ASM 2010 Sydney – Annual Scientific Meeting & Exhibition

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March 2010
Volume 31 Number 1
Welcome to our first online edition of *Microbiology Australia*. Over the next few editions we hope to introduce some new features to the magazine that will take advantage of the electronic format. You will see some examples in this version along with the traditional themed stories that have been so successful in the past. I would like to take this opportunity to thank everyone who helped make this transition of the magazine to electronic format, including Chris Burke and Ian Macreadie, along with the rest of the MA Editorial Board and the staff in the ASM National Office, most notably Michelle Jackson. We welcome feedback on how we can make the journal better. If you have any thoughts, please feel free to email me directly (hatch.stokes@uts.edu.au).

In my last Vertical Transmission I reported that Lina Raco had left the National Office. Late last year, Carol Ginns resigned and moved on from ASM. Although she was only with us a relatively short time, Carol helped the Society in a number of ways. As you are probably aware, this included updating the Constitution and By-Laws that culminated in the changes mostly approved at the last annual general meeting.

With the start of the new year, the next national meeting in Sydney is not too far away. As always, it will be an outstanding meeting in all the usual ways and I hope to see as many of you there as possible. Professor Harald zur Hausen will be attending this year, meaning that this will be our second meeting in a row with a Nobel Laureate in attendance. This year will be exceptional by the additional fact that the Australasian Mycological Society (AMS) will be integrating their 2-day scientific meeting into our national meeting. This arrangement may prove a great model for the future. In the meantime, Sydney will be a must-do meeting for the mycologists in either society as well as providing an opportunity for the non-mycologists to broaden their expertise. In conjunction with AMS joining us we have introduced a special ‘2-day rate’ for the meeting. This allows attendance at any 2 days of the meeting and includes access to all of the functions that occur on the nominated 2 days in the same way that the full registration allows. Apart from the mycology program this may also appeal to members of either Society that cannot attend the full 4 days through time constraints. Please see the meeting website for details.

Late in 2009 I had the opportunity to visit two of the state branches. The first of these was the Research Retreat held by the Queensland Branch in the fabulous glasshouse mountains. As well as catching up with my Queensland colleagues, it was a chance to listen to some outstanding science, with Laura Frost all the way from Canada, who was sponsored by the ASM Visiting Speakers Program, through to several talented postgraduate students. In December I also caught up with the Victorian Branch Committee and had a fabulous time. In the course of my remaining time as president I hope to visit the other branches and get further feedback on the future direction of the Society. So I hope to talk to many more of you soon.

**Hatch Stokes**  
President ASM
The challenges of teaching microbiology

By its nature, education looks to the future – in that the benefits are in the future with an educated populace. However, education functions in the present and faces problems that must be resolved now, in order to achieve the future benefit. The true measure of education, then, is the success of student learning, which is served by good teaching. Altering our perspective as teachers to seeing the goal as student learning outcomes rather than being ‘good teachers’ opens up many different challenges. Understanding too that if we have taught well, then student learning will continue lifelong. As the American philosopher, Eric Hoffer, said “The central task of education is to implant a will and facility for learning; it should produce not learned but learning people”

What students learn in one class influences and is influenced by what is learnt elsewhere, so that we need to teach with reference to the whole student learning experience. By doing this, teachers can construct courses that produce learning that is greater than the sum of the parts. The traditional collegiality of higher education should provide a fertile ground for academics to work in this manner. However, compared to the collegiality of research, teaching has often been done in isolation. Apart from the lost opportunity of effective integration within courses, this has meant that teaching practices have been less likely to be rationally reviewed against the effectiveness of their learning outcomes. Even good teachers may not be able to explain why and how students learnt in their courses. Over the last decade or so this has been changing, particularly since the seminal work of Boyer focused attention onto the scholarship of teaching (and learning) in higher education. The scholarship of teaching and learning (SoTL) provides not only the opportunity to achieve strong learning outcomes, but also a field of research. In this manner, SoTL moves from a perspective of solving teaching problems to understanding how students learn. This requires a much larger time frame and data set than one semester’s class and, like any research, establishes worthwhile questions to be answered with experimental data.

In order to understand new concepts, learners must integrate new knowledge with their pre-existing knowledge and concepts and reconsider any misconceptions. Learning can be defined as the transfer of new knowledge from short-term, limited capacity, working memory to long-term memory. Failure to do so means that knowledge retention will be poor. Identifying students’ initial knowledge is important for determining the path towards the desired learning outcomes, which should be defined at progressively finer levels: course, year, unit and topics within units. After defining the learning outcomes, the means by which their achievement will be measured must be established. From all of these, the teaching activities can then be developed to align initial student knowledge with the target – the learning outcomes. Essentially, we define the what and how of a unit and can explain why the teaching program can achieve its learning goals.

Another challenge to teaching science is the changing nature of society. We are faced with ever more complex conundrums that require an educated populace to make ever more complex political decisions (for example, the recent Copenhagen Climate Change conference). Thus, it is vital that our students graduate with a sound understanding of their disciplines, in order that they will be able to participate rationally in such decisions. It is not feasible that we can teach all that students need to know, but must instead teach them how to continue learning within the discipline – how does a professional microbiologist think? With what learning resources are they familiar? Can they apply their existing knowledge to pose sensible questions and then examine these questions? All of this underlines the importance of teaching students not only what to know within microbiology, but also how to think as a professional. In this context, the discipline societies such as the Australian Society for Microbiology (ASM) can play an important role. The American Society for Microbiology has been active within the field of microbiology education for some time now and has developed or contributed to substantial programs such as:

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The MicrobeLibrary, which provides peer-reviewed teaching resources.

The annual Conference for Undergraduate Educators, ASMCUE.

The Biology Scholars Program for teaching and applying SoTL.

The Journal of Microbiology and Biology Education for publication on SoTL.

The developments of communities of practice such as these provide powerful tools for enhancing teaching and learning in microbiology, simply because teachers can learn from others, rather than always starting anew. It would be timely for the ASM to likewise determine how it can influence microbiology education in Australia. What do we want graduate microbiologists to know and to be able to do with their knowledge? What do we want other graduates to know and understand of microbiology? See for example the National Graduate Attributes Project.

Finally, there is the challenge of the changing nature of education. Perhaps the most obvious of these are the changes being implemented to the undergraduate programs at the University of Melbourne: the Melbourne model. This is based on six broad undergraduate programs followed by a professional graduate degree, research higher degree or entry directly into employment. The emphasis in the new degrees is on academic breadth as well as disciplinary depth. Depth is described as the expertise gained by studying a core program in a major discipline, whereas breadth results from choosing additional subjects from outside the major area of study, to develop other kinds of expertise. Breadth studies make up at least 25 per cent of the academic program.

The Melbourne model has impacted on the study of microbiology at Melbourne University in two main ways. Firstly, the disciplines of microbiology and immunology have been combined to constitute one major rather than two. The major includes one microbiology and one immunology lecture unit and a practical unit including some immunology and a microbiology practical unit. For students enrolled in a biomedicine degree, a subject combining medical microbiology and immunology with case-study based practicals is taught. Both science and biomedicine students then complete the same combined major in their third year. Class sizes are comparable to previous years, with the exception of the entry subject for biomedicine students which has expanded significantly. As in previous years, the only subjects required as prerequisites for studying microbiology in second year are two first-year biology units. Microbiology features in some of the breadth subjects and some microbiology subjects are able to be chosen as breadth subjects by other than science and biomedicine students. In this way, a taste of our discipline can be disseminated to an interested few, but for the large part it will continue to be the domain of committed science students and students enrolled in a postgraduate medical or dental degree.

This issue of Microbiology Australia addresses all of the issues raised in this editorial and we hope that you find the articles thought-provoking and helpful as you develop your teaching programs to engender the learning outcomes that you believe appropriate. In the end, the challenge for all microbiology educators, both within formal educational institutions as well as employers training staff, is to be able to explain why we teach in the manner that we do and how it leads to good learning outcomes. We thank the contributors, reviewers and editorial staff for their combined efforts in producing this issue.

References

Biographies

Chris Burke is a senior lecturer and degree coordinator in the NCMCRS. He has a strong interest in teaching and has taught in microbial ecology and aquatic ecology for nearly 20 years. In 2007 he was awarded a Carrick Citation for Outstanding Contribution to Student Learning and is currently a UTas Teaching Fellow.

Cheryl Power is a lecturer in the Department of Microbiology & Immunology at the University of Melbourne. She has taught microbiology to students enrolled in many different courses for over 30 years. Her educational research interests include the use of assessment to drive student learning and the importance of practical class experiences in microbiology courses. She was Convenor of the Education Special Interest group for over 15 years and was the Guest Editor of Microbiology Australia, Volume 24, No. 4, November 2003 which was the first issue of the journal devoted entirely to educational issues.
Many recent publications have highlighted the need for, and value of, concept assessments (also called inventories) in undergraduate biology education. Current interest in such assessments is primarily due to the emergence of a community of science education researchers in biology, who both approach teaching from a scientific perspective and want to measure the potential successes of their teaching reforms. Well-designed, valid and reliable assessment tools that allow instructors to capture student learning of the main concepts of biology are becoming an essential way to inform biology instructors about what students learn in college biology courses. This review summarises the general approaches taken in creating such concept assessment tools and presents some of the ways to effectively use them.

Concept assessments are sets of multiple-choice questions, often based on common student misconceptions, that are designed to test understanding without relying on memorisation. When the Force Concept Inventory (FCI) was first given to introductory physics students, instructors were surprised by the inability of their students to answer such seemingly easy conceptual questions. While students could use formulas they had memorised to solve complex mathematical problems, they could not answer questions that required an understanding of the concepts without the formulas. These results stimulated many in the physics community to reconsider how they were teaching introductory physics. The results of such efforts, first in physics and more recently in biology, have shown that changing the mode of instruction can have a positive impact on student learning. Validated assessment tools like the FCI have proved useful for first identifying problems in conceptual understanding and then benchmarking change by administering the assessment tool again to see whether different pedagogies have improved understanding. As biology educators have embraced the idea that learning biology should be more than simply memorising a collection of facts, a variety of concept assessments have been developed as independent measures of student understanding in particular topics of biology. As long as an assessment has been designed to address the conceptual nature of particular learning goals or big ideas, it can theoretically be used by anyone with any group of students to measure learning gains or diagnose topics on which students struggle.

Perhaps because biology is such a diverse field, biologists have not necessarily yet agreed on a core suite of ‘big ideas’ that undergraduate students should learn. This is a particularly difficult problem for introductory biology, since the topics taught in such courses can range from ecology to molecular biology and can include both or neither. It is likely that the best way to ensure the construction of useful concept assessments in the future will be by using the techniques described by D’Avanzo, which include faculty development workshops to help teach faculty members about their uses and the involvement of professional societies, which could encourage meaningful assessment and provide avenues for networking. Thus far, the instruments developed have followed a similar but not identical validation process and are intended (as indicated by their respective authors) for slightly different uses. The term ‘concept assessment’ is used in this review to encompass all the tools that have been developed so far. Some focus on helping to diagnose student pitfalls and others on capturing an overall picture of student understanding, but all of them assess student learning.

Current biology concept assessments
Several recent reviews have listed the currently available instruments for science in general and biology in particular. Table 1 reproduces only the known published biology concept assessments for which the questions are readily available online or from the authors and which have undergone extensive validation and reliability testing. Table 2 reproduces a list of other biology projects that are in development or revision, or are published but without extensive validation.

Getting the most out of concept assessments: Tips for administration
Concept assessments should be given in an environment that encourages students to put effort into the assessment. If the assessment will be used to measure student understanding both before and after instruction (pre-post), it is best to give the assessment on the first day of class prior to any content instruction (pre-test). Students receive participation credit for

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In Focus

Completing the pre-test; to help ensure that students take the assessment seriously, they can be told that the results will help guide instruction. One should ensure that students do not keep a copy of the assessment, since circulation of the assessment would devalue its future use. The identical assessment is then given at the end of the course as a post-test. One way to administer the post-test is to give it on the next to last day of class, informing students that their answers will be used to help construct a useful review session for the final. An alternative is to give the post-test as part of the final exam. Because students do not know the pre-test questions will be repeated in the final exam, they cannot study specifically for this part of the exam. They will take the questions seriously because they are graded (even 0.5 points per question will still be valued by the students). Ultimately, the most important factor is consistency in administration. If one is interested in comparing learning gains in two different courses, or in the same course over several semesters, the pre- and post-tests should be administered the same way every time. Otherwise, differences in administration will likely impact student performance and make the data sets incomparable.

Using data from concept assessments to inform teaching

Overall improvement in each student’s understanding from pre-instruction to post-instruction is called learning gain. To calculate a normalised learning gain (<g>), which takes into account the possible gain, the following standard formula is used: \( <g> = 100*(\text{post-} - \text{pre})/(100 - \text{pre}) \). This formula can be used for all students in the course unless a student has a negative learning gain, in which case the normalised change formula 100*(post-pre)/pre is recommended instead. The normalised learning gains for all students can then be averaged to give an overall normalised learning gain for a group of students.

For a more fine-grained analysis of what students are learning, one can separate out performance on groups of questions that test individual learning goals and calculate normalised learning gain for each goal. This can be especially useful if one has implemented a new pedagogical technique focused on one topic only. While student interviews are the most informative for exploring student thinking, the most commonly picked distractors (wrong answers) on a well-designed concept assessment can provide a snapshot of student thinking. Normalised learning gains can also be compared among different groups of students in the same course (for example, students who are co-enrolled in

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another related course in comparison to those not co-enrolled),
or among students taking different, but related, courses (for
example, non-science majors compared to science majors 17, or
two similar courses at two different universities).

**Construction, validation and statistical analyses of concept assessments**

The framework for constructing and validating concept assessments has been summarised recently by several authors
2, 5, 15 and generally follows the Standards for Educational and
Psychological Testing 18. Figure 1 briefly outlines these steps, a
few of which are highlighted below.

Because one of the goals of concept assessments is to reveal what
students are thinking when they have an incorrect or alternative
conception of how something works, it is critical to capture
student thinking at the outset of generating an assessment. Once
a set of concepts has been agreed upon by faculty, open-ended,
‘think-aloud’ student interviews, in which students explain their
answer to an open-ended question, can be used as the starting
point for building multiple-choice questions 13, 14, 19. Such student
interviews are also valuable for hearing how students use natural
language to describe biology concepts. This in turn allows the
assessment to be worded with less jargon, ensuring that students
can understand the question and that one is not testing only
knowledge of vocabulary.

After a pilot assessment has been written and administered
to students, a second round of student interviews is required
for validation: in these interviews, students select the correct
answer from the choices and explain their reasoning. Questions
for which students pick the correct answer but supply incorrect
reasoning must be reworded. In addition, each distractor should
be chosen as a correct answer by some students in order to
be considered a true distractor that captures student thinking.
Finally, each question should address only one concept; the
answers should avoid words like none, always and never;
and the answers should be of equal lengths and complexity 1.

Once questions are constructed and tested through student
interviews, experts should be asked to review the assessment.
One method is to ask experts to take the assessment and rate
each question for clarity, scientific accuracy and how well the
question addresses the learning goal it was written to assess 15.
Questions that are not highly rated by experts should then be
rewritten and revalidated.

Three statistical measures are common for collecting evidence
of validity: item difficulty, item discrimination and reliability of
the instrument 16, 20. Item difficulty (P) measures the percentage
of students who answer a question correctly; thus one expects
to see this value increase from the pre-test to the post-test
for most questions (high P=high % of students answering
question correctly; low P=low % of students answering question
correctly). However, some questions remain difficult and thus
will have a low P value in both pre- and post-tests. When
combined with item discrimination, D (how well a question
discriminates between students who have performed well on the
assessment overall vs students who have performed poorly on
the assessment overall), the two values can provide insight into
student understanding. For example, items that begin with a high
D value on the pre-test and end with a similarly high D value but
low P value on the post-test are concepts that remain challenging
for all but the strongest students in a course 13. In addition, the
overall difficulty of the assessment should be considered. If the
average pre-test performance on a concept assessment is above
70%, the overall possible gain from pre-test to post-test is smaller
than if the average performance is below 50%. Thus, an average
pre-test performance between 25 and 40% (25% would be the
score expected if students were guessing, given an average of
four answers for each question) is common 9, 13, 14.

