.8% agreed, compared with 38.5% neutral and 8.8% disagreed and strongly disagreed; Figure 1). Additionally, in 2015 when we probed the students in greater detail about their thoughts on the utility of the sessions, the students again overwhelmingly agreed (including the cumulative agreed and strongly agreed responses) that these sessions provided them with:

1. a better understanding of why they were required to follow certain practices in the subject such as completing a Lab Notebook (57.8%);
2. a better understanding of the importance of research ethics and integrity in RCR (58.4%);

Table 1. Questions included in the voluntary, anonymous questionnaires deployed in 2014 and 2015.

Year	Question Number	Question	Type of Student Response
2014	Q1	I attended the Research Ethics and Integrity sessions and found them useful[A]	Desired response (on a scale of strongly disagree to strongly agree) selected on a computer scannable response sheet
2015	Q1	I attended the Research Ethics and Integrity sessions and found them useful*	As above
	Q2	After attending the Research Ethics and Integrity sessions I feel I now have a better understanding of why I am required to follow certain practices in the subject (such as completing a Lab Notebook)	As above
	Q3	After attending the Research Ethics and Integrity sessions I feel I now have a better understanding of their importance in conducting responsible research	As above
	Q4	After attending the Research Ethics and Integrity sessions I feel I now have a better understanding of what constitutes responsible research	As above
	Q5	After attending the Research Ethics and Integrity sessions I feel I now have a better understanding of who I can speak to if I have concerns about the responsible conduct of research	As above
2014 and 2015	Q6	If you attended the Research Ethics and Integrity Sessions, did you find them useful and interesting? Please comment........	Written response required in the space provided on the questionnaire

[A]The wording of Q1 in the 2014 and 2015 MIIM30016 questionnaires is as shown, however the wording of Q1 in the 2014 and 2015 MIIM30015 questionnaires was: I found the research ethics and integrity session(s) useful.

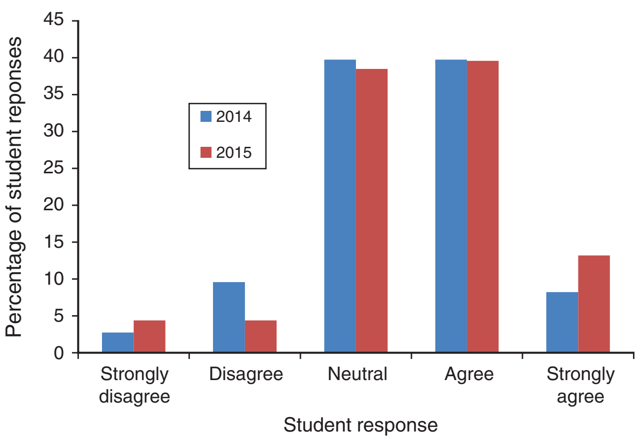


Figure 1. Graphical representation of the student responses (on a scale of strongly disagree to strongly agree) to Q1 of the 2014 and 2015 questionnaires in both MIIM30015 and MIIM30016. Across both subjects, 73 out of 96 students responded to Q1 in 2014 (overall response rate 76%) and 91 out of 140 students responded to Q1 in 2015 (overall response rate 65.0%). Students overwhelmingly agreed (including the cumulative agreed and strongly agreed responses) that they found the research ethics and integrity sessions useful (2014: 47.9% agreed; 2015: 52.8% agreed).

3. a better understanding of what constitutes responsible research (59.1%); and
4. a better understanding of who they could speak to if they had concerns about the responsible conduct of research (59.7%; Figure 2).

A review of the written comments (cumulative from both years and both subjects) returned by students in response to Question 6 (Table 1) also revealed many positive comments regarding the utility and interest-value of the sessions. Some of these comments have been supplied below:

- *Yes, it gave a good 'heads up' for things to be considered in future research tasks* – 2014, MIIM30016
- *Yes, topic was interesting. Hadn't* [sic] *it been for this session, I wouldn't have thought of the issues* – 2014, MIIM30016
- *Yes. They were useful and interesting. Learned many things that I wasn't aware of* – 2015, MIIM30016
- *I found them interesting because I hadn't learned it before* – 2015, MIIM30016

However, like most questionnaires, a few comments returned by the students indicated that some students had not appreciated the utility of these sessions, as demonstrated by:

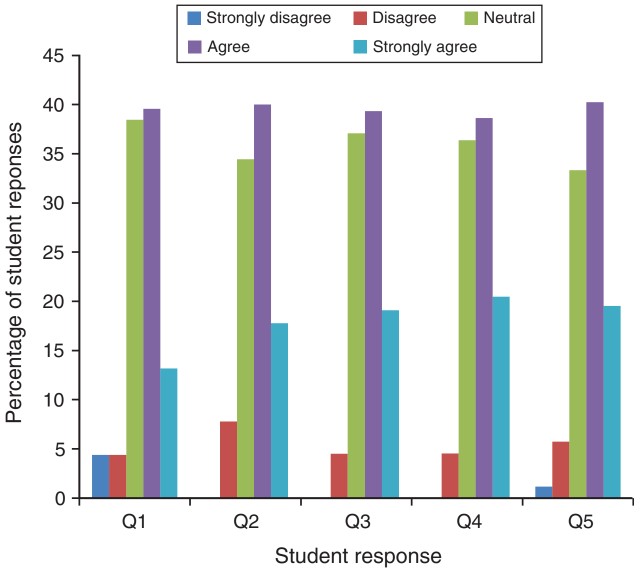


Figure 2. Graphical representation of the student responses (on a scale of strongly disagree to strongly agree) to the expanded question set used in the 2015 questionnaire. In 2015, a minimum of 87 students (maximum 92) out of 140 students across MIIM30015 and MIIM30016 responded to each question, equating to an overall response rate of 62.1%-65.7% (min-max.) per question. Students overwhelmingly agreed (including the cumulative agreed and strongly agreed responses) that these sessions provided them with: a better understanding of why they were required to follow certain practices in the subject such as completing a Lab Notebook (Q2, 57.8%); a better understanding of the importance of research ethics and integrity in RCR (Q3, 58.4%); a better understanding of what constitutes responsible research (Q4, 59.1%); and, a better understanding of who they could speak to if they had concerns about the responsible conduct of research (Q5, 59.7%).

- *...pointless* – 2015, MIIM30016
- *Not particularly useful as we are not researchers yet* – 2015, MIIM30016

These latter comments are particularly interesting (and troubling) to us as educators as they seem to highlight the fact that some students did not see the applicability of the information to them. Perhaps this is because, as third-year undergraduate students, they were not currently conducting or contributing to primary research, and/or most were not likely to be currently engaged or employed in STEM disciplines. Disappointingly though, such comments may also indicate that some students could not foresee the future applicability or utility of this knowledge to their potential employment in STEM disciplines (and perhaps even employment more broadly). To address this issue of applicability and relevance in future iterations of these subjects, greater emphasis will be placed on reminding the students that a basic, working knowledge of research ethics and integrity is extremely beneficial for the whole of their trajectory through STEM disciplines, from the educational to the vocational. And, for those students who choose to move away from STEM disciplines after graduation, a basic, working knowledge of research ethics and integrity and its importance in RCR is still highly beneficial in terms of producing more well-rounded graduates who can contribute to building a better informed general public.

Concluding remarks

In summary, the data herein demonstrate that the majority of students found the research ethics and integrity sessions useful, and that following these sessions, they had a greater appreciation and understanding of the responsible conduct of research and the importance for it. Although there is obvious room for improvement in the deployment of these sessions in future iterations of the subjects, overall we feel the incorporation of these sessions into our third year practical subjects has directly redressed a curriculum gap and yielded beneficial outcomes to many of our undergraduate students. Ultimately, it would be highly desirable if all undergraduate tertiary degrees in STEM disciplines included a curriculum component on relevant research ethics and integrity to provide an opportunity for students to attain a basic, requisite working knowledge prior to graduation.

Human ethics approval

This study was conducted under the approval of Human Ethics Application 1646306.1 at The University of Melbourne.

References

1. National Health and Medical Research Council (2007). http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/r39.pdf (accessed 10 February 2016).
2. Begley, C.G. *et al*. (2015) Institutions must do their part for reproducibility. *Nature* **525**, 25–27. doi:10.1038/525025a
3. Shaw, D.M. and Erren, T.C. (2015) Ten simple rules for protecting research integrity. *PLOS Comput. Biol.* **11**, e1004388. doi:10.1371/journal.pcbi.1004388
4. Alfredo, K. and Hart, H. (2011) The university and the responsible conduct of research: who is responsible for what? *Sci. Eng. Ethics* **17**, 447–457. doi:10.1007/s11948-010-9217-3
5. Kalichman, M.W. (2007) Responding to challenges in educating for the responsible conduct of research. *Acad. Med.* **82**, 870–875. doi:10.1097/ACM.0b013e31812f77fe
6. Kalichman, M. and Plemmons, D.K. (2007) Reported goals for responsible conduct of research courses. *Acad. Med.* **82**, 846–852. doi:10.1097/ACM.0b013e31812f78bf
7. Steneck, N.H. and Bulger, R.E. (2007) The history, purpose, and future of instruction in the responsible conduct of research. *Acad. Med.* **82**, 829–834. doi:10.1097/ACM.0b013e31812f7d4d
8. Mahmud, S. and Bretag, T (2013) Postgraduate research students and academic integrity: 'It's about good research training'. *J. High. Educ. Pol. Manag.* **35**, 432–443. doi:10.1080/1360080X.2013.812178
9. Bretag, T. *et al*. (2014) 'Teach us how to do it properly!' An Australian academic integrity student survey. *Stud. High. Educ.* **39**, 1150–1169. doi:10.1080/03075079.2013.777406
10. Heitman, E. *et al*. (2007) New graduate students' baseline knowledge of the responsible conduct of research. *Acad. Med.* **82**, 838–845. doi:10.1097/ACM.0b013e31812f7956
11. Marocco, D.A. (2000) Biology for the 21st Century: The Search for a Core. *Am. Biol. Teach.* **62**, 565–569. doi:10.1662/0002-7685(2000)062[0565:BFTCTS]2.0.CO;2
12. Bowater, L. and Wilkinson, M. (2012) Twelve tips of teaching (legal and ethical aspects of) research ethics/responsible conduct of research. *Med. Teach.* **34**, 108–115. doi:10.3109/0142159X.2011.588738

13. Bulger, R.E. and Heitman, E. (2007) Expanding responsible conduct of research instruction across the University. *Acad. Med.* **82**, 876–878. doi:10.1097/ACM.0b013e31812f7909
14. Irish Universities Association (2015) National policy statement on Ensuring Research Integrity in Ireland. http://www.iua.ie/research-innovation/research-integrity/ (accessed 15 February 2016).

Biographies

Dr Karena Waller is a Senior Lecturer in the Department of Microbiology and Immunology at The University of Melbourne and Chair of the ASM VIC Branch. Karena completed her PhD and subsequent post-doctoral and fellowship positions in malaria research at Monash University and Albert Einstein College of Medicine (New York, USA) before taking up an Academic Teaching-focused position at The University of Melbourne in 2010. Karena was the recipient of an ASM Teachers Travel Award (2010) and a Melbourne Medical School Early Career Development Teaching Award (2014).

Dr Daniel Barr is the Associate Director of the Office for Research Ethics and Integrity at The University of Melbourne. Dan graduated with a PhD in immunology from The University of Melbourne. Dan educates students, researchers and administrators, and manages processes and provides advice for research misconduct investigations. He is passionate about research integrity and research about research, particularly understanding the role of policy and cultures of research integrity.

Dr Paul Taylor is the Director of the Office for Research Ethics and Integrity at The University of Melbourne. Paul graduated with a PhD in microbiology from The University of Melbourne and has been working in research management for 13 years. At OREI, Paul leads the development and implementation of research ethics and integrity policy, education and training and support.

Dr Odilia Wijburg is a Senior Lecturer in the Department of Microbiology and Immunology at The University of Melbourne. She is an internationally recognised expert on the immunobiology of mucosal bacterial infections and has over 15 years' experience as a senior research fellow. She changed careers in 2013 when she was appointed as Academic Teaching-focused senior lecturer and was the recipient of Melbourne Medical School 2014 Teaching Award.

The iGEM competition: research-led teaching in microbiology

Nicholas V Coleman

School of Life and Environmental Sciences
Building G08, Maze Crescent
University of Sydney
Darlington, NSW 2006, Australia
Tel: +61 2 9351 6047
Fax: +61 2 9351 5858
Email: nicholas.coleman@sydney.edu.au

The International Genetically Engineered Machine Competition (iGEM) is a global science fair in synthetic biology (SynBio). The relatively new discipline of SynBio is distinguished from 'genetic engineering' in its more systematic approach, and its focus on understanding life via creation, rather than dissection[1]. Microbiology is central to SynBio, which usually relies on *Escherichia coli* or yeast as model systems.

The iGEM competition is structured around teams of undergraduates, who compete to make the most novel and/or useful genetically modified organisms (GMOs). The teams work for 6 months in the lab, and present their work at the iGEM Jamboree (Boston, USA) in October. The competition now includes approximately 250 teams from around the world, including five from Australia (Macquarie University, University of Sydney, University of New South Wales, University of Melbourne, Australian National University). iGEM projects are diverse, and reflect the astounding possibilities of SynBio, such as biocomputers, bioplastics, biosensors, and much more. Perhaps the most famous example is 'bacterial photography', in which an *E. coli* strain was created that deposited a black pigment in response to light[2].

iGEM offers a complete and authentic scientific experience to undergraduates. iGEM promotes a culture of open source science and transparency of research. All teams publish their research in an online wiki that is open to the public, and all new genetic constructs generated are freely shared via the Parts Registry[3]. The skills needed for a good team include microbiology, molecular biology, biochemistry, mathematical modelling, web design and educational outreach, and thus teams typically consist of students from several different degree programs, who must learn to work together.

I have been the supervisor of iGEM teams from The University of Sydney for the past three years. I believe this competition offers a unique research-led teaching opportunity, which develops graduate attributes which are often neglected in our core teaching program, as summarised in the following sections.

Inquiry and problem solving

Most undergraduate practical classes in microbiology involve experiments where the outcome is known prior to starting work. While such practical classes are useful for teaching important techniques, they are not reflective of a real scientific investigation. In the iGEM competition, each team is aiming to construct new GMOs with novel properties, and although much effort goes into design and modelling, ultimately the outcomes are not predictable, necessitating troubleshooting, problem-solving, improvisation, and critical reading of the literature to achieve the desired goals.

As an example, our 2013 team attempted to reconstruct a pathway for biodegradation of 1,2-dichloroethane in *E.coli*. Only four genes are required, and on paper, it seemed simple to move these genes into a plasmid in *E.coli*. However, about half-way through our project, the team realised that one enzyme required an unusual cofactor not found in *E. coli*, necessitating a rapid re-think and redesign of our plasmid construct. We learned an important lesson that year, i.e. read the literature thoroughly before getting into the lab!

Communication

iGEM teams need to communicate their results in several different formats, some of which are 'non-standard' in microbiology education. The most important document that the teams generate is a web page (wiki). This webpage is open to the public, and is maintained in perpetuity by the iGEM organisation; as a result, the students feel that they are part of the global scientific community, and that their work 'matters' – this sense of belonging and significance is central to a career as a professional scientist, but is not commonly experienced by undergraduates. Please visit our USyd iGEM wiki pages to see some examples[4–6].

 10.1071/MA16028

Teams must also be able to effectively communicate their work to the competition judges and to other teams as talks and posters. The intensely competitive environment of the jamboree leads to outstanding performances in the talks, with their engaging style, professional use of modern technology, and creative thinking, including the use of theatre, costumes, comedy, time-lapse animations, etc.

iGEM teams must engage with the wider community, and express complex concepts in simple language; such skills are not usually taught in undergraduate science degrees. Our iGEM students have helped to run hands-on microbiology and molecular biology workshops for school students, and they have participated in Science Week activities at the Australian Museum. We have collaborated in the setup of a community-based lab[7], which aims to enable public access to SynBio technologies. An analysis of our 2015 outreach activities is shown in Figure 1; note the use of diverse media (newspaper, radio, social media, in-person activities) that enabled us to reach out and engage with diverse age-groups.

Personal and professional responsibility

Graduate attributes relating to ethical conduct are critical for employers, but are only very rarely addressed in undergraduate curricula. iGEM is unique in its focus on safety and ethics, which can be quite confronting for students who have not had to think about these issues before. All teams in the competition have to document in considerable detail the biosafety issues relating to their project, and how any risks will be managed; this is especially important since almost all iGEM projects revolve around the creation of new GMOs.

Our USyd iGEM teams undergo extensive safety training before they are allowed into the lab, and they assist in preparation of documents for our Institutional Biosafety Committee. Our teams have embraced the bioethics issues, merging this with their outreach activities by running a writing competition aimed at high school students, which encourages them to think critically about the impact of genetic technologies on society[8].

Conclusions

The iGEM competition develops valuable graduate attributes and skills which are often neglected in science undergraduate degrees, such as inquiry-based problem solving, communication, professional responsibility, fundraising, outreach, and media engagement. I would also add 'resilience' to this list, since these students learn to grapple with real-world problems, which require repeated efforts and many failures before eventual success (if any). I believe these attributes and skills greatly enhance the employability of graduates from this program. Informal feedback from USyd students indicates that all believed iGEM was a valuable part of their education, and half indicated that the iGEM experience was *the most* valuable part of their university education to date. My lab will once again host an iGEM team in 2016; I encourage you to get involved, and join our growing local synthetic biology community.

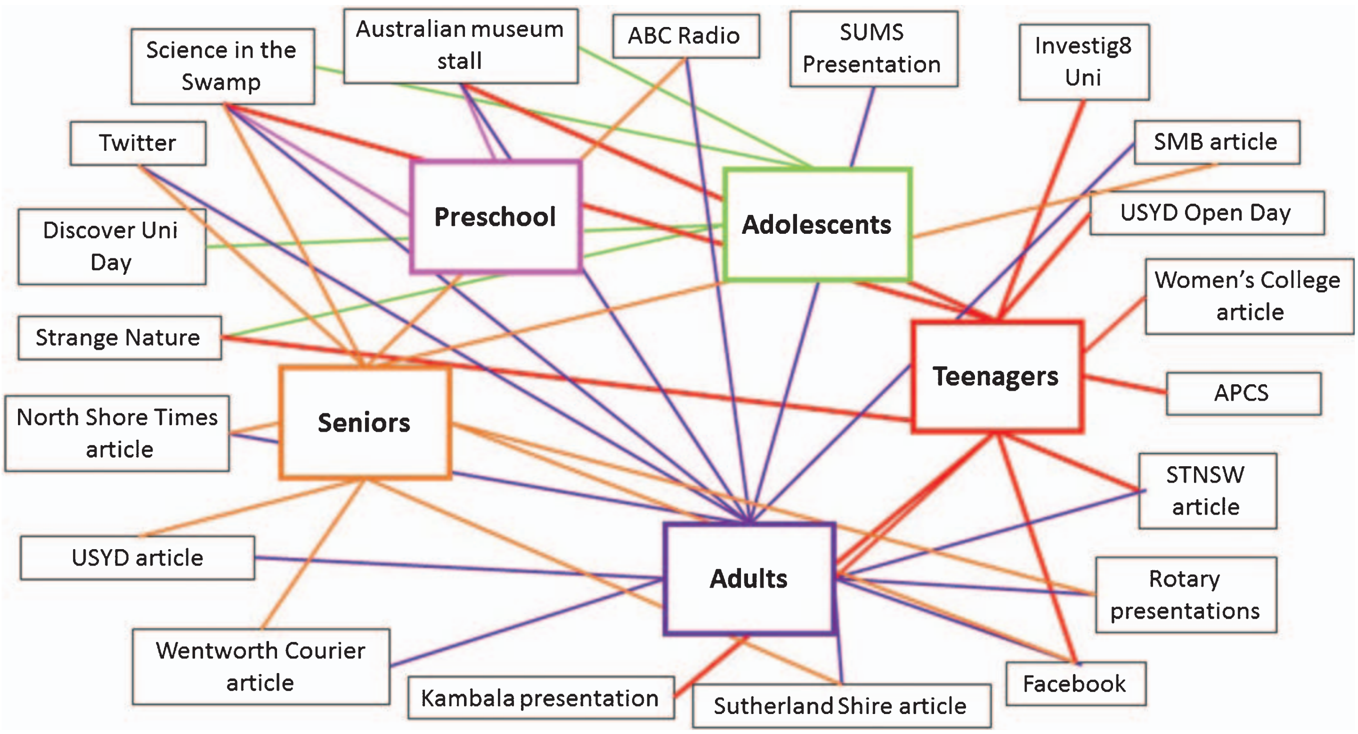


Figure 1. Graphical representation of age-group targeting of USyd iGEM team science outreach activities in 2015. Diagram prepared by Elizabeth Richardson.