**Figure 1. Steps for constructing biology concept assessments**

1. Review literature on common misconceptions on subtopic of biology.
2. Interview faculty to develop a set of learning goals describing the concepts central to a particular subtopic of biology.
3. Use ‘think aloud’ interviews or analysis of student essays on these concepts to gather information about student thinking.
4. Generate and administer a pilot assessment based on known and perceived misconceptions using student–provided distractors
   and natural language.
5. Validate and revise the questions through student interviews and expert review.
6. Administer the assessment to many students (preferably >300, in several courses at several institutions).
7. Evaluate the assessment using statistical analyses to measure item difficulty, item discrimination and reliability.
8. Repeat steps 5-7 as necessary.

*adapted from 15,15
Finally, for measuring reliability, a commonly used test is the test-retest approach 20, 21, where the assessment is given to students taking the same course in consecutive semesters and the coefficient of stability is then calculated between the two sets of pretest results. The internal consistency test (Cronbach’s α) is favoured by designers of standardised tests; however, concept assessments comprise questions that test different concepts and thus performance on individual concepts need not be correlated 15.

**Challenges of biology concept assessments**

As mentioned earlier, widely applicable concept assessments in biology are challenging to build for at least two reasons. Firstly, different biology content is emphasised differently in each department at each institution and secondly, biologists have not yet agreed on what concepts are most important to assess even within sub-disciplines. Because most instructors want to use an assessment that is relevant to the content taught in their courses, they may be tempted to use only subsets of questions from published concept assessments, choosing the questions that are most valuable to them. Some assessments are designed to be offered this way (e.g. the Biology Concept Inventory 19 and the Molecular Life Sciences Inventory 22). However, others suggest that an assessment is only valid if always administered with the same questions in the same order 23.

Several additional issues remain for biology faculty to consider. Should all concept assessments rely on the multiple choice format? Can critical thinking or logical skills be assessed with multiple choice questions, or should written assessments with rubrics be developed and validated? How important is the mastery of process skills such as hypothesis testing and experimental design and should such skills be measured within concept assessments intended for lecture courses, or through separate assessments designed for use in laboratory classes 25? Whatever the directions chosen by biology educators, concept assessments will continue to provide valuable feedback to instructors about student thinking and learning.

**References**


**Biography**

Jenny Knight is a senior instructor in the Department of Molecular Cell and Developmental Biology at the University of Colorado, Boulder, where she has taught for 10 years. With a background in neuroscience and developmental genetics, she has focused on biology education research since 2004 and has been the coordinator of the MCDB division of the Science Education Initiative (http://www.colorado.edu/seq/) since 2006. She wishes to thank Jia Shi, Michelle Smith and Bill Wood for their integral roles in this work.
Mentoring in microbiology: tips and traps for PhD supervisors

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This article focuses on postgraduate supervision as a critically important part of university teaching in microbiology. It is written for the PhD supervisor and is intended to encourage reflection on their role as a mentor for the students under their care. Much of the material comes from the documentation supplied by a large number of scientists in Australia and beyond who proposed their mentor for the 2006 Nature Awards for Mentoring in Science. As one of the judges for the Australasian awards, the author had access to this material which he, with Carina Denis and Philip Campbell, the editor in chief of Nature, used as a basis for the Nature’s guide for mentors.

Introduction

I would like to congratulate Cheryl Power and Chris Burke on this issue of Microbiology Australia dedicated to teaching. Microbiology has a long history of fostering excellence in teaching. There is something about microbiologists that results in a larger proportion being interested in teaching and being great teachers than in many other disciplines. I’m not sure why, but maybe it correlates with the great time we have at ASM meetings when we let our hair down! Maybe the common denominator is fun. We love microbiology and teaching microbiology not only because it is interesting but also because it is fun.

I taught microbiology to science and medical students for a hundred years at UNSW where I came to via a postdoc in New York, having done my PhD at Melbourne in the Bugs school when Syd Rubbo was Head and we were taught by a galaxy of amazing microbiologists. I was going to be a biochemist, but the inspiring teaching at Melbourne turned me. The education group of ASM was first led by Horst Doelle in the late 1960s and I took over in 1971 for 11 years. This interest in education in microbiology and good teaching stayed with me and was a strong factor in my decision to cross to the ‘dark side’ of university administration by becoming Pro Vice Chancellor (Education and Quality Improvement) at UNSW. Although my focus was mainly on undergraduate teaching, which I have continued in my retirement, I also had a strong interest in trying to improve the quality of postgraduate supervision. Having led a committee to investigate the PhD, I had been horrified at some of the poor practices I observed and determined to try to help academics provide a more fulfilling and productive postgraduate training for their students. The theme of this article is to reflect on strategies that will help supervisors in microbiology provide a better postgraduate experience for students under their care.

This article partly comes out of my own experience as a supervisor but also from the words of nearly 100 scientists who had experienced a very positive time as a young and budding scientist and had proposed their mentor, often their PhD supervisor, for a Nature award for mentoring in science. These awards for outstanding mentorship are now awarded annually in a specific country or countries each year. In 2006, I had the honour of being on the judging panel for the Australasian awards. It was a daunting task with a superb group of mentors being strongly supported by large numbers of their mentees. Following discussions about what are the attributes of a good mentor, we realised that there, in the massive supporting documentation written by the mentees and by the mentors themselves was the answer. Thus more than 200 informative quotes were distilled, synthesised and finally written as a publication called Nature’s guide for mentors which looked at what made a good mentor. Below, I give my impression of the lessons to be learnt from the comments of the mentees and my own experience. I do this in the hope that readers reflect on their role as a mentor currently or what they would like to be when they take over a supervisory role in the future and that they are able to improve the experience of those young scientists under their care. The tradition of quality supervision remains high in microbiology but we can always do better.

Be available

This is the tough one. By far the most common attribute spoken of by the mentees was the availability of their mentor. They spoke of the open-door policy of their supervisors, of rapid responses to emails, always being there to talk about problems, to inspire and give advice. In our hearts we know how important this is but how hard it is to maintain. As mentioned later, group meetings are important but we must make a regular timeslot to meet with...
all our graduate students, postdocs and research assistants for 30 minutes minimum each week or 2 weeks. Life is busy but no excuses. No last-minute cancellations. If we can’t do it, should we be supervising? Of all the tips in this paper this is the one we have to adhere to. Did I? Do you?

**Respect**

A good supervisor treats their postgraduate students as thoughtful colleagues. The students are an integral part of the team and junior students should feel the science they are doing is as important and as interesting as the student about to submit their PhD. The worst supervisors are the ones who treat their students as an ‘extra pair of hands’. This does happen and it is noticed. A supervisor who does not openly and visibly respect their student loses the respect of their peers.

**Be generous**

A very obvious trait of the great mentors was their unselfishness and willingness to share. They share their own ideas and are happy when someone picks them up and runs with them. They generously allow them to take on senior authorship, even though they could claim it for themselves. They allow younger people to take credit for their work even if it is to the apparent disadvantage of the mentor. Of course it is not. The generosity is apparent to all and only enhances the status of the supervisor. We have all seen leaders of big and important groups who are more concerned with using group members to promote their own scientific standing. I like to feel this meanness of spirit does not benefit them in the long term. Such generosity is harder in the early years before our international reputations are fully established but it will be of benefit in the long run and reduces the chance of our egos taking over.

**Individual differences**

We are all different. Different in the way we learn. Different in the way we think, become interested and lead our lives. We come from many varied and different cultures. A good supervisor or mentor appreciates these differences and does not try and fit square pegs in round holes. They know when to back off and let people make their own decisions and when to come in and offer support and sympathy. Not everyone wants to be a leading researcher and some are better suited to other occupations. We should acknowledge this and help them along that pathway.

Sit down with a cup of tea or glass of red and write down the strengths and weaknesses of each of your current team, the personal issues that confront them and their special circumstances. Now reflect on how you work with them. Do you feel you treat them differently taking account of these individual differences? There is more to life than what they do in the lab. They need freedom to ‘smell the roses’ as one mentee put it. If things change and appear to be going wrong, we need to try and understand why. If personal life is becoming tough, then give them time and space. Good mentors make themselves aware of this. Again we are often so busy we don’t notice.

**Mentor for life**

There is a subtle difference between a supervisor and a mentor. As someone put it:

> With the latter you find that you are not simply a student with a research project but a student with a career in front of you that the mentor helps you start.

It was remarkable how often the mentees mentioned how the mentoring relationship had continued; they spoke of mentors forging a rapport with the student that potentially last for a lifetime. We need to do that more deliberately. It is easy to lose touch. I regret that I have lost contact with many of my former students. The great mentors continue contact and link their former students with outstanding scientists throughout the world.

**Actively research**

As supervisors we need to remain in the lab and actively research. As our careers progress, our lecturing responsibilities increase and we have more and more meetings, there becomes a temptation to stay in our office and not get our hands dirty and do benchwork. Research students, postdocs and research assistants are doing the work, thus we think it reasonable to stay in our rooms reading, writing, meeting our students and thinking up the next great experiment. We should fight this and allocate one common time each week when all know we will be at the bench with a white coat on. It’s a discipline our students appreciate and allows us to look over their shoulders and help with a technique. Just as we should be strict with having dedicated time for discussion with our team so we should have a dedicated bench-active time. Also, we need to see the raw primary data or observation, not just a written-up version of it.

**Get the direction-self direction balance right**

One of the great skills of good supervision is to get the right balance between allowing the student to develop and explore their own ideas, research plans and projects and providing them with expert guidance and direction when needed. As someone stated:

> The scientific acumen to on the one hand encourage promising ideas and on the other recognise a ‘dead end’, is one of the great mentoring skills.

One of the worst deficiencies in a supervisor is to micromanage. They have thought up the experiment, written it up in their grant application and the students’ job is to do the experiment. This can stifle the student and give them no chance to develop the critical problem-solving skills students require to be a research scientist. Experiments don’t always work and they have to be given the freedom to appreciate that the unexpected result may be the right one, even though it does not fit with existing theories. Our role is to encourage and prompt students to follow their own ideas and judgement and to provide an environment...
where this is possible. In the *Nature* article we created a direction-self-direction scale.

<table>
<thead>
<tr>
<th>The direction-self-direction scale</th>
<th>Sink or swim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guided independence</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
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<tr>
<td>and scientific creativity</td>
<td>Sink or swim</td>
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Where would you place yourself on the scale? If you have the courage, ask your team members to also mark where they think you are on the scale. Have a great and fruitful discussion comparing notes!

**Celebrate**

Success in research is not celebrated enough, be it that first great breakthrough or the final submission of a thesis. All the *Nature* mentors described or were praised for their regular practice of celebrating achievement. Celebrations ranged from cocktail parties, lunches, dinners at the supervisor’s home or simply a cake at morning coffee time. One laboratory even had a special ritual of ‘weighing the thesis’ when a student was handing in the final tome. This contributed to the collegial environment of the lab and was a great practical experience in mentoring for the graduate students. Others put teams together to write drafts of papers or review their science.

**Create networks**

One of the best things we can do for our PhD students is create and share our networks for the benefit of their careers. Again this was a universal characteristic of all the great mentors, using their contacts to promote their students and young staff. My PhD supervisor Geoff Cooper, travelled to New York on sabbatical, talked to the great René Dubos about me and so off I went to the Rockefeller University to begin a lifetime immersed in the gut flora, an area I had never worked on. Other tips referred to were incentives to get the students to travel to overseas labs and conferences and link in with our networks. Universities need to put many more resources into allowing their graduate students to travel. This not only leads to better outcomes for the student, but has immense reputational benefit for the institution. Another behaviour of a good supervisor is that when a distinguished scientist comes to visit the school they not only introduce them, but also give them an opportunity to present or discuss their work. Often this is more valuable than having the students simply list in a seminar by the great woman or man.

**Question and listen**

Questioning is a skill that can be developed and listening is something we should force ourselves to do more. We may know the answers but our job is to get the students to work it out for themselves. This for me was best described in the following quote:

*There is always another question to ask. The questions seem innocuous but nothing is as it seems to be; there are more insights to be gained by probing away ... also never imposes his/ her will, but help persistently keeps the questions flowing to help the answer come along.*

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*In Focus*

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*MICROBIOLOGY AUSTRALIA • MARCH 2010*
If you have not done this before, in your next discussion with some students, ask three more questions than you normally would. Also listen and paraphrase back to the student what you think you have heard her or him say.

We learn about ‘active listening’ when we attend parent effectiveness training but don’t always practise it in our laboratories. We are all so busy that it is much easier to simply give them the answer and the solution we already know.

**Enhance skills**

Being a scientist requires skills in critical thinking, writing and oral presentation. Often we expect this to happen by osmosis during our student’s candidature. It does not; it has to be planned for. A continuing theme of this article is that we have to have a personal strategy that suits our personality such that we create the optimal learning experience for the young scientists under our care. A limited number of examples or thoughts from the *Nature* mentors and mentees are given below.

**Criticism**

From the beginning of their candidature we should be building on the skills of scientific criticism we hope they have picked up in their honours year. This should continue, with them taking an increasingly important role in the critique. A journal club is one strategy: students should not only participate in the critique of key papers but they should regularly take the lead by selecting, reviewing and critiquing papers themselves. Students should be involved from the beginning in the team’s grant applications. They should also be put in the position of interviewers in mock interviews. They should take the position of journal referee of papers submitted from the group and be encouraged to make a decision regarding acceptance, resubmission or rejection. The actual reviews that come back then provide the basis for a very rich discussion. In summary, we should create a situation where our students practise all the things we do that make us a scientist.

**Writing**

All too often we start training our young scientist how to write scientifically too late. The major writing activity is when they start to write their thesis. In reality, they should be so practised by then that writing becomes second nature to them. Early on, groups of students could be given the task of writing a review. A good strategy, which also enhances critical ability, is to present them with a manuscript they have not seen with either the abstract, introduction or discussion omitted and getting them to write their version which can then be compared with the original. With respect to papers, the student should always write the first draft no matter how much we want to get their great results published. Use of track changes in Microsoft Word makes our suggestions very informative. The more writing we give students to do the more we burden ourselves but that is part of the contract. A positive comment on all the mentors was that they gave feedback on written work very quickly. Hard to do but essential.

**Presentation**

From the beginning, possibly due to my interest in good teaching, I insisted that much effort went into training for oral presentations. Good readable slides, logical presentation and clear speaking. Our honours course had sessions on how to present. This was often embarrassing in that the standard of honours seminars and graduate student presentation was way better than the presentations of senior staff members the students experienced at ASM meetings and other conferences.

**Teaching**

It is interesting how many of the *Nature* mentors were referred to as great undergraduates teachers. This is important to me, as one reason I took on the PVC (Education) role was the conviction that great scientists can also be great teachers. Many of the mentors put forward for the *Nature* award were indeed outstanding researchers. Relevant to the theme of mentoring is my belief that supervisors should encourage their charges to take on a teaching role, for example, demonstrating to undergraduates and to do it well. As a resource for them you are referred to a website called *Guidelines on learning that inform teaching* that I have created to help academics teach well 3. Inspire your undergraduate students and they will come to you as a future supervisor.

**Seek feedback**

However comfortable we are with our supervisory or mentoring abilities, we should always aspire to do better. Thus we need to reflect and ask for feedback on our performance. At the end of the *Nature* paper there is a self-assessment entitled *How good a mentor are you?* You are invited to complete this. The article is available online 3. In the assessment you are asked to write down examples of how you tackle many of the issues described above and to reflect on what you could do better. For an optimal chance of improvement you could again ask all your team to anonymously complete the form and return it to you. Then you can have one of the social team-building activities referred to above catalysed with a very good shiraz!

**For the students among you**

This article has been written for the supervisor not the student. For those aspiring to be an academic, good luck. Hopefully you might find this useful in the future. For those of you who are still undergraduates and are contemplating a postgraduate degree, go for it, as it is a very special stage of life for anyone interested in science. But one word of advice, put as much effort into selecting your supervisor and the field you will work in as you did or are putting into your honours year. Be brave and stretch yourselves. Unlike in the USA, we tend to simply complete our honours year and progress to a PhD on the same topic with the same supervisor at the same institution. That’s what I did. However, even if you are totally happy with your honours supervisor, look around and look for alternatives. Consider another university.
consider another country, consider another field. Find groups of outstanding calibre you have read about and who may be willing to take you on. Question others about your possible supervisor. Do they have the track record and attributes referred to above? This is one of the most important decisions in your life. Take your time and investigate thoroughly. Good luck and if I can hang on a few more years, I may see you being nominated for a Nature award!