Acknowledgements

Thanks to all the members of USyd iGEM teams from 2013–2015 for their enthusiasm and effort: Robbie Oppenheimer, Andrew Tuckwell, Desmond Li, Vivian Li, Shuravi Paul, Cyril Tang, Hugh Ford, James Bergfield, Rokiah Alford, Abigail Sison, Jeanne Zhang, Andy Bachler, Callum Grey, Tom Geddes, Lizzie Richardson, Harrison Steel, Mark Somerville, Gaia Hermann, Sandi Bo, Mahiar Mahjoub.

References

1. Levskaya, A. *et al*. (2005) Synthetic biology: engineering *Escherichia coli* to see light. *Nature* **438**, 441–442. doi:10.1038/nature04405
2. Shetty, R. *et al*. (2011) Assembly of biobrick standard biological parts using three antibiotic assembly. In: *Synthetic Biology, Pt B: Computer Aided Design and DNA Assembly*. (Voigt, C., ed), pp. 311–326, Elsevier Press.
3. http://parts.igem.org
4. http://2013.igem.org/Team:SydneyUni_Australia
5. http://2014.igem.org/Team:USyd-Australia
6. http://2015.igem.org/Team:Sydney_Australia
7. http://www.foundry.bio
8. http://www.strangenature.org

Biography

Dr Nick Coleman is a Senior Lecturer in Microbiology at the University of Sydney. Nick teaches 2nd and 3rd year microbiology to students in science, medical science, and agriculture degree programs. His research interests include bioremediation, biocatalysis, bacterial evolution, and synthetic biology. He is a member of the ASM NSW/ACT Branch Committee.

Using undergraduate research to develop transferable skills for the modern workforce

Jack TH Wang

School of Chemistry and Molecular Biosciences
The University of Queensland
Brisbane, Qld 4072, Australia
Tel: +61 7 3365 4611
Fax: +61 7 3365 4273
Email: t.wang1@uq.edu.au

In the increasingly competitive global knowledge marketplace, Australian tertiary educators are looking to enrich their program offerings by providing authentic learning experiences for their students. In the biological sciences, this authenticity is best represented by hands-on inquiry and laboratory experimentation, often within the context of research internships. Authentic Large-Scale Undergraduate Research Experiences (ALUREs) aim to broaden the scope of these learning experiences by embedding research into coursework activities accessible by all students within the program. These experiences can promote learning gains in laboratory, analytical, and critical thinking skills, providing students with a transferable skillset applicable to many career paths across the science sector.

In 1998, the Boyer Commission on Educating Undergraduates in the Research University published a landmark report on the reinvention of undergraduate education. The report highlighted the emphasis on transmitting large volumes of theoretical knowledge within traditional science education, which often took precedence over practical training in inquiry-driven processes used by professional scientists. The proposed solution was to make research-based learning the standard, which has been shown to further stimulate student interest when compared to didactic instruction[1], and promote engagement and deep learning through active problem-solving[2]. Since the publication of the Boyer Commission report, undergraduate inquiry and research opportunities have increasingly been embedded in university curricula[3], spanning across a number of disciplines and higher education settings[4]. This movement has been further solidified by the Vision and Change in Undergraduate Biology Education program organised through the American Association for the Advancement of Science (AAAS) and the National Science Foundation (NSF).

Within the context of Australian higher education, the 2008 Bradley review placed significant value on student engagement in critical inquiry, citing access to these learning activities as strategic goals for all publicly funded tertiary institutions[5]. This view was further supported by the Learning and Teaching Academic Standards project conducted by the Australian Learning and Teaching Council (ALTC) in 2011[6] as well as the Office for Learning and Teaching's (OLT) Good Practice Guides for Science[7], all of which cite 'Inquiry and problem solving' as a key threshold learning outcome for Australian science graduates. The importance of these graduate attributes is further reinforced by the perceptions of STEM employers, who rank problem-solving and critical thinking as highly sought after graduate skills[8].

Undergraduate research provides training in scientific inquiry

The setting most amenable to research-based learning in large undergraduate science courses is the practical laboratory classroom – the physical site where scientific experimentation is conducted. Laboratory classes also operate in group-work settings, which enhance collaborative skills[9] and facilitate active learning[10]. There has been a shift away from the 'tedious', and 'repetitive' cookbook practical classes[11,12], and many programs have adopted student-driven inquiry within the undergraduate laboratory[1,13–20]. Inquiry-based learning classes can focus on an authentic research question and be implemented across a continuum of student responsibility, ranging from guided inquiry on specific research questions through to open-ended inquiry involving experimental design[14]. This inquiry-based learning continuum allows educators to scaffold the complexity of the research question according to prior student knowledge, and has been effective in driving student engagement across both secondary and tertiary education[13]. Furthermore, there has been a positive correlation between undergraduate research and student interest in scientific careers[13,14], as well as improved student retention into further research programs[21,22].

Developing authentic research projects for inexperienced undergraduate students can be both resource and time-intensive, and is therefore typically reserved for a small number of intrinsically motivated high-achieving students via an apprenticeship-style model[23]. To improve student access to undergraduate research opportunities, the ALTC and OLT have funded a number of national leadership grants and fellowships to investigate and support undergraduate research[24–26]. Building on these previous findings, our UQ team launched an OLT leadership project in 2012 to support Australian academics in developing Authentic Large-Scale Undergraduate Research Experiences – the ALURE project.

ALURE: Authentic Large-Scale Undergraduate Research Experiences

An ALURE is characterised by student-driven investigations into research questions in hands-on undergraduate classes that can simultaneously accommodate large numbers of students (groups of 50–500 students). If developed and implemented effectively, an ALURE can provide the benefits of one-on-one research internships through normal coursework activities for hundreds of students, many of who would otherwise not engage in undergraduate research[27]. The real-world nature of research is a key motivator for student engagement in ALUREs, and in many cases their learning outcomes have directly contributed to research publications[13,28,29]. Effective scaffolding of the learning activity is also essential, as the research question needs to be investigated using laboratory techniques that are cost-effective, scalable for large classes, and subject to iteration and optimisation through student-driven inquiry[27].

At The University of Queensland, ALURE modules have been systematically embedded throughout the microbiology major as part of the three year undergraduate Bachelor of Science degree. In second year, microbiome samples from 400–500 students are crowd-sourced each semester, and used in an ALURE project investigating microbial composition across different human body sites using culture dependent and independent identification methods[30]. Following on to third year coursework, students apply techniques in DNA analysis and protein expression in an immersive 5-week ALURE to isolate and clone bacterial vaccine antigens against Uropathogenic *E. coli*[31]. Participating in these research experiences as a normal part of their undergraduate coursework has impacted hundreds of students each semester at UQ, consistently resulting in learning-gains in key skills following ALURE modules.

Figure 1 illustrates statistically significant increases in student confidence across a range of scientific skills following completion of the third year microbiology research experience at UQ. Students reported increased confidence levels in vocational laboratory skills (e.g. using a plasmid map, designing PCR primers, DNA gel electrophoresis), as well as generic skills in numeracy (graphing, calculations, measurements) and problem solving (planning experiments, choosing between experimental strategies, and data formatting). These perceptions were further corroborated by our previous findings that revealed the high quality of student performance in

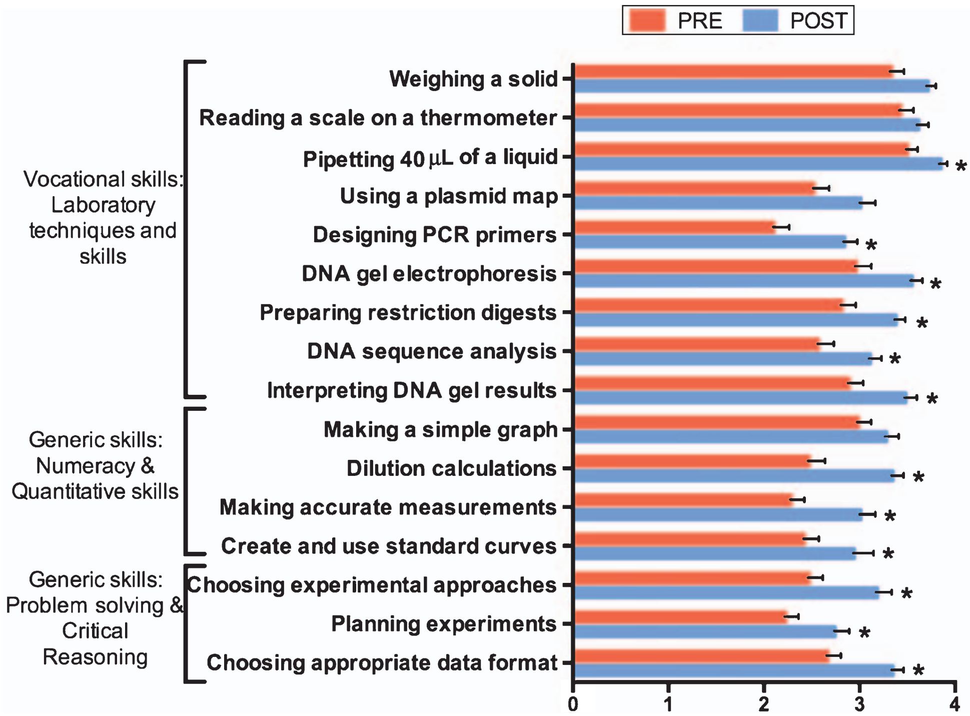


Figure 1. Research experiences promote student learning gains in vocational and generic transferable skills. Pre and post course survey results following completion of an undergraduate research experience in a third year Microbiology course at The University of Queensland in 2012 (n = 41, 30% survey completion rate). Bars represents mean ± SEM of student confidence on a 0-4 scale (0 = Do not know how to do; 1 = Not confident; 2 = Need Practice; 3 = Confident; 5 = Highly Confident). * denotes $P < 0.05$ using a two-tailed Mann–Whitney U-test.

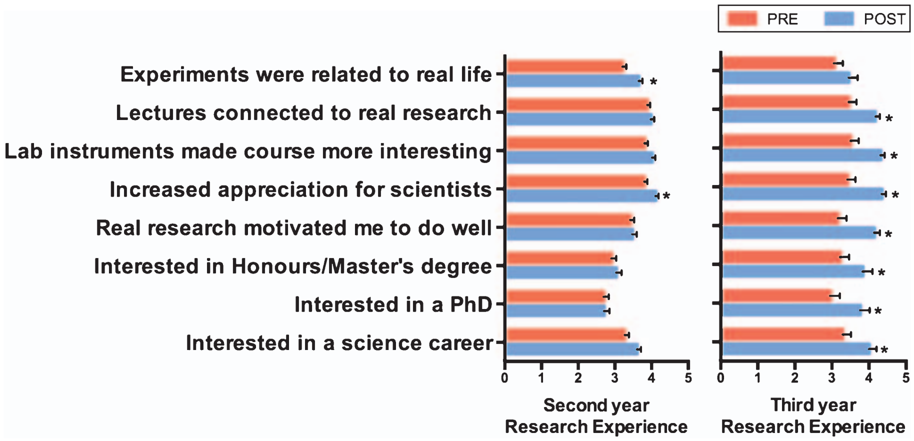


Figure 2. Undergraduate research influences students' educational and career goals. Pre and post course survey results following completion of undergraduate research experiences in second ($n = 119$, 28% survey completion rate) and third year ($n = 38$, 30% survey completion rate) Microbiology courses at The University of Queensland in 2012. Bars represents mean ± SEM of student agreement with statements on a 0-5 scale (0 = Strongly Disagree; 1 = Disagree; 2 = Barely Disagree; 3 = Barely Agree; 4 = Agree; 5 = Strongly Agree). * denotes $P < 0.05$ using a two-tailed Mann–Whitney *U*-test.

laboratory and reporting assessment tasks as part of second and third year ALURE modules[30,31]. The range of learning gains observed following ALURE participation align with graduate attributes desired by STEM employers[8] – improvement in practical competencies for pathology and research laboratories, and generic transferable skills applicable to workplaces both in and out of science[30–32].

Consistent with previous findings, we have also observed a positive shift in student attitudes towards scientific career pathways following their participation in undergraduate research experiences[13,14]. Pre and post survey analyses of second and third year UQ microbiology students revealed increased motivation and appreciation of science, and interest in pursuing postgraduate study and careers in science following the completion of an ALURE (Figure 2). Notably, these shifts in perception were much more evident in third year than second year ALURE students, perhaps indicative of smaller class sizes and increased focus on post-graduation prospects in the final year of undergraduate study. These trends could also signify the success of progressive scaffolding in ALURE activities across second and third year courses at UQ, which gradually increase the cognitive load required for student-driven inquiry while minimising extraneous cognitive burden[33]. Given the impact of engaging with undergraduate research on student retention within science programs[21,22], the long-term value of exposure to research-based learning early in undergraduate education should not be underestimated[34].

Future directions and conclusions

Throughout 2012–2015, the ALURE project has documented 21 different ALUREs developed by 39 academics at Australian tertiary institutions, spanning across Biochemistry, Physiology, Chemistry, Ecology, Genetics, Biology and Microbiology. Using a mixed-methods evaluation strategy of student surveys and focus-group interviews, the ALURE team consistently reported student-learning gains in scientific skills following the completion of ALURE modules[30,31], with higher gains observed in critical thinking and problem-solving skills when compared to traditional practical modules[32]. Undergraduate research is a high-impact activity that can be of great benefit to students, and the ALURE project has demonstrated that it can be a valuable addition to the instructor's toolkit to bolster student-learning outcomes in transferable skills.

To facilitate the development and implementation of new ALUREs to grow our community of practice, the project team has developed assessment frameworks, implementer's checklists, ALURE exemplars, and laboratory manuals, which can be accessed via the project website (http://alure-project.net).

Acknowledgements

The ALURE project was funded by the Australian Government Office for Learning and Teaching, with the project team being comprised of A/Prof Susan Rowland, A/Prof Gwen Lawrie, Dr Kirsten Zimbardi, Dr Paula Myatt, Dr Jack Wang, and Peter Worthy. The study has been cleared with the UQ human ethics committee in accordance with NHMRC guidelines (Project number 2013000073).

References

1. Lord, T. and Orkwiszewski, T. (2006) Moving from didactic to inquiry-based instruction in a science laboratory. *Am. Biol. Teach.* **68**, 342–345. doi:10.1662/0002-7685(2006)68[342:DTIIIA]2.0.CO;2
2. Schraw, G. *et al*. (2001) Increasing situational interest in the classroom. *Educ. Psychol. Rev.* **13**, 211–224. doi:10.1023/A:1016619705184
3. Kenny, S.S. (2003) New Challenges in a Post-Boyer World. *Am. Sci.* **91**, 103. doi:10.1511/2003.2.103
4. Healey, M. and Jenkins, A. (2009) Developing undergraduate research and inquiry. *The Higher Education Academy*.

5. Bradley, D. *et al*. (2008) Review of Australian higher education: final report [Bradley review]. Australian Government DEEWR, Canberra.
6. Jones, S. *et al*. (2011) Science Learning and Teaching Academic Standards Statement. Australian Learning and Teaching Council, Sydney.
7. Kirkup, L. and Johnson, L. (2013) Threshold Learning Outcome 3 – Inquiry and Problem-solving. *Office for Learning and Teaching Good Practice Guide (Science)*.
8. Rayner, G. and Papakonstantinou, T. (2015) Employer perspectives of the current and future value of STEM graduate skills and attributes: an Australian study. *Journal of Teaching and Learning for Graduate Employability* **6**, 100–115.
9. Burron, B. *et al*. (1993) The effects of cooperative learning in a physical science course for elementary/middle level preservice teachers. *J. Res. Sci. Teach.* **30**, 697–707. doi:10.1002/tea.3660300708
10. Wood, W.B. (2009) Innovations in teaching undergraduate biology and why we need them. *Annu. Rev. Cell Dev. Biol.* **25**, 93–112. doi:10.1146/annurev.cellbio.24.110707.175306
11. Wilson, J. (2008) Report: 1st year practicals – their role in developing future bioscientists. *Centre for Bioscience*.
12. Collis, M., Gibson, A., Hughes, I., Sayers, G., Todd, M. (2008) The student view of 1st year laboratory work in the biosciences – score gamma? *Bioscience Education* **11**.
13. Hanauer, D.I. *et al*. (2006) Inquiry learning. Teaching scientific inquiry. *Science* **314**, 1880–1881. doi:10.1126/science.1136796
14. Weaver, G.C. *et al*. (2008) Inquiry-based and research-based laboratory pedagogies in undergraduate science. *Nat. Chem. Biol.* **4**, 577–580. doi:10.1038/nchembio1008-577
15. Bellin, R.M. *et al*. (2010) Purification and characterization of Taq polymerase: A 9-week biochemistry laboratory project for undergraduate students. *Biochem. Mol. Biol. Educ.* **38**, 11–16. doi:10.1002/bmb.20352
16. Walter, J.D. *et al*. (2010) Expression, purification, and analysis of unknown translation factors from *Escherichia coli*: a synthesis approach. *Biochem. Mol. Biol. Educ.* **38**, 17–22. doi:10.1002/bmb.20354
17. Ruller, R. *et al*. (2011) A practical teaching course in directed protein evolution using the green fluorescent protein as a model. *Biochem. Mol. Biol. Educ.* **39**, 21–27. doi:10.1002/bmb.20430
18. Girón, M.D. and Salto, R. (2011) From green to blue: site-directed mutagenesis of the green fluorescent protein to teach protein structure-function relationships. *Biochem. Mol. Biol. Educ.* **39**, 309–315. doi:10.1002/bmb.20467
19. Drew, J.C. and Triplett, E.W. (2008) Whole genome sequencing in the undergraduate classroom: outcomes and lessons from a pilot course. *J. Microbiol. Biol. Educ.* **9**, 3–11. doi:10.1128/jmbe.v9.89
20. Boyle, M.D. (2010) 'Shovel-ready' sequences as a stimulus for the next generation of life scientists. *J. Microbiol. Biol. Educ.* **11**, 38–41. doi:10.1128/jmbe.v11i1.133
21. Hathaway, R.S. *et al*. (2002) The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study. *J. Coll. Student Dev.* **43**, 614–631.
22. Nnadozie, E. *et al*. (2001) Undergraduate research internships and graduate school success. *J. Coll. Student Dev.* **42**, 145–156.
23. Zimbardi, K. and Myatt, P. (2014) Embedding undergraduate research experiences within the curriculum: a cross-disciplinary study of the key characteristics guiding implementation. *Stud. High. Educ.* **39**, 233–250. doi:10.1080/03075079.2011.651448
24. Jewell, E. and Brew, A. (2010) Undergraduate research experience programs in Australian universities. Australian Learning and Teaching Council, Canberra.
25. Kirkup, L. (2013) Inquiry-oriented learning in science: transforming practice through forging new partnerships and perspectives. Australian Learning and Teaching Council, Sydney.
26. Howitt, S. *et al*. (2014) Teaching research – evaluation and assessment strategies for undergraduate research experiences (TREASURE). Australian Government Office for Learning and Teaching, Sydney.
27. Auchincloss, L.C. *et al*. (2014) Assessment of course-based undergraduate research experiences: a meeting report. *CBE Life Sci. Educ.* **13**, 29–40. doi:10.1187/cbe.14-01-0004
28. Leung, W. *et al*. (2010) Evolution of a distinct genomic domain in Drosophila: comparative analysis of the dot chromosome in *Drosophila melanogaster* and *Drosophila virilis*. *Genetics* **185**, 1519–1534. doi:10.1534/genetics.110.116129
29. Pope, W.H. *et al*. (2011) Expanding the diversity of mycobacteriophages: insights into genome architecture and evolution. *PLoS One* **6**, e16329. doi:10.1371/journal.pone.0016329
30. Wang, J.T. *et al*. (2015) Do you kiss your mother with that mouth? An authentic large-scale undergraduate research experience in mapping the human oral microbiome. *JMBE* **16**, 50–60. doi:10.1128/jmbe.v16i1.816
31. Wang, J.T.H. *et al*. (2012) Immersing undergraduate students in the research experience. *Biochem. Mol. Biol. Educ.* **40**, 37–45. doi:10.1002/bmb.20572
32. Rowland, S.L. *et al*. (2012) Is the undergraduate research experience (URE) always best? The power of choice in a bifurcated practical stream for a large introductory biochemical class. *Biochem. Mol. Biol. Educ.* **40**, 46–62. doi:10.1002/bmb.20576
33. Leppink, J. and van den Heuvel, A. (2015) The evolution of cognitive load theory and its application to medical education. *Perspect. Med. Educ.* **4**, 119–127. doi:10.1007/s40037-015-0192-x
34. Harrison, M. *et al*. (2011) Classroom-based science research at the introductory level: changes in career choices and attitude. *CBE Life Sci. Educ.* **10**, 279–286. doi:10.1187/cbe.10-12-0151

Biography

Dr Jack Wang is a lecturer and convenor of the microbiology major at The University of Queensland. His work revolves around undergraduate research and technology-enabled assessment in science education, for which he received a Citation for Outstanding Contribution to Student Learning from the Australian Awards for University Teaching in 2015.