Conclusion

There is much more that could be said. The most common words coming through those many reports from the Nature mentees supporting their mentors were passion, enthusiasm and love of science. There are no tips that can be given to help the development of these characteristics other than if you feel you don’t have them, maybe mentoring is not for you. However, my guess is that many reading this article have these traits in abundance and are doing a great job supervising already. I hope the words of the very successful mentees and mentors who participated in the Nature venture have been helpful. I conclude with two great quotes which sum up key issues for me.

Often, ... would leave the latest, hottest paper on my desk, with an enthusiastic note attached that not only conveyed his/her own excitement about the field, but also piqued my interest. His/her door was always open to discuss not only my latest results, but also the latest paper.

… has an optimistic outlook is willing to push the boundaries. Going to …’s office with your head down, armed with a plot or calculation showing that the project appeared to be going nowhere, you will leave believing that you’ve solved the mysteries of Universe.

Guidelinesonmentoring.com

This mentoring project has continued in my retirement and has resulted in the construction of another website in which appear many of the thoughts written above 4. You are invited to look at it but more importantly send me more examples, tips and strategies that you think could be usefully included.

References


Biography

Adrian Lee did his BSc and PhD at the University of Melbourne and a postdoc at the Rockefeller University in New York. In 1968, he took up a lecturing position at the University of New South Wales progressing to Professor of Medical Microbiology and Head of the School of Microbiology and Immunology. He was an active researcher investigating the spiral bacteria of the gut including Helicobacter species and held NHMRC grants continuously from 1972-2003. He became Pro Vice Chancellor (Education and Quality Improvement) at UNSW from 2000-2006 due to his interest in teaching. Adrian has had a long relationship with ASM, chairing the organising committee for the annual meetings in Sydney in 1972 and 1978 and sat on the National Council for many years. He was awarded the inaugural ASM Distinguished Teaching Award in 1989, the ASM Distinguished Service Award, was the 2002 Rubbo orator and became an Honorary Member of ASM in 2004. Now Emeritus Professor, Adrian continues to support quality teaching and research mentoring. In 2008, he was awarded a Career Achievement Award from the Australian Learning and Teaching Council.
Peer review of teaching to promote learning outcomes

In 1990, American educator Ernest Boyer asked us to reconsider scholarship. In doing this he recognised not only the importance of teaching, but also that it was undervalued. Boyer concluded that for teaching to become valued it needed to be evaluated as rigorously as research is and suggested, among other things, that peer evaluation was an effective means of assessing quality – just as it is in research. Boyer noted that peer evaluation of teaching was not commonly practised in American higher education. The situation remains similar to this day in Australia with peer review of teaching (PRT) being uncommon.

Ask yourself: How much feedback have I had about my teaching and its effectiveness for engendering strong learning amongst my students? Most Australian universities mandate student evaluation of teaching in some form, so Australian educators will probably have student feedback. Maybe you have reflected on your teaching and how well your students have learnt the subject (or not), but you may not have obtained feedback from peers. If you are a new teacher, then possibly you have yet to be given any feedback; nevertheless there you are teaching in higher education. Contrast this with the amount of peer feedback obtained by researchers from supervisor comments, grant application and journal article reviews and seminars, as well as informal comment from research colleagues. While research is a highly visible activity, teaching appears to be largely hidden from our peers. The focus of this paper is to urge you to reconsider the role of PRT in developing good teaching practices in order to engender deep learning amongst your students.

What is PRT?

Firstly, although PRT can be used managerially to evaluate academic performance, this paper focuses entirely on the collegial use of PRT in which it has an academic developmental purpose of enhancing student learning outcomes. In essence, PRT is voluntary, collegial, confidential, thought-provoking, embedded in critical reflection of one’s teaching and reciprocated. It provides opportunities for learning by both the reviewer and the reviewee; it models good practice and opens the door for mentoring less experienced teachers. By providing alternative viewpoints about teaching, PRT can initiate uncomfortable reconsideration of the assumptions we all make about our teaching practice. Brookfield discusses the vital importance of “hunting assumptions” about our teaching, in order that we can know why we do what we do. Without critical reflection, assumptions underlying our teaching can remain untested. For example, our experiences as learners heavily influence our practice as teachers. We may falsely assume that what worked for us, will work for our students. To have a colleague review our teaching practice can provide data to help us critically and rationally understand our teaching activities and whether or not they are effective. Finally, PRT offers opportunities for both the reviewer and the reviewee to cast themselves as learners, which can open their minds to new or different ideas and perspectives of good teaching. Both are impelled to reconsider their own roles in their students’ learning.

Why would we use PRT?

PRT has many advantages that are conferred on both the reviewer and reviewee. Firstly, advice is specific for the teacher and context being reviewed rather than a generic comment about good teaching taken from the literature. Teachers can learn at a practical level the things that make classes work better. Secondly, teachers can learn new pedagogical approaches and even change their philosophy of teaching on the basis of an effective PRT. Bell describes PRT as helping improve teaching skills, pedagogy, teacher confidence and the congruence of the reviewee’s theories of teaching with their practices. Consequently, when integrated with ongoing reflective practice on teaching, PRT helps teaching evolve to match changing classroom dynamics. It helps clarify educational aims and provides evidence to support rational decisions, such as modifying learning outcomes to better reflect the overarching aim of the subject being taught. Additionally, the act of PRT in the classroom demonstrates the importance of reflective practice to students – students see the teacher being reviewed and responding rationally to...
points raised by the reviewer. It also helps develop collegiality amongst staff within a department and, by engendering critical self-reflection, enhanced professional development via rational planning for teaching improvement. By using collegial PRT, teachers can expound their own theories of teaching and will gain confidence if faced with compulsory PRT for promotion or other employment-related reasons. A further benefit is that, by developing the scholarship of teaching as espoused by Boyer, PRT data may be used in scholarly publications.

An emerging challenge for many academics is the increasing use of online or blended learning approaches to provide greater flexibility for the student population. For some teachers, this will mean learning new pedagogies and methods of teaching, so even experienced teachers will require feedback on their practices. The lack of knowledge of PRT in e-learning and whether or not it is qualitatively different from face-to-face teaching are discussed by McKenzie et al. and Wood and Friedel.

How to carry out PRT

Although PRT does not appear to be practised systematically throughout Australia, it is very easy to find information about PRT on many Australian university websites. Many comment that it is highly beneficial and may also provide advice on how to carry out and use PRT; for example, the Universities of Queensland, Tasmania, NSW and South Australia. There is common ground across the literature on how to practice PRT [for example points 3, 6, 9, 10 below, as well as the online university links listed above]. Where it is used for academic development PRT is most effective when it is:

1. Embedded within the reviewee’s self-critique of their teaching.
2. Voluntary – the reviewee wants feedback on their teaching.
3. Controlled by the reviewee – who determines the reviewer and makes the initial approach. The reviewee should clearly define the limits of the review to ensure that their aims for it are met. By doing this the reviewee gives the reviewer permission to critique particular aspects of their teaching.
4. Highly structured – with times for preliminary meetings and follow-up discussion. Outcomes are written and provided shortly after PRT and then discussed.
5. Confidential – thus both reviewer and reviewee can speak clearly.
6. Able to recognised the teaching strengths of the reviewee. In this sense, the primary purpose of PRT is to build from the teacher’s strengths in order to improve learning outcomes.
7. Able to identify areas of teaching practice that are not working as well as they could and to enable the reviewee to work through and solve any such problem areas.

Figure 1: A cyclic mechanism for including PRT with ongoing development of teaching.
8. Collegial – the reviewer couches their critique in terms directed objectively to the teaching reviewed, rather than the characteristics of the reviewee. So although PRT is evaluative, it should be non-judgemental.

9. Reciprocal – which furthers collegiality and open discussion of teaching and learning in order to improve student learning.

10. Openly discussed afterwards by the reviewee with other colleagues – although it is confidential initially, a teacher can expand the impact of PRT on their teaching by more broadly discussing the outcomes.

**Conclusion**

Clearly, strong views in favour of PRT have been expressed in this paper. From personal experience I have found that PRT has transformed aspects of my teaching, in particular keeping the thought of the student in the forefront of my mind as I plan a teaching activity: *What will the learner be doing in this class?* **How can I maximise the learning by the students?** However, although PRT can greatly improve teaching and therefore learning, it does require the teacher to open their work up to critique. The communication skills of the reviewer will have a significant influence on whether or not the critique is accepted. PRT requires us to explain why we do what we do, and if we cannot, then we are impelled to reconsider our thoughts. This is disquieting, but by definition so is all learning. We ask our students to accept this disquiet every day we take a class and challenge their knowledge, concepts and beliefs. So why shouldn’t we be prepared to do the same?

**References**


**Biography**

Chris Burke is a senior lecturer and degree coordinator in the NCMCRS. He has a strong interest in teaching and has taught in microbial ecology and aquatic ecology for nearly 20 years. In 2007 he was awarded a Carrick Citation for Outstanding Contribution to Student Learning and is currently a UTas Teaching Fellow.
Academics who teach upper-level biology courses at tertiary education institutions typically establish prerequisites for their courses, with the anticipation that students will arrive at class prepared with a good understanding of basic concepts of chemistry and biology. Establishing prerequisites serves two purposes: it justifies the omission of ‘previously learned’ material from the curriculum and also permits the assumption that students are prepared to move to higher-level learning domains and tackle conceptually complex topics.

The extent to which students transferred prerequisite knowledge to upper-level courses was recently investigated at the community college (Technical and Further Education or TAFE in Australia) level. Over four semesters, students enrolled in microbiology and human anatomy and physiology were evaluated for their retention and understanding of basic biology and chemistry concepts, presumably learned in their prerequisite courses. Less than a third of the students evaluated were able to correctly answer more than half of the questions on the evaluation instrument. Students who reported earning As or Bs in their prerequisite courses fared no better than those who reported lower grades. Students with only high school level biology and chemistry courses demonstrated the lowest ability to recall concepts. The results strongly indicate that expected retention and transfer of prerequisite knowledge does not occur, which is likely to contribute to students’ observed and self-reported difficulty with complex topics such as metabolism and genetics.

The problem of under-prepared students is not a new one for community college faculty. Initially created as a ‘stepping stone’ or ‘junior’ college for students lacking either the grades or money to go directly from high school to a 4-year college or university, this model is evolving into that of the ‘comprehensive’ community college, serving a broader set of student and community needs. The typical cross-section of students in a microbiology class ranges from traditional-age students who graduated from high school with honours to those who earned vocational or equivalency degrees 10 or more years before. The diversity of learning styles and abilities underscores the necessity for establishing prerequisite requirements, but do the prerequisites promote student success, or are we simply setting students up for failure?

Much of the scholarship related to the role of prerequisite courses in preparing students for more advanced study is directed toward distance and online learning, assessing learning outcomes and the teaching and learning process. Significantly less has been written about the consequences of inadequate initial learning of basic concepts and skills. In the field of cognitive psychology, researchers have investigated the degree to which students retain factual information and how this relates to their ability to access and then transfer previous learning to new learning challenges in advanced courses. May and Kahnweiler and others have reported that, without some depth of initial learning, students lack the capacity to retrieve needed concepts and skills and as such are not truly prepared for higher order learning. This is reinforced in a comparative study of low and high prior knowledge students in an advanced placement biology course, in which it was shown that the low prior knowledge group lacked adequate domain knowledge to build an understanding of more complex biological concepts.

To investigate the degree to which students retained previously learned concepts, a test for retention and understanding of basic
biology and chemistry concepts was administered to students enrolled in microbiology and human anatomy and physiology (Figure 1). Although many of the students had completed their prerequisite courses successfully (and often with high grades), the majority were unable to answer more than 70% of the questions correctly. This outcome implies students do not retain factual information much beyond the completion of a test, much less the prerequisite course. At what point is the knowledge lost?

The results of a separate and ongoing study provided some insight to this question. One of the more heavily enrolled courses that serves as a prerequisite to both microbiology and HAP is a non-majors introductory biology course called Principles of Biology. This course is team-taught and covers core principles of cell biology. It is taught in a series of ‘units’, each building upon material learned in previous units. To investigate the efficacy of the teaching and learning model used in this course, students were given an exam for credit early in the semester, which covered basic principles of chemistry such as atomic structure, bonding, pH and solutions. Without informing students that they would be retested on this material, the same exam was given to students on the first day of Microbiology or other upper-level course. The following semester concept questions were rewritten in multiple choice format. Many, such as the example shown below, were based on questions taken from exams in Principles of Biology, the non-majors biology courses many students use to fulfill a Microbiology prerequisite requirement.

The open ended instrument shown was administered during the first semester of the study. Answers were evaluated and rated on a scale reflecting correct, approaching correct, incorrect, or no answer. Only approximately a third of the students answered more than half of the questions correctly.

The conclusions drawn from the analysis of the initial data have prompted the instructors of microbiology and human anatomy and physiology to propose specific changes (a grade
standard) to the prerequisite requirements for these courses. In the near future, we intend to develop a ‘placement test’ to more accurately assess the conceptual knowledge of students before they are permitted to enroll. Those that meet an as yet undetermined standard will be allowed to enroll in either course. What to do for those that do not meet the standard is problematic and requires additional investigation. Development of a dedicated prerequisite experience, a ‘biology boot camp’ so to speak, that will specifically address the gaps that were noted in students’ prerequisite knowledge and skills is being considered.

References

Biography
Holly Ahern is Associate Professor of Microbiology at SUNY Adirondack, a community college in Queensbury, NY (USA), where she teaches both microbiology and anatomy and physiology to science majors and health science students. She is a past recipient of the President’s Award for Excellence in Teaching and the SUNY Chancellor’s Award for Excellence in Scholarship. She directs a community-based environmental initiative centered on small lakes using students as research assistants, with a current research focus of teaching and learning at the community college level. She was a 2008 American Society for Microbiology Biology Scholars Fellow.
Digital wet laboratories: blended learning to improve student learning

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To create great learning environments we need to actively engage our learners 1. Microbiology laboratory work experience for students is a powerful motivator; students returning from placement back to university often buzz with stories and look forward to a future place in industry. Unfortunately, opportunities for working in industry are limited and thus the next best thing is to ensure that university laboratory practicals also actively engage students. Traditional laboratory practical classes can be supported by and better simulate the activities undertaken in the workplace through the blending of computer-aided instruction with wet practical exercises 2.

The laboratory practical experience can vary widely. Think back to your own time at university. How many students actually read the practical instructions before coming to the laboratory? Do you think students were prepared to work safely during those classes? How many distractions occurred during the class; did the laboratory simulate a quiet productive workplace or was it quite noisy with more unrelated-to-prac-class discussion occurring? My own experiences were brought into focus when I began to demonstrate in microbiology classes. Concepts could be more easily explained if I could gain access to an appropriate image. Students would be delayed in their progress while they waited for an available demonstrator. Having in-lab computers and their digital repositories means that both students and demonstrators can quickly access useful resources; in other words, just-in-time teaching.

In 2006, the School of Medical Sciences at RMIT University converted their wet laboratories so that each of the 50 student bench spaces was equipped with a PC. All student PCs were linked to an instructor workstation with NetOp® software, enabling flow of files in both directions. Students had access to banks of images that helped them to reference and compare blood films in haematology practical exercises. Imagine the improvement in learning outcomes for students when they compare their practical results to expected results and can engage their demonstrator in a discussion of the differences before they write up their report. They can then complete the report and submit online before leaving the classroom. Previously, students thought they had understood the point of the exercise only to find out when writing up the experiment at home that results no longer made sense. When learning environments combine both face-to-face and online delivery, the resulting learning outcomes can be greater than the sum of each form of delivery and this is termed blended learning 3.

In 2008, a large practical laboratory was refurbished into what we now call the digital wet laboratories. This space can run as one

Figure 1. Student and demonstrator accessing digital reference material during a biology practical class at RMIT digital wet laboratories.

Video link: http://www.youtube.com/view_play_list?p=F7392CB5 505434FA&search_query=MicrobeGarden
large or two smaller laboratories and provides for 116 student places, each with a student computer workstation. Two instructor workstations are provided, one acting as a master station for the combined space. A chief concern for staff working in the digital wet laboratories was the proximity of Bunsen burners to electrical equipment, so we created an online video instructional package to prepare students on how to safely manage their learning in this space. The laboratories have now been in use for 2 years without damage to the computing equipment. We are currently undertaking a project to develop further video learning packages where video segments can be used in a variety of ways such as pre-practical preparation, in class tuition and as school promotional material.

Blended learning uses and integrates the strengths of both face-to-face learning and online learning to deliver a complete learning experience. Through the support of an RMIT Learning and Teaching Infrastructure Grant, first year classes in microbiology at RMIT have been redesigned to include pre-prac preparation activities, guides to performing exercises, time management guides, links to useful resources and video and finally tips and traps for each practical class. All exercises have been structured as case studies of typical analyses performed in industry. We found that the new blended curriculum has meant students come to class better prepared and are able to interpret and discuss their findings in more meaningful ways. A survey of students’ attitudes towards learning in this new environment was undertaken and the results are presented in Table 1.

Students can readily access help while waiting for a demonstrator and demonstrators can use the online resources to better illustrate the help they give to students (Table 1). The following student comment was received:

**In this particular class the digital learning has been exceptional. Instructions clear, information easy to find and follow and assistance given quickly when assistance required.**

Students have commented they value this innovative use of visual instruction as a departure from the lengthy written instructions of older style practical manuals. From a teaching perspective, we find this blended learning environment an excellent solution to just-in-time teaching and a valued step towards work integrated learning. At RMIT University, students complete an independently administered survey to determine student perceptions of teaching quality. From this a Good Teaching Scale (GTS) is determined. We were able to compare the GTS obtained in 2008 from two cohorts of students at different campuses where the curriculum and teaching staff were the same but only one cohort had digitally enabled laboratories. The other cohort had access to the learning aids but not during their practical classes as their laboratory is yet to be converted into a digital wet laboratory. There was a significant increase in GTS (75/100 versus 53/100) obtained from students who undertook their practicals in the digital laboratory. Interestingly, staff have commented on how focused students appear in dealing with their laboratory exercises in the digital laboratory. The following staff comment is reproduced with permission:

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**Table 1. Students’ rating of their responses to questions regarding their experience of learning in a digital wet laboratory. Scale 1 for strongly disagree to 5 for strongly agree.**

<table>
<thead>
<tr>
<th>Questions</th>
<th>Rating/5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The role of the digital learning support of my practical classes has been clearly communicated to me</td>
<td>4</td>
</tr>
<tr>
<td>I have been provided with constructive feedback in my digital learning support of practical classes</td>
<td>3.9</td>
</tr>
<tr>
<td>Digital learning made my practicals more interesting</td>
<td>4</td>
</tr>
<tr>
<td>Digital learning helped me with my understanding of my practical classes</td>
<td>4</td>
</tr>
<tr>
<td>Digital learning enabled me to prepare for the practical class</td>
<td>4</td>
</tr>
<tr>
<td>I have sufficient support to enable me to use the digital learning materials</td>
<td>4</td>
</tr>
<tr>
<td>Digital learning helped me identify areas in my learning that required further attention</td>
<td>4</td>
</tr>
<tr>
<td>Digital learning demonstrated that I was making progress in my understanding of the practicals</td>
<td>4</td>
</tr>
<tr>
<td>Digital learning demonstrated that I was making progress in my understanding of the overall course</td>
<td>4.2</td>
</tr>
<tr>
<td>Working with digital learning support enhanced my IT skills</td>
<td>3.5</td>
</tr>
<tr>
<td>Digital learning combines well with the learning in the practical laboratory</td>
<td>4.2</td>
</tr>
<tr>
<td>The whole digital learning experience was positive</td>
<td>4.5</td>
</tr>
</tbody>
</table>
I was impressed with how focused the students were in this class I observed in the digital wet lab (quite different to what I see in my lab classes, though I note it is a different student cohort, so that might make the difference!) I want one! I can’t wait until we get a similar lab in my area!

References

Biography
Dr Danilla Grando is a senior lecturer in clinical microbiology at RMIT University. She is also the Digital Technologies Coordinator for the School of Applied Sciences at RMIT.
Learning to teach – teaching to learn

Demonstrating in a practical class has shown a cohort of honours students that effectively communicating knowledge and instructions to students requires careful preparation, precise time management and a clear and inclusive manner and, whilst an enjoyable and rewarding experience, is not as easy a task as they had assumed from their experience as students in their undergraduate days. It has also shown that there are valuable opportunities for personal development for both teacher and learner in a practical class setting.

Teaching in practical classes has invariably been both a valuable and enjoyable experience for many postgraduate research students during their years at university and has provided them with both financial and educational rewards. In our department, the participation of postgraduate research students in practical classes has contributed significantly to the high profile and success of our department in undergraduate teaching, measured not by our scores in quality of teaching surveys, but also by high recruitment rates into our honours and other postgraduate courses. Honours students have not traditionally been included in this teaching experience as it was thought their time was better spent on their course and laboratory work to optimise their chances of receiving research awards.

This view was challenged by a proposal asking honours students to demonstrate in practical classes to students enrolled in a third year engineering subject. It was suggested that learning about the art and science of teaching would significantly enrich the honours students’ program by improving their basic communication skills and providing a setting to develop leadership and group management skills. The practical class work was simple in concept and design and required only a basic knowledge of microbiology, so the focus was not on content delivery but rather on the safe and efficient use of some simple microbiological techniques included in some simple experimental protocols.

The importance of sound preparation before expecting students to begin teaching was well understood. Before the practical classes commenced, the honours students were given 4 hours’ training, 2 hours on the theory and practice of teaching and 2 hours’ instruction and practice in carrying out the practical exercises that they were to teach. Subsequently each honours student was required to teach a group of eight engineering students for 2 sequential weeks, for a total of 4 hours’ practical work. They were also required to mark practical reports. After the laboratory teaching had been completed, a further 1-hour session served as a debrief session, an opportunity to work through the report marking guide provided and a discussion about the reflection they were required to write on the exercise. No marks were attached to this latter task; nevertheless it was completed thoughtfully by all students. Students were paid for participating in the exercise.

It was hoped that this exercise would have three main outcomes. The first would be an increased awareness of the importance of communicating clearly in a laboratory environment. The second would be an increased willingness by honours students to participate in practical teaching in subsequent years and so develop teaching skills as well as their research skills. The third desired outcome, for the engineering students, was an improved understanding of the material covered in their microbiology lectures. To determine if these outcomes had been achieved, honours students were surveyed both before and after their teaching and engineering students answered additional questions on their Quality of teaching surveys.

The first survey, taken before they commenced teaching, showed that the majority of the honours students were looking forward to the experience. Some students expressed concerns around
not knowing what to expect and not being confident about the subject material they had to teach. Most students had found the workshop about demonstrating to be useful and believed it had given them confidence to begin demonstrating; however, one wisely commented “it was wonderful, but you still need to improvise and experience is the only way to learn those skills”.

Students thought they would gain many different things from demonstrating, including experience and confidence in teaching and public speaking and an appreciation of the difficulty of passing ideas and information on to others. For one student it was the opportunity to “Experience as someone who is giving others information and skills rather than receiving them”. For another, it appeared to serve a reinforcing role “… improve my ability to explain basic concepts of microbiology and through that give me more confidence in my own understanding”.

The second survey, taken after the honours students had completed both demonstrating sessions, showed that the majority of students felt a sense of achievement accompanied by relief and that their second teaching session had been more successful than their first. One student, however, was more concerned about how the engineering students rated his performance and commented, “Demonstrating felt great, but I’ll wait to see how they got on with their reports to know if I did a good job”.

Asked to name the greatest difficulties they had faced, the majority of honours students nominated judging the time needed for different activities included in the practical class; others nominated managing their own nervousness, managing slow students, answering questions and successfully demonstrating the techniques.

Overall many things had gone well, in particular their finding that the engineering students were interested, enthusiastic and attentive. A common remark was, “I had a good group of students who were friendly and eager to learn”. For one student, the best part was, “Earning the respect of the students and passing ideas and information on to others. For one student it was the opportunity to “Experience as someone who is giving others information and skills rather than receiving them”. For another, it appeared to serve a reinforcing role “… improve my ability to explain basic concepts of microbiology and through that give me more confidence in my own understanding”.

When asked what changes they would implement in any future teaching, students focused on more effective time management, such as: “keep the students moving especially the slower students” and more careful preparation and detailed explanation. One student said he would “Be less nervous and talk at a slower pace”, another that he would “Practise the techniques more beforehand”.

Honours students were adamant that they had learnt many different things from the experience, including a heightened sense of their ability to take a leadership role and to direct and convey ideas to people. Several reported feeling a significant boost to their self-confidence and self-worth. Overall students said they enjoyed the experience and found it useful. Best of all was the simple statement: “Demonstrating is fun”. Many comments showed an appreciation of the skill and training needed to teach effectively:

“A teacher’s job isn’t as easy as it looks because it depends on the students as well.”

“How different it is knowing how to do something to teaching others how to do something.”

“Thank you for making this part of our course.”

“I enjoyed this aspect of the coursework. It was a nice change from the rest of coursework and lab work.”

“It was definitely a fun and worthwhile experience.”

The engineering students also responded positively. Eighty-four per cent said the microbiology practical classes helped them understand the microbiology material covered in lectures and 82% said the microbiology demonstrators were well-prepared and helpful in the practical classes.

Conclusion

Practical classes offer unique possibilities for discussion and interaction between students and teachers. They are ideal settings in which to enhance the quality of student learning, but only if careful planning and preparation has preceded the actual class. The honours students’ survey responses showed they understood the importance of being well-prepared so they could communicate clearly what needed to be done and how and when to do it.

Their obvious enjoyment and pleasure in interacting with the students augers well for their participation in practical teaching in subsequent years. The positive response by their pupils further confirms the value of continuing this exercise.

References


Biography

Cheryl Power is a lecturer in the Department of Microbiology & Immunology at the University of Melbourne. She has taught microbiology to students enrolled in many different courses for over 30 years. Her educational research interests include the use of assessment to drive student learning and the importance of practical class experiences in microbiology courses. She was Convenor of the Education Special Interest group for over 15 years and was the Guest Editor of Microbiology Australia, Volume 24, No. 4, November 2003 which was the first issue of the journal devoted entirely to educational issues.
Utilising the learning management system to enhance feedback for students

Internet-based learning management systems (LMS) allow academics to automate the provision of timely feedback to students. However, to fully exploit this LMS capability and to further encourage student involvement, teaching staff can add an element of summative assessment to the feedback process.

For those teaching microbiology at the tertiary level, information and communication technologies (ICT) have changed the way in which academic responsibilities are undertaken: the overhead projector has been replaced by PowerPoint slide presentations and web-based LMS are rapidly becoming the central subject administration tools. LMS are university-wide, internet-based systems that provide a platform for the provision of subject content, communication with and between students and both formative and summative assessment. A range of commercially developed and public-access educational software systems are available; however, Blackboard and Blackboard Vista (incorporating WebCT) are the dominant brands of LMS, having been adopted by the majority of Australian universities.

Inherent in the introduction of a university-wide LMS is the risk that its utilisation by academics may involve:

- fairly unsophisticated use of the tools available and in some cases ... (be) used primarily to provide access to information rather than to engage students directly.

In an overview of the use of LMS, Coates suggests that an “LMS may enrich learning by providing automated and adaptive formative assessment which can be individually initiated and administered”. The provision of timely feedback underpins principle seven of the Nine Principles Guiding Teaching and Learning at the University of Melbourne. It is recognised that, for optimal learning, students need to be provided with opportunities to test their understanding by undertaking learning cycles of experimentation, feedback and assessment. This is particularly important in the teaching of microbiology, where students are initially required to become fluent in a new language (microbial nomenclature) while simultaneously acquiring a broad knowledge base to support their understanding of research-based material presented later in their courses.

Case studies on the use of feedback

For the past 6 years, academics in the Department of Microbiology & Immunology at the University of Melbourne have been using the LMS quiz function to provide feedback for their individual classes. These online quizzes serve as formative assessment, giving the students instant, automated feedback on their understanding of core material from their lectures or practical classes. Despite the use of relatively simple true or false questions, staff have found that with careful crafting of questions they can highlight and clarify common student misconceptions.

Feedback quizzes have also been used for a combination of formative and summative assessment in several second year microbiology subjects at the University of Melbourne.

Case study 1

Mrs Cheryl Power coordinates a second-year, lecture-based microbiology subject in which the final mark for around 10% of the class would inevitably fall between 45% and 49%. In 2009, in an effort to encourage students to improve their marks by regularly revising their work throughout the semester, a weekly bank of 10-15 true or false questions was provided for students on the subject site on the LMS. Students had 5 days to complete the questions, with the answers and associated feedback automatically becoming available in the week following each quiz. If students correctly answered at least half of the questions, they received a (small) mark as part of their summative assessment for the subject.
In an in-house survey of these students conducted by Mrs Power [unpublished, 2009] a common response was that the quizzes were very helpful and allowed students to gauge their progress and understanding. Students commented that:

Without them I would have studied much less.

It’s about reminding people to study.

Enforced weekly revision of topics kept me on track and up-to-date.

However, some students criticised the delayed feedback. They were not prepared to note their responses and review their answers a week later.

There should be more immediate feedback so we know what we got wrong.

By the time the feedback is released you forget what you have answered so you can’t see where you went wrong.

Staff recognised that immediate feedback would be optimal but that this would compromise the quizzes, given that the tasks were part of the summative assessment. Students were informed about the aims of the process and also told that it had been hoped that the delayed feedback would provide a useful revision strategy. (A possible resolution for 2010 would be to make a second version of each feedback quiz – with inbuilt immediate feedback – available to students after the summative assessment time frame.)

At the end of semester, there was a 50% reduction in the number of students with a final mark between 45 and 49%, without significant grade inflation, suggesting that the goal of encouraging revision was achieved for at least some of the cohort.

Case study 2

In another second-year microbiology subject, compulsory short answer questions to be submitted before each week’s practical class were introduced on the LMS in 2009. To encourage completion of the weekly tasks, students who made a reasonable attempt at the question/s were rewarded with a small mark towards their final result. The aim was to ensure that students completed the pre-reading and had a clear idea of the main concepts prior to each practical class. An added advantage of this system was that misconceptions apparent in the students’ answers could be readily addressed during the practical classes. Anecdotally, demonstrators reported that students generally seemed well-prepared for the practical classes [personal communication, 2009]; however, one drawback inherent in the 7-day time span allotted for the completion of the questions was that some of those who submitted their responses early had forgotten the material by the time they undertook the practical class. (In 2010, the time allowed for submission of quiz answers will be reduced to the 4 days immediately before each practical class.)

Conclusions

Overall, the LMS provides a convenient portal for communication and teaching, with the possibilities limited, to some extent, by time constraints and the technical abilities of academic staff. Training from LMS support staff and the sharing of pedagogical developments across campus can enhance the usefulness of the LMS as an adjunct to formal microbiology teaching programs. The ability to provide pertinent, timely feedback to students using the LMS appears to enhance teaching and learning, as evidenced by the experiences of academics teaching microbiology at the University of Melbourne.

References


Biographies

Helen Cain is a lecturer in the Department of Microbiology & Immunology at the University of Melbourne. As a medical laboratory scientist, she worked in diagnostic microbiology laboratories at the Fairfield Infectious Diseases Hospital and St Vincent’s Hospital before becoming involved in microbiology education through the teaching of tertiary practical microbiology classes. Her educational research interests include the optimisation of student learning through the use of ICT to enhance the provision of feedback.

Cheryl Power is a lecturer in the Department of Microbiology & Immunology at the University of Melbourne. She has taught microbiology to students enrolled in many different courses for over 30 years. Her educational research interests include the use of assessment to drive student learning and the importance of practical class experiences in microbiology courses.
Collaborative practice re-energises bioscience teaching in schools

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This year marks the first decade of operations for the Gene Technology Access Centre (GTAC). The decade has seen a grassroots initiative by a small group of eminent research scientists and dedicated personnel from the University High School in Melbourne grow into a specialist education centre in cell and molecular biology that attracts over 6000 students and their teachers each year. GTAC has not only refocused student and teacher attention on the interdisciplinary nature of contemporary biology, but has also highlighted how a ‘centre model for learning’, based upon collaboration and partnerships, can exist within ‘the school system’ and meet the needs of students and teachers from across Victoria and beyond.

The key feature of the GTAC learning environment is the role scientists, from postgraduates to eminent research scientists and other professionals play in redefining ‘science learning’ for both students and teachers. Haga 1 in her review of Teaching Resources of Genetics points out that:

... the use of scientists ... as an educational resource is probably under-exploited by the educational system, perhaps because of the absence of liaison between professional scientists and teachers, or because of scientists’ lack of knowledge on how to become involved. [They can] ... provide experience and guidance with laboratory experiments, lead discussions about ethical, legal and social implications, promote careers in science or provide insights about the life of a scientist.