Future issues of *Microbiology Australia*

September 2016: Diseases of Aquaculture

Guest Editor: Nicky Buller

November 2016: Microbiology of Travel

Guest Editors: Ipek Kurtböke and Laura Bowater (joint issue with UK's Microbiology Society)

March 2017: Bat-associated Diseases

Guest Editor: Glenn Marsh

May 2017: Industrial Microbiology

Guest Editors: Ian Macreadie and Ipek Kurtböke

Enhancing employability through group work

M Josie Lategan

Department of Chemistry and Biomolecular Science
Faculty of Science and Engineering
Building F7B
Macquarie University
Macquarie Park
NSW 2091, Australia
Tel: +61 2 9850 9684
Email: maria.lategan@mq.edu.au

Graduates are expected to demonstrate a wide set of soft skills in order to compete successfully in the current job market. Evidence of effective skills in teamwork, organisation, time management and interpersonal relationships are ultimately very important in determining levels of success as they show how one leads, relates and works along with other people. Experiencing leadership roles in the microbiology laboratory classes encouraged the development of soft skills and provided examples to support job applications.

Employers often seek to hire staff that will work well in a team and be able to communicate effectively with colleagues and customers. It is important therefore to create opportunities to develop strong and effective interpersonal skills alongside scientific skills. For example, 'I completed all my assignments on time'. Would this statement serve as evidence of effective organisation and time management skills? Or would 'I worked in a group' infer that teamwork had been effective and active listening, decision-making, emotional intelligence, social awareness, leadership – the varied components that make up interpersonal skills – had been developed? Guides on addressing selection criteria in job applications[1,2] would suggest otherwise.

Herein is a case study where principles of Process Orientated Guided Inquiry Learning (POGIL)[3,4], implemented in the microbiology laboratory learning environment encouraged the development of soft skills. Students groups (3/group chosen at random) were empowered to work in a self-directed, cooperative exploration, instilling a sense of ownership, accountability and responsibility for the work that enhanced critical thinking and problem-solving skills[5]. The core element that leads to development of soft skills however was in the allocation of main and auxiliary roles[6,7] (Table 1) to the group. The roles, managed by the group are rotated weekly over a 5-week period, providing each student the opportunity to experience all leadership roles (with one role at least twice) over the lifetime of the project. The roles enforce active and effective interactions between the team members leading to substantial gain in social skills[3,8] likely to maximise employability.

A fast-paced learning environment is implemented to keep the groups focused and tutors meet immediately after each laboratory session to discuss and moderate all aspects of group/student performance including whether aspects of interpersonal skills (for example decision-making, organisation, differences of opinion, etc.) influenced the delivery of expected project outcomes for the session. Feedback was constructed to identify both strong and weak points of each group, including its individual members and to recommend areas for improvement. See an excerpt of feedback relevant to developing soft skills:

> *The Manager must revise his facilitation skills as tutors observed that the Recorder for the group was left out of the group's discussion. Recorder, the onus is also on you to signal that your opinion should be considered. You had some very good ideas but these were lost to the other members of the group.*

The group-specific feedback therefore provided each member with the opportunity to identify and target personal soft skill areas requiring further development. For example, a group achieving only part of the expected weekly outcome could reflect a Manager, which might have delegated an inappropriate time frame for completion of a task i.e. the team member's capabilities in relation to the complexity and time required to complete the task were not considered effectively. Therefore, this manager needs to develop aspects of his/her organisation/time management skills further; a Recorder submitting a progress report that is dissimilar or contradicts the content delivered by the Presenter reflects poor communication links between the team members, inferring the lack of cohesiveness and transparency within the group; natural discord due to differences in opinion/personality will force the group to reflect in unity and the ability of the group to develop and implement interpersonal strategies that allow them to work in harmony, or at least in agreement, becomes a measure of the success of the group in progressively delivering project outcomes. Consequently, each group progressed steadily, with each member becoming increasingly aware of the importance of investing in effective interpersonal skills that form the mainstay of successful work/social life interactions.

10.1071/MA16029

Table 1. Components of Main and Auxiliary roles designed to encourage development of soft skills.

Week	Presenter	Manager	Recorder
Main role	Designs and presents the weekly seminar	Manages time for activities; leads and delegates; ensures outcomes are achieved. Manages roles of group members. Facilitates discussion; reviews and manages feedback.	Records all laboratory work in the project folder. Prepares weekly progress report.
Aux role	Participates in laboratory work; reflects and contributes to discussion; maintains active communication links with Recorder.	Participates in laboratory work; reflects and contributes to discussion; supports the design of the weekly seminar. Reviews project folder.	Participates in laboratory work; reflects and contributes to discussion; maintains active communication links with Presenter.

Whilst Learner Experience of the Unit surveys revealed an overwhelming preference for empowered self-directed group work in learning, interpersonal interactions, as lifelong learning outcomes are difficult to measure[9,10]. Therefore we sought comments from our microbiology graduates to determine whether their experience of group work in our laboratory classes influenced both their personal development and the outcome of job applications.

- *I enjoyed being a manager, presenter and recorder. I had to take charge of the group but I worked hard to concede that leadership to better work as a team and allow another's ideas to drive the direction of the group.*

- *The projects allowed us to explore and understand cultural differences and effectively communicate with one another. This has allowed me to work well in a team environment, both socially and through my work life. When attending interviews I now have firm examples of when I have applied these skills.*

- *When going for the job, I spoke about how we worked in groups to solve a case study or task in a certain time frame; how these exercises have enhanced my understanding of working in a team where everyone has different ideas and personalities and how to adjust to those differences. I got the job!*

- *When applying for both my current and most recent jobs, I used the microbiology projects as examples of how I met the selection criteria. Both jobs demanded demonstrated ability to work as a part of a multidisciplinary team, and the ability to organise and prioritise workload. Completing these projects enhanced both of these skills, and I was particularly grateful that I could use specific examples of my university experience to meet the job criteria. I was successfully employed in both of these positions, and I believe the knowledge gained was invaluable.*

The view of an industry representative commenting on the soft skill capability of our graduates is also included:

- *The microbiology students from Macquarie University have shown good aptitude for the work. They are able to communicate with referring practitioners, patients and staff at all levels and adapt quickly to most situations. I feel confident that that we will be able to offer more students employment in the future now that we are confident of the caliber of students.*

The above comments would suggest that implementing components to encourage the development of soft skills at undergraduate level could be as important in maximising employability as achieving the scientific skills required to do the job.

Acknowledgements

Thank you to past students and the industry representative for the permission to include their comments in this article.

References

1. Addressing selection criteria: a guide for professional staff. Careers and Employer Liaison Centre. http://www.flinders.edu.au (accessed 14 March 2016).
2. Addressing selection criteria. Career Service. http://www.careers.mq.edu.au (accessed 14 March 2016).
3. Hanson, D. (2006) Instructors guide to process-oriented guide inquiry learning. *Pacific Crest, Lisle* **IL**, 20–30.
4. Hale, D. *et al*. (2009) Designing process oriented guided inquiry activities: a new innovation for marketing class. *Mark. Educ. Rev.* **19**, 73–80. doi:10.1080/10528008.2009.11489063
5. Eberlein, T. *et al*. (2008) Pedagogies of engagement in science: a comparison of PBL, POGIL, and PLTL. *Biochem. Mol. Biol. Educ.* **36**, 262–273. doi:10.1002/bmb.20204
6. Farrell, J. *et al*. (1999) A guided inquiry general chemistry course. *J. Chem. Educ.* **76**, 570–574. doi:10.1021/ed076p570
7. Bailey, C. *et al*. (2012) Learning transferrable skills in large lecture halls: implementing a POGIL approach in biochemistry. *Biochem. Mol. Biol. Educ.* **40**, 1–7. doi:10.1002/bmb.20556
8. Minderhout, V. *et al*. (2007) Lecture – free biochemistry. *Biochem. Mol. Biol. Educ.* **35**, 172–180. doi:10.1002/bmb.39
9. McGarrah, M.W. (2015) Lifelong learning skills for college and career readiness: considerations for education policy. http://www.ccrscenter.org (accessed 14 March 2016).
10. Prince, M. (2004) Does active learning work? A review of the research. *J. Eng. Educ.* **93**, 223–231. doi:10.1002/j.2168-9830.2004.tb00809.x

Biography

Dr M Josie Lategan is currently an honorary academic at Macquarie University having lectured Microbiology at this university from 2009 to 2015. Her research interests are in both the medical and environmental fields of microbiology. She also holds a special interest in microbiology education, particularly in developing active learning techniques.

Providing an authentic experience of laboratory accreditation processes in a final year microbiology unit

Michael Phillips

School of Science and Health
Western Sydney University
Richmond Campus
NSW 2753, Australia
Tel: +61 2 4570 1315
Email:
m.phillips@westernsydney.edu.au

Julie Markham

School of Science and Health
Western Sydney University
Richmond Campus
NSW 2753, Australia

The value of gaining industry experience during undergraduate degrees is well recognised[1,2] and there is much interest currently in the concept of work-integrated learning (WIL)[3,4]. Industry experience equips graduates with job-ready skills, but university staff have reported that time, resources, and availability of industry places are obstacles in setting up placements for students[3,5]. An alternative approach is to provide a 'real-world' learning experience within the university. In this paper we will describe an example of an 'authentic' learning experience that familiarises students with the procedures involved in laboratory accreditation, and enables students to develop skills that address issues identified by employers during recruitment. These issues include lack of team work, communication, understanding how industry 'does business', and lack of practical experience and laboratory skills[2,6]. Laboratory Quality Management (LQM) is a final year unit at Western Sydney University that addresses some of these issues.

LQM is a laboratory based unit that has been running for over 25 years in cooperation with the National Association of Testing Authorities (NATA), initially with two cohorts, chemistry and microbiology, and more recently with a third, forensic science. Within each discipline, student groups of 6–10 set up a mock testing laboratory and choose one analysis to undertake. The most common tests chosen by students are for indicator organisms such as *E. coli* and specific pathogens in food, indicator organisms in water samples, sterility testing and bioassays of antimicrobials. Students then develop, document and operate a laboratory quality management system for their testing method and for the organisation as a whole. The documentation is consolidated in a laboratory quality manual that conforms to the requirements of ISO 17025[7] and the NATA guidelines for different types of testing laboratories[8]. This process requires effective team work, organisation, communication and higher order thinking relevant to the techniques and their primary purpose.

Apart from two introductory lectures, including one from NATA, the unit is run as laboratory sessions. The aim is to have the groups operate as autonomously as possible and to emphasise the need for critical thinking and problem solving within the group. The role of the laboratory supervisor is to facilitate the groups to organise and run themselves. In the first weeks the students are given ISO 17025, NATA resources and worksheets that aid in the preparation of the quality manual. The laboratory technique chosen needs to engage several students and be reasonably challenging; however, it does not need to be complex or technically difficult as NATA assesses the ability to complete the test as documented, not its degree of difficulty. Once the groups have decided on a test they are responsible for making their own media, solutions, buffers and determining how test material is handled and sampled. The process of perfecting the technical skills needed to complete one assay from start to finish, week to week, is a novelty, and challenging for some students. As the classes are held weekly, the group needs to organise how subcultures and analyses can be undertaken out of class time. This requires good planning and communication with both laboratory staff and each other. Normally the groups spend the first few weeks concentrating on the laboratory work and then, with the supervisor's encouragement, begin to focus on quality management and the preparation of the manual. While supervisors provide encouragement and discuss the process, this can be a period of adjustment for some students as they adapt to the need for independent decision making. However, as the need to prepare a quality management system is addressed, the uncertainty dissipates.

A critical component of the unit is the involvement of NATA as an expert body on industry standards. The assessment of the manual and the assessor's audit of the student group follow a streamlined version of the actual procedures used by NATA when accrediting laboratories. The students recognise that this represents the 'real world' and it makes the whole experience more meaningful. The manual is submitted three weeks prior to the last lab session so that when the auditors, scientists who are employed by NATA to accredit laboratories, meet with each group, they can provide feedback on the document, as well as observing the groups' technical proficiency and ability to follow the documented test procedure (Figure 1). The assessor sends the group a list of corrective actions and the revised manual is then marked by NATA (40% of the unit mark). The remaining marks are individual and based on an oral exam, peer assessment and each student's contribution to the manual and group.

Most groups work harmoniously, but disagreements often occur. While this is monitored by supervisors, it is up to the group to resolve the issues and produce a manual on time; the supervisor only intervenes if the disagreements become acrimonious. Interestingly, internal disagreement can lead to productive discussion within a group and these groups have often received high marks from NATA, while other groups lacking a critical dynamic have not performed as well as could be expected. Previously much conflict has arisen from poor communication and this seems to have diminished in recent years with the adoption of social networking as a means of communication within groups.

Figure 1. Lyndon Thomas from NATA assesses Microbiology students.

The fact that the procedures used by NATA follow their normal protocols means the students are confident that this is a real world experience and that they understand the documentation and levels of quality management expected when they enter the workforce. Students respond to this challenge and the unit typically scores well over 90% agreement in student feedback for questions such as 'I was able to see the relevance of this unit to my course' and 'I've had a satisfactory learning experience in this unit.' Similarly, when informally discussing the unit following the oral exam, many students say that this was the best unit they undertook in their degree. Typically students cite the benefits of self-directed activities and learning, freedom to choose the test system, relevance of the unit to the work environment, opportunity to do co-operative work in a meaningful way, and the clear goal-oriented nature of the class as reasons why they like this unit.

Anecdotal information received from past students indicates that this unit is recognised by employers as very desirable, with some students suggesting this was critical in successfully gaining a job. Several have reported subsequently being involved in updating manuals in their workplace or, in some cases, preparing laboratory quality manuals from scratch for their new employers. While most university subjects have little distinctive impact on prospective employers, LQM and its connection with NATA is readily identifiable as an indication that the students have the practical skills and knowledge necessary for working within a quality and standards based framework, and this facilitates transition to the workplace.

References

1. Prinsely, R. *et al*. (2015) *STEM-trained and job-ready*. Office of the Chief Scientist, Occasional Paper Issue 12, 1–4. http://www.chiefscientist.gov.au/2015/08/occasional-paper-stem-trained-and-job-ready (accessed 27 January 2016).
2. Deloitte Access Economics (2014) *Australia's STEM workforce: a survey of employers*. Office of the Chief Scientist. https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-australia-stem-workforce-report-010515.pdf (accessed 27 January 2016).
3. Atkinson, G. *et al*. (2015) *Work integrated learning in STEM disciplines: employer perspectives*. National Centre for Vocational Education Research. http://www.chiefscientist.gov.au/wp-content/uploads/NCVER_WIL-employer-perspectives.pdf (accessed 4 February 2016).

4. Edwards, D. *et al*. (2015) *Work Integrated Learning in STEM in Australian Universities*. Final Report Submitted to Office of Chief Scientist by Australian Council for Education Research (ACER). http://www.chiefscientist.gov.au/wp-content/uploads/ACER_WIL-in-STEM-in-Australian-Universities_June-2015.pdf (accessed 31 January 2016).
5. McLennan, B. *et al*. (2008) Work-Integrated Learning (WIL) in Australian Universities: The Challenges of Mainstreaming WIL. *ALTC NAGGAS National Symposium* June 2008, Melbourne.
6. Graduate Careers Australia (2016) *What employers want.* http://www.graduatecareers.com.au/CareerPlanningandResources/StartingYourSearch/GraduateSkills-WhatEmployersWant/index.htm (accessed 27 January 2016).
7. Standards Australia (2005) AS ISO/IEC 17025-2005, General Requirements for the Competence of Testing and Calibration Laboratories, Sydney, NSW: Standards Australia.
8. NATA (2013) Biological Testing ISO/IEC 17025 Application Document. http://www.nata.com.au/nata/phocadownload/publications/Accreditation_criteria/ISO-IEC-17025/Biological-Testing/Biological-Testing-ISO-IEC-17025-Application-Document.pdf

Biographies

Dr Michael Phillips is a lecturer in the School of Science and Health at Western Sydney University. Since joining the teaching staff in 2007 he has taught a variety of microbiology units including Laboratory Quality Management. He has been the subject coordinator for the past four years.

Julie Markham is a lecturer and Academic Course Advisor for the Bachelor of Medical Science degree at Western Sydney University. She has taught microbiology at the tertiary level for more than 25 years and has extensive experience in curriculum design and course development.

Threshold learning outcomes for a microbiology major

C Burke, H Cain, N Coleman, D Grando, M Hughes, P Johanesen, J Lategan, M Lloyd, J Markham, M Mohideen, K Waller and J Wang

EdSIG working party with representatives from University of Tasmania, The University of Sydney, RMIT University, Monash University, Macquarie University, The University of Western Australia, University of Western Sydney, The University of Melbourne and The University of Queensland

Corresponding author. Email: c.burke@utas.edu.au

The concept of National Guidelines for Microbiology Curricula was workshopped at the inaugural meeting of EduCon (the ASM Microbiology Educators' Conference) in 2014. Subsequently, an *ad hoc* special working group was formed at the 2015 EduCon to formulate National Guidelines for the threshold learning outcomes of Australian undergraduate microbiology curricula. The group, through discussion and several iterations, developed draft threshold learning outcomes for microbiology majors based on the Science Learning and Teaching Academic Standards Statement[1] and informed by the curricular guidelines of the American Society for Microbiology[2].

In this context, microbiology is taken to mean study of any or all microorganisms. Collectively, the group agreed that a major in microbiology should demonstrate significant learning of the key concepts of microbiology (see Merkel *et al*.[2]) at an advanced undergraduate level and recognised that there are diverse course structures that could enable this outcome. Commonly, the course structure would require completion of four units of microbiology at years 3 (single degree) or 3 and 4 (double degree) depending on the degree undertaken; however, one of these units could be replaced with a complementary science unit. A capstone unit of microbiology in which students demonstrate critical evaluation and synthesis of a microbiological topic should be included. These standards would necessitate that assessment tasks be linked to each of the learning outcomes and should show progressive development throughout the major. To help Australian academics validate that their students have reached these threshold learning outcomes, each subcategory will be progressively linked to curriculum learning resources that will be available with these guidelines at an EdSIG website hosted by the ASM. Additionally, a list of some current microbiology majors at Australian universities will provide examples of what subjects might be included in a microbiology major (Table 1).

The draft threshold learning outcomes were discussed and supported by the National Examinations and Qualifications Board of the ASM at their December, 2015 meeting and subsequently by National Council in February 2016. The draft threshold learning outcomes were then circulated to the state branches and to all members of EdSIG for comment. The threshold learning outcomes for a microbiology major presented here are the outcomes from these discussions. It is not the intent of EdSIG that ASM would accredit microbiology majors nor to exactly define curricula, but rather to give guidance to Australian academics on what ASM considers that a microbiology graduate should able to do whilst working professionally as a microbiologist.

Introduction to microbiology major threshold learning outcomes

A major in microbiology should demonstrate significant learning of the key concepts of microbiology (see Merkel *et al*.[2]) at an advanced undergraduate level. In this context, microbiology is taken to mean study of any or all microorganisms, including bacteria, viruses, fungi, and parasites. There are diverse student pathways that can enable this outcome, but commonly, the course structure includes four units of microbiology at year 3 (single degree) or years 3 and 4 (double degree) depending on the degree undertaken. One of these advanced units may be replaced with a complementary science unit. A capstone unit in which students demonstrate critical evaluation and synthesis of a microbiological topic addressing the course learning outcomes should be included. These standards necessitate that assessment tasks be linked to each of the learning outcomes and should show progressive development throughout the major. The threshold learning outcomes for microbiology majors are based on the Science Learning and Teaching Academic Standards Statement[1] and informed by the curricular guidelines of the American Society for Microbiology[2].

Threshold Learning Outcomes for Majors in Microbiology

Understanding microbiology

1. Demonstrate a coherent understanding of microbiology and its applications by:

 10.1071/MA16031

1.1. Demonstrating a broad knowledge of, and applying the principles and concepts of microbiology.
1.2. Articulating and applying the scientific method of hypothesis testing to the field of microbiology.
1.3. Articulating and competently applying analytical methods to advance their understanding of microbiology.
1.4. Recognising and explaining the manifold roles and relevance of microbiology to society.