The pivotal role that research scientists can play in redefining the teaching of science in the school classroom was recognised by Professor Suzanne Cory, the former Director of the Walter and Eliza Hall Institute of Medical Research (WEHI) and Professor Dick Strugnell and his colleagues from the Department of Microbiology & Immunology at The University of Melbourne. Inspired by her visit to the Dolan DNA Learning Centre at Cold Spring Harbor Laboratories on Long Island New York in 1995, Professor Cory and her colleagues at WEHI established a pilot program in DNA Science for senior school students from selected schools. Encouraged by the enthusiastic response from students and teachers, Professor Cory teamed up with Professor Jim Pittard from the Microbiology and Immunology Department of the University of Melbourne. In 1996 they initiated a week-long DNA Science Summer School for secondary school teachers to update their knowledge of DNA science.

In 2000 the then Principal of University High School, Bronwyn Valente, and I held discussions with Professor Suzanne Cory and Professor Dick Strugnell. These discussions resulted in a joint application, under the Victorian government’s Science in Schools Partnership (SIS), to establish programs, accessible to all Victorian secondary students and teachers, in contemporary molecular cell biology, under the GTAC banner, at the University High School. The GTAC logo depicting the four letters that constitute the genetic code not only represented the nature of the specialisation, but also reflected how teaching and learning objectives would link vision to practice.
Genes (and other biomolecules)

The molecular basis of life not only reflects the focus of much of contemporary biological research but highlights the interdisciplinary nature of contemporary biology. GTAC places particular reference on the role played by the physical sciences and information technology in the emerging fields of genomics, proteomics and chemical biology. A raft of programs introduces students to DNA manipulation techniques and basic microbiology through to tracing primary and secondary antibody responses to a vaccine through the use of an ELISA protocol. Many programs have a ‘real life scenario focus’. In the Bacteria Bandit, Year 10 students investigate an outbreak of food-borne disease at a music festival and employ diagnostic microbiology tools to identify the species and strain of bacteria responsible, based on morphology and biochemistry. On elucidating the identity of the bacteria bandit, they use molecular techniques to determine the source of this outbreak and recommend control measures to stop the spread of this food-borne pathogen.

Technology

Technologies are used to highlight the nature of contemporary bioscience and to present concepts using highly visual multimodal representations that capture student interest and assist learning. ICT is used to visualise higher order concepts in cell and molecular biology through animations, simulations and website resources. GTAC was the first to develop a range of bioinformatics tasks for students and teachers that use global databases in real time. In addition, teachers and students have access to visual representations and podcasts via our website to assist teaching and learning.

Access

Programs not only provide all Victorian teachers and students with quality resources that assist the learning and teaching of molecular and cell biology, but also provide school students with the opportunity to work in small groups with young scientists at the laboratory bench. GTAC conducts one of the largest mentoring programs in the country, with over 50 postgraduate students working with school students on a weekly basis throughout the school year. The building of a positive and supportive learning environment that engages the student builds confidence and promotes a dialogue that informs the student about the nature of the scientific enterprise and the diversity of scientific career options. Of equal importance is the opportunity the programs provide for postgraduate students to engage in ‘an outreach activity’ that develops their communication and presentation skills.

Teacher professional learning programs give teachers access to eminent research scientists and provide them the opportunity to update their skills and knowledge and so enrich classroom practice and to reconnect with their academic discipline. Over 100 of the country’s eminent research scientists have inspired teachers with their research stories. Programs delivered by University of Melbourne staff from the Department of Microbiology & Immunology include presentations and workshops on the innate and adaptive immune responses, vaccine technology and case studies of current local issues such as the Bairnsdale Ulcer and the H1N1 influenza virus.

Centre, collaboration and culture

The strength of formal and informal partnerships with stakeholders and supporters from tertiary and scientific research sectors has ensured that the centre is not only well resourced physically beyond the ‘school norm’, but is also knowledge-rich. Collaborative work practices have resulted in a learning environment that spans the secondary and tertiary education and research sectors. GTAC is indebted to the teaching and research staff from the Department of Microbiology & Immunology and to their many postgraduate students who have acted as ‘scientist mentors’ over the years. They have given generously of their time, intellectual property and resources to assist GTAC staff in the development, implementation and delivery of programs for students and teachers. Haga concludes that partnerships between scientists and teachers and school systems are probably the most effective way to advancing science education.

GTAC is an exemplar model of such a partnership in action.

To find out more about GTAC visit
http://www.gtac.edu.au

Reference


Biography

Mr Stevenson has taught biology and chemistry for over 35 years and has headed semi-autonomous sub-school structures to facilitate student management and learning in various Victorian government schools. In addition he has been chemistry and biology method lecturer in the Faculty of Education at the University of Melbourne. Mr Stevenson has played a pivotal role in the establishment of GTAC and is currently GTAC Director. He was a member of the VCAA Biology Study Design Review Committee in 2004 and previously a member of the Cold Spring Harbor DNA International Advisory Panel that recommended the production of the DNA Interactive DVD as a classroom teaching tool. Mr Stevenson is author of Talking Molecules, a student workbook that promotes student understanding of the molecular concepts in the senior biology curriculum. He is a recipient of the Australian Federation Medal for his work in the establishment of GTAC and more generally in the promotion of contemporary biotechnology education. Mr Stevenson has been twice nominated for the Prime Minister’s Prize for Excellence in Science Teaching in Secondary Schools.
Practicum and work experience in microbiology and related disciplines

Gaining hands-on experience throughout an undergraduate degree is regarded as a competitive advantage by science students. At the Gippsland campus of Monash University, the Industry Placement Program (IPP) allows students to gain industry experience throughout their entire course. Science students enrolled in the IPP undertake a practicum learning experience, equivalent to a 12-point unit, whose emphasis is on identifying and building transferable skills while gaining technical competency. The combination of academic studies, relevant paid work experience and professional development training produces capable, work-ready graduates.

The ability to develop transferable skills during undergraduate courses has become an important feature for students and employers alike. Students graduating from their academic course with skills obtained in a workplace setting have a competitive advantage in their search for employment. At Monash University in Gippsland, the IPP integrates academic study with practical work experience. Similar cooperative or work-integrated learning (WIL) programs are also conducted across all academic sectors in other states of Australia and overseas.

Cooperative programs provide a structured educational strategy that allows the student to integrate and apply academic concepts through productive work experience in a field related to their professional future. Such programs help students relate theory to practice while providing the experience of working in a professional environment and, therefore, the opportunity to develop relevant professional skills. These experiences, at the heart of the program, involve a partnership between students, educational institutions and employers. This effective partnership must be embedded in the scheme’s practice with the responsibilities of each party agreed and clearly specified.

The IPP at Monash Gippsland combines academic study with periods of relevant work experience. Students enrolled in the Bachelor of Science and associated degrees are eligible to participate in the IPP; selection is based on academic merit and interview. The typical pattern of work placement involves an introductory, 2-week placement, followed by a 6-week placement in the second year of degree studies, then a 6-month placement in the final year of the degree. Work placements are preceded by extensive workplace training provided by the university.

For example, students have often only held temporary or part-time jobs without receiving interview exposure. Trial interviews enhance students’ performance in pre-placement interviews and assist in building students’ self-efficacy to a level where comprehensive, formal interviews will not be a formidable challenge. A range of other activities are conducted to assist in the development of competencies, including development and practice of communication skills, professional ethics and conduct, personal organisation and networks and industry or organisational knowledge and participation. The 6-month placement is credited as a 12-point unit, so constitutes one-quarter of a year’s study load. On an hourly basis, the study load for this unit greatly exceeds that of two 6-point academic units, yet demand for participation in the IPP exceeds the number of places. This reflects both positive feedback from previous participants in the program and the high value that students place on obtaining relevant work experience.

Science students participating in the program are required to work through a set of activities to identify learning objectives appropriate to the individual and to the placement. These fall into the following broad categories:

- Personal and professional development.
- Industrial understanding at the team, organisation and industry level.
- Scientific skills and knowledge.
Once the student’s personal learning objectives have been identified, a learning contract that identifies these objectives, along with a pathway to achieving them, is produced. This is a consultative process resulting in an agreement between the student, the organisation and the academic advisor and is usually finalised within the first few weeks of placement. Martin and Leberman (2005) argue that the development of the learning contract is an important way to formalise student, university and organisation expectations by clearly establishing initial project objectives and anticipated outcomes.

Examples of personal learning objectives that students have identified, strategies to obtain them and resources they would require are provided in Table 1. Self-confidence is the competency most often referred to by supervisors and identified by students. Developing personal learning objectives around competencies identified allows the student to develop strategies to overcome specific challenges. The placement review comprises feedback from the industry supervisor and a self-assessment by the student. Upon completion of the industry placement, the student is required to provide evidence for his or her learning based on the identified objectives, by preparing a written report (approximately 3000 words) and delivering an oral presentation to university and industry members and peers, both of which are assessed by academic staff. Final assessment is by Pass Grade Only (PGO).

In general, the university manages the placement positions and engages with the industry partners. An initial screening by the university is done to match the type of employment or industry to the student’s course and interest. Employers are invited to interview a number of students before selecting the most suitable candidate. Effective communication between the university and industry supervisors and the student is especially important during the early days of their placement, so that any issues that arise are recognised and suitable intervention measures implemented. It is important that students are given opportunities to discuss their transition to the workplace and are aware of support available should problems arise.

As students’ exposure to workplaces can range from tackling a specific task or project within the workplace, to acting in a fully integrated workplace role, the students’ scientific and technical skill development may vary accordingly. Aspects that feature prominently in any work experience situation are those of personal development; self-confidence; diversity and flexibility of the organisation; a greater awareness of regulatory environments and occupational health and safety requirements; and, in particular, identifying the role of teams and individuals within teams.

Technical skill development has required students to draw on generic skills to produce a successful outcome. For example, one project involved commissioning an instrument designed for affordable automated pathogen screening, such as Salmonella sp. in the dairy industry. This involved communication with technical staff, familiarisation with the instrument, developing operation protocols and finally a training program for other staff. In a different situation, a student was involved in monitoring the quality of drinking water released from a limited capacity

### Table 1: Students are required to identify personal learning objectives for their industry placement and to demonstrate that these objectives have been achieved. A table, such as the one below, forms the basis for initial discussions between the student and the supervisory team and provides the framework for the formal learning contract, signed by all parties.

<table>
<thead>
<tr>
<th>Category</th>
<th>Placement Learning Objectives</th>
<th>Strategies to Meet Objectives</th>
<th>Resources Required to Meet Objectives</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team and Organisation</td>
<td>Identify the various positions and task within teams and learn to utilise current and new skills within a team</td>
<td>Become involved in different teams where possible Be responsive and aware of roles and duties within the team and at the organisational level</td>
<td>Supervisor/manager Work colleagues Peers</td>
<td>Participation in different management teams, with different personal roles Taking responsibility for team work when appropriate</td>
</tr>
<tr>
<td>Ethics</td>
<td>Adhere to practices that will maintain confidentiality of information</td>
<td>Understand the level of confidentiality needed for given scenarios/situations Become familiar with ethics policy.</td>
<td>Official policy documents Supervisor Higher ranking peers</td>
<td>Adherence to company code of conduct Ensure confidentiality when working, e.g. leave off names or addresses when sending out information</td>
</tr>
<tr>
<td>Scientific skills</td>
<td>Expand my knowledge and experience with scientific practices in the field and interpreting data from both the field and databases</td>
<td>Follow instructions given by supervisors in given situations Clarify doubt by engaging supervisors when unsure on given topics Where possible use material from tertiary studies in work situations</td>
<td>In-house training materials, Inter/intranet Supervisors, Work colleagues Books/journals Seminars, conferences</td>
<td>Field work and data collection Acquisition of specific skills, including workplace software, data management and LIMS systems</td>
</tr>
<tr>
<td>Scientific knowledge</td>
<td>I want to learn about the major impacts on water quality in significant catchments and how the issues can be minimised</td>
<td>Review the current literature Design and conduct a project studying catchment water quality issues</td>
<td>Books and journals Government or other official publications and documents Scientific experts Field visits</td>
<td>Written review of past research Produce project report</td>
</tr>
<tr>
<td>Personal development</td>
<td>To learn how to prioritise work, so that all projects are completed within a required timeframe</td>
<td>Create a ‘to do’ list on a regular basis, with priorities and dates where possible</td>
<td>Conversations with supervisors to determine relative priorities Have a copy of my ‘to do’ list with me all the time</td>
<td>Work diary Punctual completion of projects</td>
</tr>
</tbody>
</table>
water storage facility. This required the student to familiarise herself with the analytical and microbiological tests required on a routine basis, as well as researching some more unusual occurrences associated with the prevailing drought conditions.

During their placement, students obtain a deep understanding of how teams operate and how they, as individuals, best contribute in a team situation. Having seen a variety of teams in action, they appreciate that, in some instances, structured teams with clearly identified reporting lines are required, while more flexible team structures are appropriate in other situations.

Students enrolled in placement units are able to translate theory into practice and become acutely aware of the workplace framework. In particular, the importance of risk assessments and compliance with occupational health and safety legislation highlights the importance of these, often underappreciated, areas of study. In this regard, the advantages provided by the IPP extend to students not enrolled in the program. The classroom becomes informed by the practical experiences of students undertaking placements, who are often able to provide alternative examples and/or case studies that enrich the learning experience.

In summary, the IPP benefits the entire university community:

- **IPP students** acquire personal and technical skills that enhance their employability.
- Their ability to offer new perspectives and to contribute to class discussion enriches the learning experiences of other students and assists lecturers to provide theoretical information in an applied context.
- Communication between academic supervisors and employers highlights opportunities for industry collaboration and community engagement.
- The placement of capable students in industry situations assists in marketing and promotion of courses and programs.

While the organisation and management of such a program requires a significant commitment by university academics and administrative staff, this is adequately compensated by the advantages it provides to the students enrolled in their program and their peers. Students have been able to meet potential employers and form lasting networks while at the same time gaining broader knowledge and life skills. Interest in the program is high among students and the continued interest demonstrated by industry partners highlights the perceived value of such programs within the wider community.

### References


### Biographies

Kirsten Schliephake is an industrial microbiologist with teaching and research interests in the area of environmental biotechnology and industrial application of micro-organisms. She has guided and supervised projects as diverse as investigating the remediation potential of surfactant wastewater from air force base firefighting equipment, removal of petroleum hydrocarbons by aerobic micro-organisms using composting technologies, decolourisation of paper mill wastewater using fungal enzymes and fungal biomass and anaerobic digestion of industrial wastewaters.

Jennifer Mosse is a molecular biologist, with a particular interest in molecular virology. Jennifer is currently involved in projects studying the expression of negative sense genes in HIV-1, investigating mechanisms of drug resistance and strategies for antiviral therapy in influenza viruses. Jennifer has a long-standing interest in science education, particularly in the flexible delivery of science programs to remote students and in designing science programs of both local and international relevance.
Science by its very nature is interdisciplinary and scientific research relies on the collaborative skills and expertise of researchers across the disciplines. Yet, science as taught in the university classroom is usually compartmentalised into separate subjects. Most undergraduate students are not exposed to the excitement and challenge of connecting the concepts, skills and processes learnt within these distinct disciplines until they enter the laboratory as an honours student. Indeed, opportunities for problem-solving, novel application of concepts, articulation of the broader impacts and societal benefits of scientific research and understanding are not usually explicitly designed and scaffolded as an integral part of the university syllabus, but these lifelong skills are essential for scientific thinking.

Furthermore, one of the most crucial elements that nurtures scientists’ engagement and creativity is seldom considered an essential component of the curriculum – the interaction with local, national and international peer communities to share, to receive feedback and to foster new ideas and collaborations. Considered from a holistic perspective, many academics tend to focus on content, while the process of scientific inquiry is peripheral to the formal syllabus. The scholarship of teaching and learning brings the focus back to inquiry thinking and learning, by prompting academics to critically engage with the pedagogical process.

The scholarship of teaching and learning (SoTL) enables academics and their respective disciplines to consider a more integrative approach to student learning. In 1990, Ernest Boyer’s seminal report Scholarship Reconsidered: Priorities of the Professoriate called upon universities to rethink what scholarship means. Four types of academic scholarship were outlined by Boyer:

- Scholarship of discovery, referring to the disciplinary research academics engage in and publish.
- Scholarship of integration, referring to the intellectual work and writings allowing us to construct, see and understand the connectedness of all things.
- Scholarship of application, referring to the application of knowledge to real world problems for the betterment of worlds big and small.
- Scholarship of teaching, referring to the works of helping others understand and construct knowledge so they may engage in the other forms of scholarship.