Knowledge of and practical skills to study microbes, their interactions and their applications

2. Exhibit depth and breadth of knowledge by:

2.1. Demonstrating well-developed knowledge of microbiology.
2.2. Demonstrating competency in core microbiological skills and techniques.
2.3. Articulating the interactions of microbes with their environment and applications.

Inquiry and problem solving

3. Critically analyse and solve specific microbiological problems both individually and in teams by:

3.1. Gathering, analysing and synthesising both quantitative and qualitative data /information from a range of sources relevant to the issue at hand.
3.2. Designing and planning a safe and efficient investigation or experiment.
3.3. Selecting and correctly applying relevant and appropriate practical and/or theoretical techniques or tools in order to carry out an experiment or investigation.
3.4. Collecting, accurately recording, interpreting and drawing conclusions from scientific data.

Communication

4. Be effective communicators by:

4.1. Using appropriate written and oral forms to communicate understanding of microbiology to a broad range of stakeholders.
4.2. Working collaboratively in teams.
4.3. Effectively advocating for a rational understanding of microbiological issues.

Personal and professional responsibility

5. Be accountable for their own learning and work by:

5.1. Working effectively, responsibly and safely with microorganisms.
5.2. Being independent and self-directed learners.
5.3. Demonstrating knowledge of the legal and regulatory frameworks relevant to microbiology.
5.4. Practicing ethical conduct in science.

References

1. Jones, S. *et al*. (2011) Learning and Teaching Academic Standards Project SCIENCE. Learning and Teaching Academic Standards Statement September 2011. Australian Learning and Teaching Council Report, 36 pp.
2. Merkel, S. and ASM Taskforce on Curriculum Guidelines for Undergraduate Microbiology. (2012) The development of curricular guidelines for introductory microbiology that focus on understanding. *J. Microbiol. Biol. Educ.* **13**, 32–38. doi:10.1128/jmbe.v13i1.363

Table 1. Example course structures of microbiology majors in Australia. The list includes examples of microbiology majors taught at some Australian Universities. The information is current as of January 2016. The listed majors show minimum requirements and only a single version. Some universities allow different prerequisites for example.

Code	Unit name	Weight	Level
Sydney	**Microbiology major**		
BIOL1001	Concepts in Biology	12.5	Introductory
MBLG1001	Molecular Biology and Genetics (Intro)	12.5	Introductory
CHEM1001	Fundamentals of Chemistry 1A	12.5	Introductory
The major is the 6 units below, but the introductory units (or similar) are prerequisites			
MICR2021	Microbial Life	12.5	Intermediate
MICR2022	Microbes in Society	12.5	Intermediate
Any 4 of:			
MICR3011	Microbes in Infection	12.5	Advanced
VIRO3001	Virology	12.5	Advanced
MICR3032	Cellular and Molecular Microbiology	12.5	Advanced
VIRO3002	Medical and Applied Virology	12.5	Advanced
MICR3042	Molecular Microbiology Research Skills	12.5	Advanced
URL	http://sydney.edu.au/courses/pathways/major-microbiology		

Table 1. (*continued*)

Code	Unit name	Weight	Level
Western Sydney	**Microbiology**		
300802.1	Biodiversity	12.5	Introductory
300816.1	Cell biology	12.5	Introductory
300803.1	Essential Chemistry 2	12.5	Introductory
300936.1	Functional Proteins and Genes	12.5	Introductory
The major is the 8 units below, but the introductory units (or similar) are prerequisites			
300936.1	Functional Proteins and Genes	12.5	Intermediate
300833.1	Microbiology 1	12.5	Intermediate
300896.1	Microbiology 2	12.5	Intermediate
300817.1	Molecular Biology	12.5	Intermediate
Any 4 of:			
300866.1	Analytical Microbiology	12.5	Advanced
300826.1	Medical Microbiology	12.5	Advanced
300905.1	Advanced Immunology	12.5	Advanced
300883.1	Laboratory Quality Management	12.5	Advanced
300924.1	Science Research Project	12.5	Advanced
URL	http://handbook.westernsydney.edu.au/hbook/specialisation.aspx?unitset=M3099.1		
Queensland	**Microbiology**		
BIOL1020	Genes, Cells and Evolution	12.5	Introductory
BIOL1040	Cells to Organisms	12.5	Introductory
CHEM1100	Chemistry 1	12.5	Introductory
BIOC2000	Biochemistry and Molecular Biology	12.5	Intermediate
MICR2000	Microbiology and Immunology	12.5	Intermediate
Plus 1 of 7 choices:			
	e.g. from fields such as Biochemistry, Genetics, Ecology, Biostatistics, Forensic Science	12.5	Intermediate
MICR3001	Microbes and Human Health	12.5	Advanced
And any 3 of:			
BIOC3005	Molecular Systems Biology	12.5	Advanced
BIOL3003	Advanced Immunology	12.5	Advanced
BIOL3004	Genomics and Bioinformatics	12.5	Advanced
BIOL3009	Arthropods and Human Health	12.5	Advanced
MICR3002	Virology	12.5	Advanced
MICR3003	Molecular Microbiology	12.5	Advanced

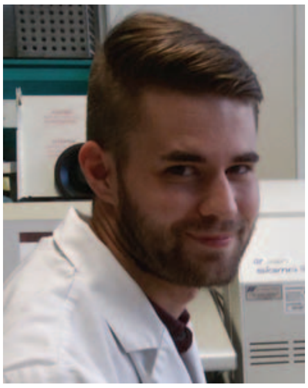
Table 1. (*continued*)

Code	Unit name	Weight	Level
MICR3004	Microbial Genomics	12.5	Advanced
URL	https://www.uq.edu.au/study/plan_display.html?acad_plan=MICRBX2030		
Tasmania	**Microbiology major**		
Choose 2 introductory units from:			
	Biology, Chemistry, Cell Biology	12.5	Introductory
KLA256	Microbes and Man	12.5	Intermediate
One of:			
KLA200	Microbiology (Marine)	12.5	Intermediate
KLA210	Microbiology	12.5	Intermediate
Choose any 4 of 8 microbiology units:			
KLA304	Foodborne Pathogens	12.5	Advanced
KLA346	Plant Pathology	12.5	Advanced
KLA392	Microbiology Research Project	12.5	Advanced
KLA394	Advanced Food Safety Management	12.5	Advanced
KLA396	Food Microbiology	12.5	Advanced
KLA398	Applied Environmental Microbiology	12.5	Advanced
CJA313	Medical Microbiology	12.5	Advanced
CJA314	Advanced Immunology	12.5	Advanced
URL	http://www.utas.edu.au/courses/set/courses/73o-bachelor-of-science		
RMIT	**Microbiology major**		
BIOL2257	Introduction to Microbiology, Immunology and Genetics	12.5	Introductory
BIOL2158	Microbiology	12.5	Intermediate
ONPS2113	Food Microbiology	12.5	Intermediate
ONPS2115	Industrial Microbiology	12.5	Intermediate
ONPS2118	Medical Microbiology 1	12.5	Advanced
ONPS2120	Medical Microbiology 2	12.5	Advanced
ONPS2388	Immunology	12.5	Advanced
ONPS2186	Science Project	12.5	Advanced
URL	http://www.rmit.edu.au/study-with-us/levels-of-study/undergraduate-study/bachelor-degrees/bp226/#pageId=BP226P7		
Monash	**Microbiology major**		
BIO1011	Biology 1	12.5	Introductory
BIO1012	Biology 2	12.5	Introductory
MIC2011	Introduction to Microbiology & Microbial Biotechnology	12.5	Intermediate
MIC2022	Microbes in Health and Disease	12.5	Intermediate

Table 1. (*continued*)

Code	Unit name	Weight	Level
Any four of:			
MIC3011	Molecular Microbiology	12.5	Advanced
MIC3022	Molecular Virology and Viral Pathogenesis	12.5	Advanced
MIC3032	Pathogenesis of Bacterial Infectious Diseases	12.5	Advanced
MIC3041	Medical Microbiology	12.5	Advanced
MIC3990	Action in Microbiology Research Project	12.5	Advanced
URL	https://monash.edu/pubs/2016handbooks/aos/microbiology/		
Melbourne	**Microbiology and immunology major**		
BIOL10004	Biology of Cells and Organisms	12.5	Introductory
BIOL10005	Genetics and the Evolution of Life	12.5	Introductory
MIIM20001	Principles of Microbiology and Immunology	12.5	Intermediate
MIIM20002	Microbes, Infections and Responses	12.5	Intermediate
The major is the 4 units below, but the introductory and intermediate units (or similar) are prerequisites			
MIIM30011	Medical Microbiology: Bacteriology	12.5	Advanced
MIIM30014	Medical Microbiology: Virology	12.5	Advanced
MIIM30016	Techniques in Microbiology	12.5	Advanced
Plus one of 11 choices:			
	e.g. from fields such as Biochemistry, Genetics, Molecular biology, Pharmacy, Pathology	12.5	Advanced
URL	https://handbook.unimelb.edu.au/view/2016/%21B-SCI-MAJ%2B1041		
	https://handbook.unimelb.edu.au/view/2016/%21B-SCI-SPC%2B1022		
UWA	**Microbiology and immunology major**		
SCIE1106	Molecular Biology of the Cell	6	Introductory
SCOM1101	Introduction to Scientific Practices	6	Introductory
One of:			
ANHB1101	Human Biology I: Becoming Human	6	Introductory
ANHB1102	Human Biology II: Being Human	6	Introductory
BIOL1130	Frontiers in Biology	6	Introductory
MICR2208	Introductory Microbiology	6	Intermediate
MICR2209	Introduction to Infectious Diseases and Immunology	6	Intermediate
MICR3310	Applied and Environmental Microbiology	6	Advanced
MICR3320	Viruses and Viral Disease	6	Advanced
MICR3330	Bacteria and Bacterial Disease	6	Advanced
MICR3340	Immunity and Infection	6	Advanced
URL	http://handbooks.uwa.edu.au/majors/majordetails?vdir=mjdmcbim		

BD student Awardee values networking opportunities offered by the ASM Conference



Christopher Atkinson
University of Tasmania
Email: christopher.atkinson@utas.edu.au

In 2015, I was the Tasmanian recipient of the annual Becton Dickinson (BD) Award, given to one student member of each state branch of the Australian Society of Microbiology. As a recipient of this award, I was given the opportunity to give an oral presentation at the 2015 ASM National Scientific Meeting in Canberra where I discussed some of the research I had been undertaking at the University of Tasmania relating to the characterisation of macrolide antibiotic resistance in nontypable *Haemophilus influenzae*. Dr Stefan Schwarz, of the Institute of Farm Animal Genetics of the Friedrich-Loeffler-Institut (FLI) in Germany, was also in attendance at the conference as an invited speaker. I first met Stefan at the ASM Student Breakfast where we discussed some of the research I had been doing and how it related to his own. He was also part of the audience during my presentation and we maintained contact with each other after the conference had concluded.

As a result of continuing correspondence between Stefan, myself and Dr Stephen Tristram, my primary PhD supervisor, I was eventually given the opportunity to spend the February of 2016 living in Germany and working with Stefan at the Institute of Farm Animal Genetics, located at Mariensee, a district of Neustadt am Rübenberge in Lower Saxony. During my time at the institute, I worked alongside Stefan's group, performing studies on acquired antibiotic resistance determinants in *H. influenzae*. In doing so, I was exposed to a number of new techniques that I would not have been able to perform at my current facility, and I was also able to develop new professional and personal contacts. I returned home with a wealth of experience that I would not otherwise have, and I currently have plans to continue the study back in Tasmania, with the intention of publishing a manuscript and incorporating the work into my thesis.

I feel that my experiences at last year's ASM conference emphasise the value of making conference opportunities such as the BD awards available to student members of the ASM. My own participation at the conference and the subsequent developments that lead me to Germany have been invaluable, not just as a learning experience but also for potential future employment opportunities after I have completed my PhD. I believe my decision to apply for the BD award has opened up many doors for me, and for this I cannot thank BD or the ASM enough. As a result of my experiences, I can only encourage other student members to get out there and participate in initiatives like the BD awards and the annual ASM conferences wherever possible. The networking opportunities that these initiatives provide may prove to be a helpful way for many students to bridge the gap between study and research employment.

8th Australasian Virology Society Meeting

Natalie E Netzler and Peter A White

The 8th Australasian Virology Society (AVS) Meeting was held 6–9 December 2015 in the Hunter Valley, NSW. This student-orientated, biennial conference was organised and hosted by the AVS Local Organising Committee. The 2015 AVS Meeting was held consecutively with the 11th National Scientific Workshop Australian Centre for HIV and Hepatitis Virology Research (ACH2) Meeting. The ACH2 conference followed AVS, running 9–11 December in the same venue. This successful joint AVS and ACH2 meeting allowed many delegates to seamlessly attend the back-to-back conferences without additional travel. Both meetings were held in the Crowne Plaza Hunter Valley Resort in Lovedale. All conference facilities were onsite, set amongst the accommodation, enabling continuous networking opportunities throughout the conference duration.

The AVS conference was attended by 215 delegates with students comprising 32% of attendees. The ACH2 conference had 112 registered attendees and 43 researchers went to both conferences. For the AVS meeting, international conference delegates made up 7% of the attendance register, while the largest proportion of Australian attendees came from Victoria (35%), followed by Queensland (24%), then New South Wales (21%), and the remaining 13% of combined delegates travelled from Western Australia, Australian Capital Territory and South Australian states.

A balanced AVS meeting programme showcased a wide range of topics across the four day conference, maintaining both interest and energy from the diverse audience. These included sessions focused on: immunity and immune invasion, viral immunology, viral pathogenesis, new and emerging viruses, therapeutics, viral replication, RNA and viruses, viral epidemiology, diagnostics and insect antiviral immunity.

Invited international speakers included; Professor Jonathan Yewdell (USA), Professor Carla Saleh (France) and Associate Professor Marco Weinberg. National speakers included; Professor Mariapia Degli Esposti, Associate Professor David Tscharke, Professor Cheryl Jones, Professor Eddie Holmes, Associate Professor David Harrich, Professor Alex Khromykh, Professor Damian Purcell, Professor Bill Rawlinson, Associate Professor Heidi Drummer and Associate Professor Paul Cameron. For the ACH2 meeting, the invited international speakers were Associate Professor Vincente Planelles and Associate Professor Andrea Cox.

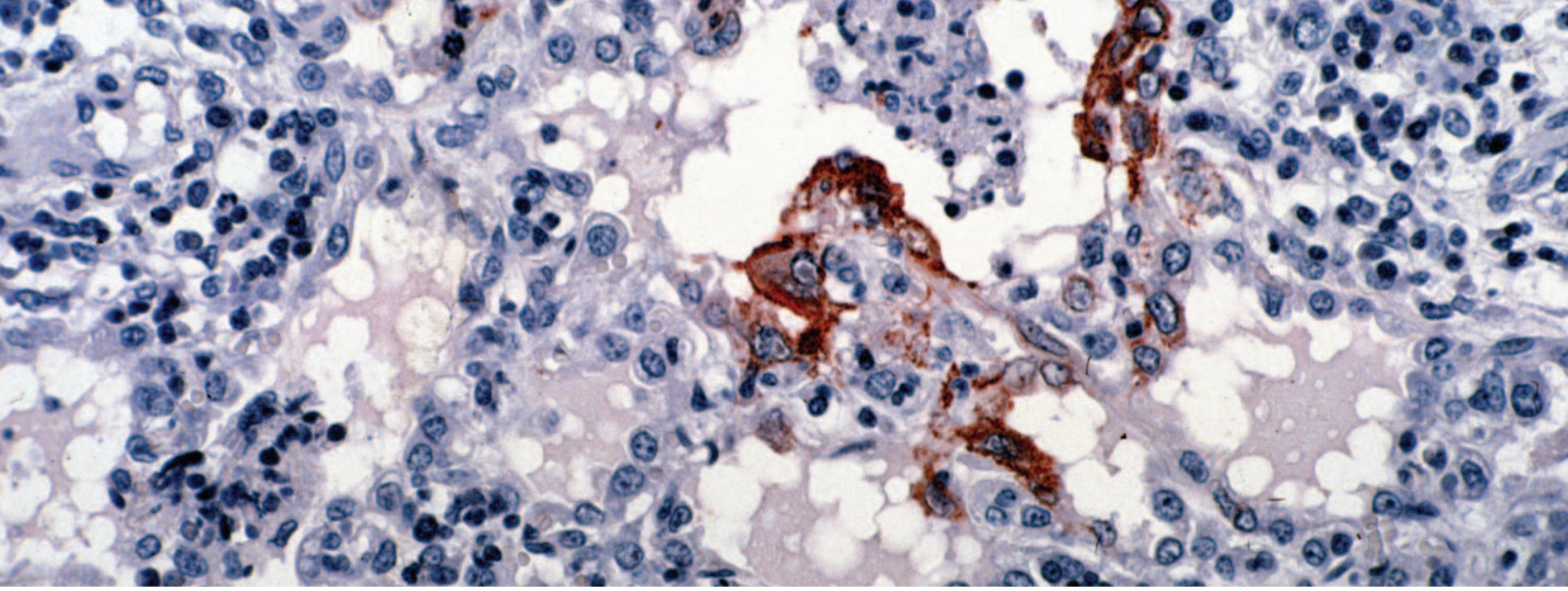
The 'Oral Poster' sessions offered a novel AVS presentation format, specifically aimed to encourage and develop students and early career researchers (ECRs) in conference presentations. These sessions were exciting, high tension and held at the end of each of the full conference days. The condensed talks were strictly limited to six slides delivered within six minutes. These lively sessions proved to be both popular and well received.

The AVS meeting also offered a 'Meet the Professors' lunch event, where delegates, particularly students and ECRs, could meet the keynote speakers in a relaxed setting. This popular event was organised by Dr Sacha Stelzer-Braid, POWH and ran for an hour and a half in a small group situation, to promote dialogue between ECRs and experts, encouraging questions and insights into their career experience. This enlightening and intimate lunch allowed a unique opportunity for ECRs to benefit from expert mentorship and make connections with leaders in their chosen field.

The meeting concluded with an outstanding joint conference dinner at the spectacular Hope Estate Vineyard. The evening commenced with a networking session over canapés, followed by a formal dinner, prize giving, speeches and dancing, with live music from the pianist and singer Dan Beazley. This event enabled further networking in a more relaxed setting and was graced by a spectacular lightning storm, providing an excellent visual backdrop to the event, over the wine yards.

Overall, the 8th AVS Meeting was rated as 'excellent' by the vast majority in feedback surveys, confirming the event's success. Special thanks go out to the Local Organising Committee, members from the AVS Committee, also Maree Overall and Kara Taglieri from ASN and finally Tony Cunningham and Denise Brown (ACH2) for assistance in ensuring this event was a success.

 10.1071/MA16033



Confirmed Plenary speakers

Professor Peter Hawkey
University of Birmingham
Nosocomial infection control and antibiotic resistance

Professor Dan Andersson
Upsalla University
Environmental pollution by antibiotics and its role in the evolution of resistance

Assoc Prof Susan Lynch
University of California San Francisco
Colitis, Crohn's Disease and Microbiome Research

Dr Brian Conlon
Northeastern University, Boston
Drug discovery in soil bacteria

Professor Anna Durbin
Johns Hopkins
Dengue and vaccines

As with previous years, ASM 2016 will be co-run with EduCon 2016: Microbiology Educators' Conference

Watch this space for more details on the scientific and social program, speakers, ASM Public Lecture, workshops, ASM awards, student events, travel awards, abstract deadlines and much more..

NOW CONFIRMED!

2016 Rubbo Oration

Professor Anne Kelso
CEO NHMRC

www.theasm.org.au **www.westernaustralia.theasm.org.au**

The Australian Society for Microbiology
bringing Microbiologists together

Annual Scientific Meeting and Trade Exhibition

EduCon Microbiology Educators' Conference

CE-IVD CERTIFIED

Panther now targets HBV.

Introducing the Aptima HBV Quant assay on the Panther system: The only CE-IVD certified assay for HBV viral load with dual targets for exceptional performance across a wide linear range and all major HBV genotypes.

hologic.com | australia@hologic.com | 1800 827 364 (Australia) | newzealand@hologic.com

Gen-Probe Australia Pty Ltd. ABN 91 150 687 773 . Suite 402, Level 4, 2-4 Lyon Park Road, Macquarie Park, NSW, Australia, 2113. Phone: 1800 827 364 Fax: +61 2 9870 7555

Visit AptimaVirology.com

Aptima® HBV
Quant Assay