The first three scholarships are easily understood and practised by science academics. As defined by Boyer, the scholarship of teaching (now extended to include learning) connects and encompasses all other forms of scholarship and facilitates their perpetuation. Academics have years of formal and informal apprenticeship and mentoring in their discipline. They possess the fundamental knowledge to conduct evidence-based research: they know how to review and query the literature; define answerable problems; design appropriate measures; collect and analyse data; and publish their findings in scholarly journals. What has been missing is the transfer or application of these same research skills from their discipline to their teaching. When science academics engage their teaching with the same toolsets and rigour that they routinely use in their disciplinary research, the results are transformative for the academic, the students learning in their classes and the curriculum. Applying the scholarship of discovery to one’s teaching should be a natural process for scientists. It is when teaching and research are siloed into separated compartments that researchers fail to apply their research scholarship skills to teaching.

In essence, the scholarship of teaching and learning catalyses the
Integrative learning develops when teaching is considered through an integrative framework. One might consider a challenging problem in teaching and look to successful models from other disciplines to understand how a process works. Take the previous challenge described above, that of the lack of engagement in authentic science inquiry communities in undergraduate courses. Such communities interact collaboratively and develop the disciplinary habits of mind that real scientists utilise. In order for students to actively become part of a community of inquiry, they need to develop inquiry thinking. What makes it challenging to teach inquiry thinking? Common responses from science academics include the following:

- Concept of learning through inquiry versus spoon-feeding.
- Engaging in the process of learning instead of someone handing them the material.
- Connecting inquiry in principles to inquiry in reality (theory versus application or real life).
- Making abstract concepts or hypothetical situations ‘real’.
- Helping students recognise that they need to ask questions at certain key points.
- Teaching students how to ask relevant, informed questions.
- Teaching students how collaborative dialogue leads to new questions and further inquiry.

Each of these points can serve as a starting point for further investigation by academics into their students’ learning. On the other hand, one could look for a broader framework by taking the previous challenge described above, that of the lack of engagement in authentic science inquiry communities in undergraduate courses. Such communities interact collaboratively and develop the disciplinary habits of mind that real scientists utilise. In order for students to actively become part of a community of inquiry, they need to develop inquiry thinking. What makes it challenging to teach inquiry thinking? Common responses from science academics include the following:

- They lead to the empowerment of ideas.
- They lead to the empowerment of voices.
- They are ‘dendritic’ – that is, like the cells of the neural network, they branch out, they are receptive to a range of incoming signals and they function to amplify signals.
- They are ‘symbiotic’ – the interdependence of the original pedagogies that form the hybrid pedagogy facilitates cognitive blending and risk-taking.

The scholarship of teaching and learning can illuminate other ways to integrate disciplines and enable us to create more successful approaches to curriculum development for the coming generation of students, who represent a diverse learning population.

References

Biography

Kathy Takayama’s interests are in: i) the regulation of RNA processing mechanisms; ii) visualisations in science education; iii) the integration of art and science; iv) online learning communities; and v) the Scholarship of Teaching and Learning (SoTL). From 1994 to 2007 she was an academic in the School of Biotechnology & Biomolecular Sciences at the University of New South Wales in Sydney, Australia. She is currently the Associate Director for Life & Physical Sciences at the Sheridan Center for Teaching and Learning, and Adjunct Associate Professor in the Department of Molecular Biology, Cell Biology and Biochemistry at Brown University. Kathy is a Carnegie Scholar and a founding member of the International Society for the Scholarship of Teaching and Learning. She is also a recipient of the 2005 ASM David White Award for Excellence in Teaching.
“At the end of my course, students should be able to …”: The benefits of creating and using effective learning goals

At the University of Colorado at Boulder (CU), several science departments – including Molecular, Cellular, and Developmental Biology (MCDB) – are working to improve undergraduate science education as part of the Science Education Initiative (SEI). The SEI is a 5-year project designed to support faculty-led, departmental-wide improvements in students’ learning of and engagement in science 1. In each of the five funded departments, faculty are taking a scholarly approach to transforming their courses and introducing proven teaching practices 2. An important first step in course transformation has been to define explicit learning goals (also known as “learning outcomes” or “objectives”) for each course. In this paper, we focus on the process and benefit of writing learning goals, with specific examples from CU’s MCDB department.

Unlike a syllabus, learning goals do not merely list the topics to be covered. Instead they explicitly communicate the key ideas and the level at which students should understand them in operational terms 3, 4. Learning goals take the form: “At the end of this course/lecture/unit, students will be able to …” followed by a specific action verb and a task. For each course, faculty typically define five to ten course-level goals that convey the major learning themes and concepts, as well as topic-level learning goals that are more specific and aligned with the course-level learning goals. Figure 1 shows examples of learning goals from an introductory genetics course. A compilation of examples from the SEI efforts has also been developed 5.

Many faculty members have formed working groups to formulate learning goals. Those faculty members who have previously taught a course begin to write learning goals by sharing their syllabus, homework assignments, exams and other materials that demonstrate what they want students to be able to do. In addition, faculty members who teach subsequent courses communicate what they expect students to know coming into their course. These working groups typically include a facilitator whose role is to review and synthesise materials and create learning goal drafts. The members of the working group discuss and revise these learning goals until a consensus list is generated, which for any instructor teaching the course would typically cover 70% of the class time.

Based on our experiences with these working groups, we formulated a checklist to help ourselves and our colleagues create and critique learning goals (Figure 2). One of the most critical aspects of writing learning goals is choosing a verb that describes exactly what students should be able to do 3, 4. Many faculty are tempted to use the verb “understand” such as: “students should understand how to do a genetic cross.” However, “understand” is not specific – two faculty members could both say “understand” but have completely different expectations as to what students should be able to do. A more specific learning goal is: “Students will be able to design genetic crosses to provide information about genes, alleles and gene functions.”

We also aligned the verb with the level of cognitive understanding expected of students. Table 1 shows levels of learning and examples of verbs that match each level 3, 6, 7. Even in introductory courses, CU students are expected to learn, and benefit from learning, beyond the factual knowledge and comprehension level, so each course includes learning goals aligned with the higher levels of analysis, synthesis and evaluation.

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At CU, we have also made an effort to craft learning goals that convey the relevance and usefulness of any particular content to students. Specifically, we used everyday language and applications where possible and were selective and minimal in the use of specific, technical terms. In addition, we did not limit learning goals to course-specific content. Many courses at CU include goals that focus on skills, habits of mind and affective outcomes such as: “Students should be able to justify their thinking and/or approach to a biological question, in either written or oral form.”

Writing learning goals requires effort and time, but carries multiple benefits for the faculty who write the goals, their students and the department as a whole. Once defined, faculty turn to the learning goals as they plan class time, develop homework and write exams. As a result, all aspects of the course become better aligned and focus on what faculty most want students to achieve. Faculty using learning goals also report that writing high-quality exam questions becomes faster and easier. At CU, we have seen that the cognitive level of exams often increases as faculty align the questions with the higher cognitive level of the learning goals.

When faculty share learning goals with students, students and faculty both find substantial benefit from the improved communication. At CU, faculty use a variety of ways to communicate learning goals, including posting them online and beginning each lecture by presenting the relevant learning goals for the day. One MCDB faculty member, Dr Bill Wood, explains that learning goals decrease frustrations for both students and faculty by giving the students an answer, up front, to the perennial question “what’s going be on the final exam?” He adds:

Learning goals are student-centered, telling students what levels of understanding they should achieve and what they should be able to do when the course is completed.

End-of-year surveys reveal that students are overwhelmingly positive about having access to learning goals. Students report the greatest benefit is that learning goals let them “know what I need to know”, which helps students focus on important ideas and study more effectively.

For departments, writing learning goals has informed, shaped and aligned the departmental curriculum. By considering the learning goals from multiple courses, departments have discovered that some concepts were taught in an identical manner in multiple courses and other critical concepts were omitted entirely. As a result, faculty members who teach different courses have begun to work together so that their goals complement each other and encompass what every student should be able to do by graduation. For instance, some fundamental evolution concepts were added to the MCDB curriculum after this process highlighted their absence.

Finally, one of the greatest benefits we have seen with learning goals is that their creation has increased intellectual discussion among faculty regarding education issues. These discussions not only include determining key learning goals, but also what types of promising educational practices can be used to teach and assess these goals. As more faculty are systematically measuring what their students are learning, they also continue to revise their learning goals to improve upon what students should be able to do at the end of each course.

Figure 1. Examples of learning goals from an introductory genetics course.

Course learning goal: Deduce information about genes, alleles and gene functions from analysis of genetic crosses and patterns of inheritance.

Topic learning goals:

a) Draw a pedigree based on information in a story problem.

b) Distinguish between different modes of inheritance.

c) Calculate the probability that an individual in a pedigree has a particular genotype or phenotype.

d) Design genetic crosses to provide information about genes, alleles and gene functions.

e) Use statistical analysis to determine how well data from a genetic cross or human pedigree analysis fits theoretical predictions.

Figure 2. Checklist for creating learning goals.

- Does the learning goal identify what students will be able to do after the topic is covered?
- Is it clear how you would test achievement of the learning goal?
- Do chosen verbs have a clear meaning?
- Is the verb aligned with the level of cognitive understanding expected of students? Could you expect a higher level of understanding?
- Is the terminology familiar or common? If not, is knowing the terminology a goal?
- Is it possible to write the goal so it is relevant and useful to students (for example, connected to their everyday life, or does it represent a useful application of the ideas)?
Table 1. Levels of cognitive understanding and corresponding verbs.

<table>
<thead>
<tr>
<th>Level* of cognitive understanding</th>
<th>Description</th>
<th>Representative verbs</th>
</tr>
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<tbody>
<tr>
<td>Factual knowledge</td>
<td>Remember and recall factual information</td>
<td>Define, list, state, label, name</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Demonstrate understanding of ideas and concepts</td>
<td>Describe, explain, summarise, interpret, illustrate</td>
</tr>
<tr>
<td>Application</td>
<td>Apply comprehension to unfamiliar situations</td>
<td>Apply, demonstrate, use, compute, solve, predict, construct, modify</td>
</tr>
<tr>
<td>Analysis</td>
<td>Break down concepts into parts</td>
<td>Compare, contrast, categorise, distinguish, identify, infer</td>
</tr>
<tr>
<td>Synthesis</td>
<td>Transform and combine ideas to create something new</td>
<td>Develop, create, propose, formulate, design, invent</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Think critically about and defend a position</td>
<td>Judge, appraise, recommend, justify, defend, criticise, evaluate</td>
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*The levels listed here are based on Bloom’s taxonomy of the cognitive domain 7. These levels are useful for distinguishing between higher and lower levels of thinking, but do not necessarily function as a strict hierarchy 8.

References


Biographies

Michelle Smith is a Science Teaching Fellow at the University of Colorado, Boulder. Her research interests include developing pre/post assessments for biology courses and assessing and maximising the value of peer discussion in large enrolment courses.

Katherine Perkins is Associate Director of the Science Education Initiative and co-Director of PhET Interactive Simulations at University of Colorado, Boulder. Her work in physics and science education focuses on: pedagogically-effective design and the use of interactive simulations; students’ beliefs about science; and effective and sustainable course reform.

Acknowledgements

We are grateful to the Science Education Initiative, University of Colorado, Boulder for full support of M.K.S and partial support of K.K.P. We also thank Carl Wieman, Jennifer Knight and William Wood for intellectual support and comments on the manuscript. Finally we thank the CU faculty for their continued efforts towards writing learning goals.
The 2008 Review of Australian Higher Education highlighted current financial constraints on higher education in Australia that impact negatively on the quality of student experience and their learning outcomes. Practical laboratory experience is costly in providing venues, staffing, materials and equipment. However, the practical nature of microbiology necessitates acquisition of significant knowledge and experience of laboratory skills to effectively support the profession. This article provides evidence that inclusion of practical classes in undergraduate microbiology courses has multiple advantages: quality learning facilitated through experiential, engaging learning activity; undergraduates in theory plus practical courses achieve significantly higher results than those taking theory-only units; and student feedback that articulates that laboratory experience facilitates quality learning outcomes.

The recent 2008 Review of Australian Higher Education found that:

Australia is falling behind other countries in performance and investment in higher education [and] there is abundant evidence that government provision of funds for underlying infrastructure to support research in universities is very significantly below the real costs...leading to...cross-subsidy from funds for teaching, adversely affecting the quality of the student experience.

Alarmingly, Australia is the only OECD country where public contribution to higher education has remained at the same level for the 10 years: 1995 to 2005. The promise of the current Labor government of an education revolution has had little impact in the current global economic crisis and universities remain increasingly dependent upon income from international student registrations.

With these financial constraints on tertiary education, it would be tempting and arguably understandable for universities to make the strategic decision to reduce expenditure on undergraduate teaching of costly laboratory sessions that require specialist venues and infrastructure, significant technical and casual academic staffing, equipment and materials. However, the Australian Learning & Teaching Council recognised the importance of practical experience when it recently recommended a commitment to the inclusion of laboratory work, specifically in first-year undergraduate science classes.

In this sensitive financial climate, higher education is changing with remarkable rapidity and functioning in “an age of supercomplexity”, impacted upon by globalisation, digital technologies, competition, agendas of participation, access and equal opportunities as well as systems for evaluation of quality. Academics are placed in a tenuous position in teaching undergraduates where the aim is to develop and foster skills that will equip graduates well for the workplace.

The case for incorporating significant practical components in undergraduate microbiology courses is supported by several aspects, which will be addressed in the following sections.

Under the Microscope

Significance of laboratory experience in undergraduate microbiology

Engaged interactive learning during microbiology practical classes.
The inherent practical nature of the discipline of microbiology

Microbiology is a discipline involving significant hands-on skills of dexterity, accuracy and reproducibility for isolating, identifying and testing microbes, underpinned by the need for maintenance of aseptic technique. Furthermore, the ability to effectively perform molecular techniques in diagnostic, quality control and research contexts is contingent upon acquisition of significant practical skills. Such significant hands-on skills and an overarching knowledge of the theory of practical techniques and applications are therefore graduate attributes that are critical for a successful career in microbiology and necessary for application in its many facets: industrial, environmental, pharmaceutical, medical, food and agriculture.

The wet laboratory provides the learning environment for acquisition of this knowledge and practical skills. However, in a climate of increasing student numbers and decreasing tertiary budgets, evidence has been provided for effective learning outcomes using dry laboratory contexts such as case studies, problem-based activities, computer simulations and virtual laboratories. Nevertheless, Raineri believes that “nothing can or should be used to replace the traditional hands-on approach to learning experimental techniques”. By downgrading teaching of laboratory skills and aptitudes, the risk is run of a consequential skills shortage in the workplace, as is currently the case in the biosciences in the UK, both in the number of skilled graduates and the extent to which graduates are appropriately skilled.

Practical microbiology promotes quality learning

It is well-established that high-quality teaching fosters active learning through student engagement in ways likely to result in their understanding. Several studies have shown the importance of developing critical thinking skills such as problem-solving, developing concepts and experimental design. In microbiology, it is impossible to teach every possible technique and it is therefore transferable skills of reasoning and critical evaluation achieved through application, analysis and creation, that are important for today’s graduates.

Individuals learn in different ways using three senses: visual, auditory and kinaesthetic. Practical wet microbiology sessions inherently engage the kinaesthetic sense of movement and touch in hands-on activities, thus employing a kinaesthetic approach to learning. Action and activity are important for learning and by engaging all three senses, the quality of learning is improved. Practical experience also supports procedural memory by facilitating long-term memory of skills and procedures. In this context, quality learning is facilitated through relevant hands-on activities that are designed to provide students both choice and control of their learning process and also to foster interaction with peers for articulation and exchange of opinions and perspectives.

Recent research demonstrated that an inquiry-based approach enhanced student understanding in microbiology. The laboratory context is one of the most appropriate ways in which to explore research-led teaching and can be used effectively to provide research experience to students, in which they investigate problems related to the design and execution of a scientific investigation and are challenged to develop skills in critical analysis, effective communication and group interaction. Caccavo suggested that utilisation of research-based principles and techniques to facilitate active learning in higher education microbiology supports lifelong self-learning and will propel student learning within the discipline. Furthermore, the incorporation of original laboratory-based research projects for senior microbiology students was shown by McLean to motivate and prepare students to pursue careers in science. Research projects have been incorporated in the curriculum for advanced senior microbiology students at the University of Sydney for several years, fostering high order learning skills and stimulating progression to honours and higher degrees in the discipline.

Practical experience supports higher grades in undergraduate microbiology

Further evidence to support the significance of practical experience in microbiology comes through data from students enrolled in two introductory, intermediate units of study at the University of Sydney from 1998 to 2004. One unit contained both lecture and practical components, while the other was entirely lecture-based. The average number of students enrolled in the unit containing practical sessions was fourfold that of the theory-only unit, indicating, amongst other factors, that students recognised the importance of practical experience in supporting their learning in microbiology. Alternatively, students might opt to take the theory-only unit as a perceived easier alternative or if suffering from workload problems.

In analysing the results of students in the units by calculating mean values and comparing per unit per year, it was found that:

- Results of students in the lecture plus practical unit were significantly higher, by 10% on average, than results of students in the theory-only unit (P<0.015).
- The proportion of students with failing grades: absent fail, fail and conditional pass (no progression permitted) was significantly higher, by 33% on average in the theory-only cohort than in the lecture plus practical unit (P<0.05).

These findings were achieved despite the inverse finding that students taking the theory-only course entered the unit with previous academic performance significantly higher, by 9% on average, than students enrolled in the theory plus practical course (P<0.004), measured in individual AAMs (previous year’s annual average mark). Although lack of motivation, laziness and workload issues could have contributed to poorer performance by theory-only students, clearly, practical experience in introductory
undergraduate microbiology at the University of Sydney provides students with better learning outcomes than students taking the theory-only unit and significantly supports progression in the discipline.

**Student feedback recognises the value of practical classes**

Finally, in a student evaluation survey for a senior unit, MIRC3011 Microbes in Infection in 2007, when students were asked what things about the practical sessions helped their learning, written comments included:

*hands-on activity … enhanced learning and allowed us to understand the concepts better*

*gives what we learn relevance*

*taking part and interacting was … beneficial*

*provide real world applications of what we were learning in the lectures*

*in conjunction with lecture material, reinforced learning*

These students articulated how practical experience provided relevance and application, how their learning was enhanced through engagement and why deeper understanding was stimulated through reinforcement of theoretical principles. Support for these findings is found in the outcomes of a recent survey of Australian first-year nursing students that, of lecture, practical and tutorial deliveries, practical sessions were the most favoured strategy to benefit their learning with the preferred sensory mode being kinaesthetic, the hands-on approach to learning. Furthermore, first-year students in the UK articulated social interaction as an important part of their learning experience and contributed to “good practicals”.

In conclusion, this is compelling evidence that supports the inclusion of significant practical experience in undergraduate microbiology courses. Not only does the discipline have an inherently practical basis, but quality student learning outcomes result from experiential, engaged activities. Additionally, evidence is provided that students enrolled in an undergraduate introductory microbiology course, containing practical components, achieve significantly better results than students in the theory-only course. The potential exists through practical, research-led teaching to equip microbiology graduates with deep understanding and enthusiasm for the discipline by fostering assimilation, synthesis of ideas and critical thinking skills that are of real value in a dynamic, changing society.

**Acknowledgements**

Dr Peter New and Mrs Ilze Dalins are thanked for their contribution to intermediate microbiology courses 1998-2004 and microbiology students for laboratory images at the University of Sydney.

**References**


**Biography**

Helen Agus is a senior lecturer in microbiology in the School of Molecular & Microbial Biosciences, Chair of the School Excellence in Learning, Assessment and Teaching Evaluation Committee, Associate Dean for the Faculty of Science (Undergraduate Matters) and a member of the BMedSc degree program executive at the University of Sydney. She is involved with course design, strategic direction and teaching undergraduate microbiology and has research interests in medical microbiology.
Frequently there is a disconnectedness, either perceived or actual, between theoretical principles and laboratory practice in science education and this holds true for clinical microbiology where traditionally knowledge is delivered in ‘chunks’ in a lecture format with the misguided belief that students have to know ‘everything about everything’. This preoccupation with content delivery often leaves no time for active class discussion or reflection. Moreover, laboratory classes are treated as add-ons to the process, rather than an integrated part of the whole learning experience. In redesigning our units (subjects) we have bridged the gap between the theory and practice of clinical bacteriology. In doing so, we have seen a transformation in the learning experiences of our students and in the way we teach.

In studying clinical bacteriology, a student’s key learning outcome should not be acquisition of knowledge in isolation, but also concept understanding and application. According to Handelsman et al.:

*most science is taught as lectures that are dominated by facts rather than principles and ways of thinking … and yet … substantial evidence shows that lecturing alone is a relatively ineffective way of teaching and retention from lectures is poor.*

Ramsden and Watson state that:

*good teaching encourages high-quality student learning … and energetically encourages engagement with subject content.*

We argue that while content is important (that is to say, learners must have a solid knowledge base underpinning their understanding and application), graduate attributes such as critical thinking (CT) and complex reasoning (CR) skills should also be developed and refined as part of a broader and integrated learning process. Graduate attributes of CT and creativity sought by prospective employers are not easily achieved through passive observation of subject content. CT-CR skills are important for capstone students if they are to successfully transition into professional clinical practice, industry or research where such skills are not only valued, but an integral part of daily work practices [T Jennings, personal communication]. Often in the workplace, graduates undergo retraining because they lack the requisite generic attributes and higher order skills which diagnostic microbiology laboratories require and value.

As a manager of a private medical microbiology laboratory the reality is that I want a recent graduate that can assimilate into a laboratory environment readily and be trained in as short a time as possible … clinical laboratories will require microbiologists that consider the ‘big picture’ rather than just processing the specimen or cultures in front of them. It is the role of tertiary educators to produce graduates that have an understanding of the basic techniques employed in clinical laboratories, an overview of current relevant methodologies in routine use and the ability to collate the clinical information with the culture results to generate an interpretation that is clinically relevant. [T Jennings, personal communication].

In targeting these attributes, we should also ensure that our students connect in a way that they are informed, engaged and even entertained. Consequently, we are striving for an evolution in our classrooms from passive information acquisition (knowledge delivery) to active learning experiences (knowledge construction) (Figure 1).

Our traditional didactic lecture formats have been replaced with a lecture-tutorial hybrid (or lectorial). The first part of the lectorial involves either a role-playing exercise or simulated patient presentation (in the form of case scenarios). These are then dissected in an interactive question and answer (Q&A) session addressing in turn each of the steps in the infectious disease diagnosis (IDD) pathway: patient presentation, empirical diagnosis, patient management (empirical), investigation...
requested, specimen management, diagnostic laboratory processing, patient management (review) and follow-up.

Role play involves students asking questions of the lecturer as a ‘patient’ suffering with an infectious disease related to the lectorial topic and is followed with a question like: “You have worked out the likely disease state, potential aetiological agents and relevant specimen – where to from here?” Students are actively encouraged to ask and answer questions and to use their CT-CR skills in the lectorial. With each new case scenario, concepts common to the IDD pathway are revisited as a way of knowledge scaffolding, together with an emphasis on critical knowledge points and the development and refinement of concept understanding. Frequently, the starting point for this constructive learning is the student’s general knowledge or own life experiences, based on friends or relatives who have contracted an infectious disease, or their background reading or even their studies in other subjects.

A core element of the teaching and learning integration is the Learning and Teaching Guide – a hard copy resource organised into chapters according to bacterial disease states. Each self-contained chapter comprises lectorial key notes, laboratory exercises laid out in descriptive detail, recommended readings and sample questions (multiple-choice questions and short answer). These questions are intended to provide formative assessment and evaluate both knowledge and CT-CR aspects, thereby promoting independent student learning. Factual data such as isolation media formulary, bacterial identification tests and ID tables, antibiotic lists and report forms are also included as appendices. It is a ‘living document’, with students adding their own notes, reflections and additional hard copy resource material collected during the semester. The Learning and Teaching Guide replaces (and improves upon) the typical ‘lab manual’ format.

Whilst many courses in diagnostic microbiology focus on specimen analysis, our approach is a holistic one, discussing what happens before the specimen gets to the pathology laboratory as well as afterwards. It is important to point out that our cohorts are not medical students, but microbiology majors, medical science and biomedical science students, though a significant number go on to postgraduate medicine programs. This ‘big picture’ approach engages our diverse cohort of students – and both anecdotal and evaluation data confirm this, as supported by these comments derived from a survey of three clinical microbiology units comprising about 200 second- and final-year students as part of the university-wide end of semester learning experience (LEX) evaluation conducted in 2009:

I really like the critical thinking required for the patient diagnosis class discussions, they really help you think about how much is relevant for each patient and were quite fun.

We were all participating and thinking rather than just listening. Critical thinking questions were gold.

Mark has expectations of the students which promote enthusiasm for learning and working to a high standard ... [he] reinforced to the class the imperativeness of being competent in the skills required for working in a diagnostic laboratory and

Figure 1. Teaching and learning integration in clinical bacteriology: Developing and refining critical thinking (CT) and complex reasoning (CR) skills.
furthermore the skills and knowledge required for this vocation were taught in a very concise way through the format of the interactive lectorials.

Mark really helped me to understand the ‘real-world’ applications of bacteriology – rather than just injecting us with hours of theory.

I like that Mark challenges our critical thinking and takes time to explain where we are going wrong. It is made very clear how the lecture material correlates with the lab and real-life situations, the importance of decision-making and reporting in a lab.

Report form compilation in the second half of the lectorial is part of the students’ laboratory preparation; hence the innovative concept of the lectorial being a ‘dry lab’ experience. Students go into the laboratory ready to continue processing a specimen, with a working knowledge and understanding of the key concepts that underpin the practical activities to follow.

The ‘wet lab’ experience comprises two key elements: (1) Specimen processing and (2) CT-CR scenarios. The objective of (1) is to train students in the fundamental techniques of conventional diagnostic bacteriology by allowing them to work up a clinical specimen hands-on and in so doing sleuth out the identity of the infectious agent, report on its significance and provide general patient management recommendations.

The CT-CR scenarios are based on a triangulated learning understanding and application (Figure 2). Briefly, in each laboratory session, problem-solving exercises (or scenarios) in the form of a display of relevant laboratory materials or test reactions are set up and students, either independently or as a group, work through them in a type of virtual specimen processing application, answering questions along the way and interpreting data by employing their CT-CR skills. CT-CR scenarios evaluate understanding and application in general and more specifically probe for: scientific rigour, quality assurance, accurate record keeping, technical error detection and data interpretation validation – all key aspects of a real world diagnostic laboratory.

The multifaceted approach outlined in this paper is rich in strategies designed to construct knowledge rather than deliver it, based on the belief that

learning is an active process in which meaning is developed on the basis of experience ... [and] must be situated in a rich context, reflective of real-world contexts, for this constructive process to occur and transfer to environments beyond the school 4.

In comparing classroom experiences before and after the implementation of the approaches described in this paper and in analysing anecdotal feedback and preliminary student evaluation data, we have found that overall classroom engagement is improving in measurable ways in our units. That students are using and refining their CT-CR skills is clearly evidenced by the way they answer questions during lectorials, by the strategies they use in the laboratory-based CT-CR scenarios and their performance in formative and summative assessments.

Teaching practices in our units continue to undergo transformations in positive and sustainable ways. Positive because we are now enjoying teaching much more and because we believe (most of) our students are enjoying the learning experiences embedded in our ‘fresh’ approach. We are also experimenting with different learning experiences by designing spaces and creating opportunities where active classroom interactions are the norm, not the exception. This experimentation is informed by how students engage in the two (lectorials and laboratory) primary integrated learning contexts.

Acknowledgements

The principles and practices employed in the teaching of clinical bacteriology at QUT are the direct result of hard work and inspirational ideas from a collaborative teaching team including: Christine Knox, Elize Pelzer, Samantha Dando, Jeninne Hay, Paul Robins, Lee Davis, Phil Petersen and John Coulson. We very much appreciate the workplace perspective provided by Mr Tony Jennings, who is laboratory manager of one of the largest microbiology laboratories in Australia and directly responsible for the management of more than 100 laboratory staff in south-east Queensland.

References


Biographies

Mark O’Brien is a senior lecturer in microbiology at QUT, Chair of the Life Sciences Learning and Teaching Committee and an active Member of the ASM Education SIG. He has been nominated for the 2010 ALTC Program Awards - Innovation in Curricula category – Medical Microbiology Program. Mark has been teaching clinical bacteriology for over 20 years and is committed to innovative and effective practices in learning and teaching.

Stephanie Beames is a learning and teaching developer in the Faculty of Science and Technology at QUT. She has a background in software development and learning design and has worked as a sessional academic at GU and QUT.
Finding the right balance in the delivery of undergraduate biology programs: a personal perspective

Universities, and indeed the wider community, are facing a huge challenge with what has been referred to as the ‘flight from science’ of recent generations of students. This trend began some 2 decades ago and has become an acute problem in recent years. It could be argued that it has come at a time when there has never been a greater need by society for graduates with the scientific expertise to address the big issues now confronting us. The potential impact of global warming, the continuing emergence of new disease threats, the advent of cutting-edge cloning and stem cell technologies are all challenging both practical and ethical boundaries requiring considered debate and engagement. Yet, we still aren’t attracting into science enough of our ‘best’ students, nor are we retaining enough of them once they choose to undertake an undergraduate science program.

There are numerous, confounding reasons why too few of our brightest school students choose science as a career, from school curricula that don’t engage them in the excitement of scientific discovery to the relatively poor career structure and remuneration awaiting graduates when compared to many other professional paths. For those who do enrol in science degree programs, the early years can sometimes be a real ‘turn-off’ for them. For example, students wanting to major in biology can find the delivery of the essential core enabling sciences of mathematics, physics and chemistry very dry and uninspiring. To address this concern, the temptation for those designing first level curricula has sometimes been to ‘dumb down’ the perceived hard content and to flood the space with more descriptive biology courses. Like a number of other universities around the country, the University of Queensland somewhat passively went down this path with the introduction of six separate biology courses that could be taken in first year. With the accompanying explosion of specialist biology courses in later years, students could find a route through these offerings to emerge from their degree with significant gaps in core fundamental knowledge. These deficiencies were immediately apparent when they entered the research laboratory. The realisation that our life science students were not receiving a sufficiently robust grounding in the physical sciences and mathematics is not unique to Australia, with many universities around the world grappling with how to more effectively reinforce this interdisciplinary thinking in our students. An excellent summary of the deliberations of a special Committee of the Board on Life Sciences of the US National Academies on just this issue can be found in the publication Bio 2010: Transforming undergraduate education for future research biologists. This publication clearly sets out not only the challenges we face but also a raft of potential approaches and strategies that may be implemented in a redesigned curriculum. I thoroughly recommend it as a starting point for stimulating some discussion.

At UQ we embarked on a critical look at our own science offerings as part of an extensive review process over 2005-2006 that has resulted in a substantial overhaul of our Bachelor of Science degree. The restructuring of the degree has been referred to as a Back to the Future approach, with a renewed emphasis on the core enabling sciences at the centre of the changes. But in this iteration we have sought to contextualise the content. A first year course that all students are required to take, referred to as ‘Theory and Practice in Science’, now tackles analytical and mathematical content in the contemporary context of major issues such as population dynamics, climate change and human genomics. In this and other first year courses, we are also coupling some of this content with a research experience. This can be achieved via a range of formats including exposure to ‘big picture’ seminars by leading researchers that are meant to convey the excitement of discovery at the front line and practical sessions involving group activities with a degree of student-driven design. The ongoing challenge we face, whether in the classroom or practical laboratory, is the need to strike the right balance between an engaging and supportive learning environment that fits within the students’ conceptual framework, with the delivery of a course that meets the rigours and challenges of fast-developing fields such as ours.

Encouragement of student involvement and commitment to the learning process comes through providing a flexible, exciting and enjoyable program. The four cornerstones to my own educational philosophy, the 4Es, are: engage, enlighten, enthuse and entertain. With those principles as a foundation, you can
establish a learning environment that truly inspires students. In broad terms, our aim should be to engage and enthuse students with essential core content in the early years of an undergraduate program with a healthy smattering of enthralling detail that provides context, while in the latter part of a degree program the focus should be on developing the vignettes of information they have already been exposed to, into a conceptual framework of key current knowledge. It is only in their postgraduate years that they should be fully immersed in the fine detail. My view is that for some time we have been guilty of throwing too much detail at our students too early and have missed the opportunity of painting for them the grandeur and beauty of the woods. I also believe we don’t do enough to expose our students to complementary areas, for example in business skills, ethics and the humanities. Toning down the deluge of facts in an array of courses that often overlap would allow us to provide a more solid, core foundation in science that would provide our graduates with more broadly based skills to meet a changing workplace.

One of the most influential learning experiences for me in the context of undergraduate teaching has been my involvement with the UQ Graduate Medical Course (GMC). Having contributed to the old undergraduate course from 1991, my first exposure to this new course was in 1994, when I was co-opted onto several subcommittees involved in the development of course material, in the form of problem-based learning (PBL) exercises. Exposure to these new forms of facilitated learning changed my perspective of the role of didactic lectures. Up to that point, and in common with most courses at the time, my undergraduate science classes were comprised almost entirely of lectures, with assessment coming mainly from end-of-semester exams and a few assignments. With advances in information technology and the availability of different forms of multimedia, the format of presentations also became another important component of the learning process that I wanted to incorporate into my own courses. I took the PBL format to heart and introduced it into my 3rd level virology course as a variant I refer to as GBL (group-based learning) which more accurately reflects the different dynamic of an undergraduate class. Its implementation had an immediate positive feedback from the students.

I have adopted this community learning experience as only one component of a multifaceted approach. I am still a true believer in, and supporter of, the increasingly maligned ‘lecture’ as being a very effective component of a balanced program of delivery. Carefully considered and well-delivered lectures perform a vital role in providing students with the forum in which mentors or experts can lay down the concepts and core content onto which the detail can later be placed (complemented for example by tutorials and practical sessions). This is becoming increasingly important in an information-rich field such as ours, providing an essential life raft for those students drowning in a sea of facts. The problem as I see it with the perception of the ‘lecture’ is not with the format itself but rather in the style of delivery employed by some who see it as simply a mechanism for factual dissemination. Delivered with enthusiasm and with a dash of performance, students universally embrace the lecture format.

In the third level course I have coordinated for the last 18 years, covering my discipline of virology, I start by providing a series of lectures that lay down simple concepts of viral interactions with the cell, the host and the community. Throughout the semester I then build more detail onto this framework, often using my own research experiences to demonstrate key points. This is complemented with basic research-type seminars provided by myself and outside speakers (to give a feel for the realities and diversity of the discipline), library and group-based assignments, computer-aided learning (CAL) exercises and GBL sessions involving multiple presentation styles in formal (PowerPoint delivery) and informal settings (poster presentations at a catered breakfast session) for assessment. I have also embedded within their practical training a real-time research experience. The result has been a tangible increase in the quality of submissions for assessment by the students (both within an exam setting as well as in assignments) that has demonstrated a clearer understanding of fundamental issues and a greater engagement with the content. I believe the key to retaining and building on these advances is to maintain a flexible approach to delivery and to ensure the students continue to enjoy the experience.

The growing student numbers in this course (now well in excess of 100) have put unacceptable demands on the format of the practical sessions themselves. While some course convenors have addressed similar growth in numbers by moving more to computer-aided learning or other online resource approaches, my view is that, at this stage in their education, students need the hands-on exposure to laboratory techniques that only wet-lab practicals can provide. The student cohort is split into 2 weekly, 3 hour practical sessions with groups of students set the task of carrying out four practical projects run over 6 weeks. These have been designed to expose the students to basic techniques in experimental virology. However, over the last 5 years or so, these group sizes have grown to five to six members from the two members we used to have because of increasing class sizes and limited infrastructure growth. Consequently, a comprehensive hands-on experience for each student is obviously limited. So we introduced a progressive, individual, group-based research experience that each team can carry through the course to completion. Two to three members of each group are assigned an essential component of a ‘research project’, which runs for the same 6-week period as the basic practicals. This gives them active ‘ownership’ of their assigned research task rather than mere participation in a typically passive, recipe-driven practical. My aim is to challenge the students conceptually as well as providing training in specific techniques. They gain experience in experimental design as well as having the opportunity to conduct a relatively complex series of experiments. This is genuine research as each year we pose new hypotheses for testing with an unknown outcome. The experience exposes them to a
range of handling techniques as well as invoking some cohesive thinking about the outcomes of laboratory-based research. When I introduce the concept to the students in the first week of semester and explain to them that they will be embarking on a research project whose outcome we do not know in advance, they are immediately engaged and enthusiastic. One measure of their engagement in the exercise has been in the high levels of attendance at a voluntary 8am tutorial! The result of the first iteration of this exercise, when all the data from the class was compiled, was a cohesive research story about the activity of the West Nile virus protease, an important drug target. The results were written up for publication after verification by a postgraduate student and subsequently published in the Journal of General Virology. The journal editor agreed to a listing of all 110 students as contributors in a Supplementary Attachment. All of the students own this piece of work!

My aim in developing any course curricula or class resource is to strike a balance in the provision of different forms of content delivery such that my students remain engaged and feel part of a supportive, collaborative and rich learning environment. As outlined above, I believe there is a very important role for the humble lecture in providing a conceptual framework for course material and providing an expert’s view of the gems within the forest of information that confronts a student. This should be coupled with a practical component that allows students to truly experience the realities of ‘life at the bench’, from the collaborative environment of group activities to the conceptual design of the experiments themselves. Additional collaborative learning exercises help to motivate students in a peer group setting with different assessment styles developing key presentation skills. Taken together, these group-based exercises promote the development of cognitive and life skills and the self-directed aspect re-enforces content retention. The balance between these different teaching modalities needs constant monitoring and adjustment. But above all: engage, entertain, enlighten and enthuse!

One final comment on an issue that often vexes the research academic: workloads and how we fit our research around our teaching commitments. When I reflect on the very positive impact that embedding a research experience can have for our undergraduate students, I am struck by the realisation that this is very much a two-way street. Embedding a teaching experience into my research program has provided me with a much broader perspective of my own discipline. The benefits to my research of the additional insights and directions that have arisen are incalculable.

References


The author would be happy to discuss and/or provide further details of his different approaches to undergraduate delivery should the reader be interested. Please email him directly at p.young@uq.edu.au

Biography

Paul Young is a Professor of Virology in the School of Chemistry and Molecular Biosciences at the University of Queensland, where he has been a member of academic staff since 1991. His research is focused on the molecular biology of dengue and respiratory syncytial viruses as well as in the development of diagnostic, vaccine and antiviral strategies. He has been a tertiary educator for more than 25 years and was the recipient of the 2008 ASM David White Excellence in Teaching Award.

Biography

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The Bi-State meeting was initiated in 2007 by members of the Victorian and Tasmanian branches of ASM. Its main aim was to provide a local forum for microbiologists from the mainland and Tasmania to meet every second year and discuss their work. With support from ASM, r-biopharm Australia and Thermo Fisher, the meeting was held for the second time in Hobart on 20 and 21 November 2009 at the Royal Hobart Yacht Club.

Smaller meetings play an important role in bringing members together, often being attended by ASM members who do not attend the national meeting for a wide variety of reasons. The less formal program allows for more relaxed participation and conversations. The cost factor is reduced significantly as smaller venues can be used and the heavy financial burden of overseas speakers is removed, although many speakers did travel over the sea to both speak and attend this meeting. A final benefit of a small local meeting is the opportunity to recognise and hear about the depth of good microbiology that is being undertaken in Australia by Australian microbiologists.

Guy Abell (CSIRO Marine) gave the first keynote address on the microbial ecology of estuarine nitrogen cycling. He was followed by Gary Dykes (Monash University) who spoke on the attachment of food-borne pathogens to abiotic surfaces. Richard Bradbury (Royal Hobart hospital) next posed the question *When is a hookworm not a hookworm?* After a break for lunch and a chance to take in the fresh air on the balcony overlooking the water, Karen Laurie (WHO Flu Centre) spoke on the novel typeA (H1N1) influenza virus, Ellen Donnan (Dept Health VIC) talked about a multi-jurisdictional Hepatitis A outbreak investigation, a presentation that generated many questions, as did case studies of Listeria infections in the dairy industry provided by Ian McFarlane (Dairy Food Safety Victoria). To end the first day Enzo Palombo (Swinburne University) described his work on alternative antimicrobial therapies and Caroline Lavender (VIDRL) talked about multi-drug resistant TB in Victoria.
In place of a formal conference dinner, Fred Peacock, a winemaker from Bream Creek Winery, a small, local, family-owned and -operated business, hosted a wine tasting. His excellent wines were matched with platters of Tasmanian cheeses and many people trundled off with a bottle or two to share over dinner or take home as consolation prizes.

Richard Morrison (DPI, Tasmania) opened the meeting on the second day with a report on vaccine development for salmonid aquaculture. Tom Ross (UTas) discussed the survival of *E. coli* on chilled carcasses and Jason McKenzie (La Trobe University) presented stunning images of virus replication in cells. After a BBQ lunch, Dr Alex Padiglione (Monash Medical Centre) talked about the microbiology laboratory’s experience of the Victorian bushfires and finally Greg Woods (UTas) gave the inside story on Devil facial tumour disease, a truly transmissible cancer.

In a survey conducted at the end of the meeting, attendees spoke very positively about the wide diversity of topics presented and made the comment that even if the topic being addressed wasn’t their usual focus, it was all good microbiology, accessible and engaging. All attendees found the meeting to be helpful, useful, stimulating and good monetary value. This was due in no small part to the skilful organisation of the program and the venue by Sue Cornish and Louise Roddam. To add to the overall pleasure of the occasion, the setting on the water’s edge was most attractive and the catering both tasty and generous. Morning tea was a little late on the second day because the scones hadn’t cooled sufficiently to eat, but the program was sufficiently flexible for this not to be a problem! The Hobart meeting in November clearly lived up to the expectations of those who attended. One of the best indications of its success was that all attendees indicated they would attend a future meeting. Launceston 2012 perhaps?
**Student Awards**

**BD Student Awards**

This award, sponsored by BD, provides the opportunity for one student member from each ASM State Branch to attend and give an oral presentation at the ASM Annual Scientific Meeting.

All postgraduate microbiology students who have submitted or are intending to submit an abstract for the ASM Annual Scientific Meeting are invited to apply – especially those in the final year of their degree program.

**Eligibility requirements:**

- Applicants must be a student member of the ASM (or if not currently a student member, applicants must be eligible for membership and must pay for such at the time of application of the Award).
- Applicants must not previously be a recipient of a BD ASM Student Award.

**Application requirements:**

Applicants must contact their ASM State Branch to ascertain submission requirements and the deadline date.

**Award conditions:**

Within 5 days of receiving the award from their ASM State Branch, the recipient must email their presentation abstract to the ASM Conference Manager for publication in the program and abstracts book.

The recipient of the award will be required to present their paper at the BD Student Award Session at the ASM Annual Scientific Meeting.

**Assessment:**

Finalists for the award will be selected on the basis of their abstract and a presentation summary submitted for consideration to their ASM State Branch.

The recipient of the award will be selected on the basis of an oral presentation – 12 minutes plus 3 minutes question time, to be given at the BD Student Award Evening of each ASM State Branch.

**Closing date for application:**

Contact your local ASM State Branch for details.

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**BIOMERIEUX ASM Identifying Resistance Award**

This award, sponsored by bioMerieux, is given to an individual on the basis of career achievements in the field of the identification of bacterial resistance to antimicrobials in the clinical setting.

**Eligibility requirements:**

Applicants must be a member of the ASM of 12 months’ standing at the time of application.

**Application requirements:**

- A current curriculum vitae (including a list of publications).
- The names and contact details (including email addresses) of two referees.
- A brief summary of the applicant’s contribution to the study of bacterial resistance to antimicrobials in a clinical setting.

**The award consists of:**

- $1,000 cash prize.
- Plaque.
- Provision for flights and accommodation for the recipient to attend the Award Presentation Ceremony at the ASM Annual Scientific Meeting.

**Assessment:**

The award committee will take into account the quality and originality of the published research and service to Australian microbiology in general. The award is based on the applicant’s entire career rather than a single achievement.

**Closing date for application:**

Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.
OXOID ASM Culture Media Award

This award, sponsored by Oxoid, assists an individual to attend and make a presentation on the use of culture media at the ASM Annual Scientific Meeting.

Eligibility requirements:

Applicants must be a member of the ASM of 12 months’ standing at the time of application.

Application requirements:

- A current curriculum vitae (including a list of publications).
- A current position description.
- The names and contact details (including email addresses) of two referees.
- A brief synopsis of the presentation to be made.
- A copy of the abstract to be submitted for presentation.

Award conditions:

The winner must present a paper or poster relevant to the use of culture media in microbiology as the ASM Annual Scientific Meeting. This may be based on original research, a method evaluation or validation or a review of a culture-based diagnostic method. For example, this may include improved isolation methods, rapid or presumptive identification or novel ways of using culture media.

The award consists of:

- $1,000 cash prize.
- Certificate of award.
- Up to $1,000 travel expenses for the recipient to attend the award presentation ceremony at the ASM Annual Scientific Meeting.

Assessment:

The award committee will take into account the eligibility of the applicant for an encouragement award, together with the quality and originality of the planned presentation and its relevance to the use of culture media in microbiology.

Closing date for application:

Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.

PFIZER ASM Mycology Award

This award, sponsored by Pfizer, assists a laboratory scientist or technician to attend and make a presentation in the field of medical mycology at the ASM Annual Scientific Meeting.

Eligibility requirements:

Applicants must be a member of the ASM of 12 months’ standing at the time of application.

Application requirements:

- A current curriculum vitae (including a list of publications).
- A current position description.
- The names and contact details (including email addresses) of two referees.
- A brief synopsis of the presentation to be made.
- A copy of the abstract to be submitted for presentation.

Award conditions:

The award recipient must present a paper or poster in the field of medical mycology at the ASM Annual Scientific Meeting. This may be based on original research, case reports, a new or updated methodology or a review article.

The award consists of:

- $500 cash prize.
- Certificate of award.
- Return economy class airfare.
- Full conference registration.
- Allowance of $120 per day for 5 nights towards hotel accommodation.

Assessment:

The award committee will take into account the eligibility of the applicant for an encouragement award, together with the quality and originality of the planned presentation and its relevance to medical mycology.

Closing date for application:

Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.
**ROCHE ASM Molecular Diagnostic Award**

This award, sponsored by Roche, assists an individual to attend and make a presentation of the use of PCR in the field of diagnostic infectious diseases at the ASM Annual Scientific Meeting.

**Eligibility requirements:**
Applicants must be a member of the ASM of 12 months’ standing at the time of application.

**Application requirements:**
- A current curriculum vitae (including a list of publications).
- A current position description.
- The Names and contact details (including email addresses) of two referees.
- A brief synopsis of the presentation to be made.
- A copy of the abstract to be submitted for presentation.

**Award conditions:**
The winner must present a paper or poster on the use of PCR in the field of diagnostic infectious diseases at the ASM Annual Scientific Meeting. This may be based on original research, case presentations or a review of a PCR method used to diagnose an infectious disease.

**The award consists of:**
- $1,000 cash prize.
- Certificate of award.
- Up to $1,000 travel expenses for the recipient to attend the award presentation ceremony at the ASM Annual Scientific Meeting.

**Assessment:**
The award committee will take into account the eligibility of the applicant for an encouragement award, together with the quality and originality of the planned presentation and its relevance to molecular diagnostic microbiology.

**Closing date for application:**
Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.

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**ASM Frank Fenner Award**

The purpose of this award is to recognise distinguished contributions in any area of Australian research in microbiology by scientists in a formative stage of their career, rather than to reward senior scientists for a lifetime of achievement.

**Eligibility requirements:**
- Applicants must be a member of the ASM of at least 2 years’ standing at the time of application.
- Applicants must have been engaged in research at postdoctoral level or equivalent for less than or equal to 15 years of full-time research since acquiring their postdoctoral degree in cases of significant career interruption.

**Application requirements:**
- Current curriculum vitae (including a list of publications).
- One page summary of contributions to research in microbiology.
- The names and contact details (including email addresses) of two referees.

**Award conditions:**
Applicants need to show that their area of research excellence was work done substantially in Australia or, for those applicants recently returned from overseas, is ongoing work in Australia that will encourage the nation’s international reputation in microbiology.

The recipient is required to present the Fenner Lecture at the ASM Annual Scientific Meeting.

**The award consists of:**
- Bronze plaque given at the ASM Awards Ceremony at the Annual Scientific Meeting.
- $1,000 cash prize.
- Full ASM Annual Scientific Meeting registration.
- Return economy flights.
- Up to 5 nights’ accommodation.

**Closing date for application:**
Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.
ASM Teachers’ Travel Award

The aim of this award is to encourage ASM members involved in teaching microbiology at the tertiary level to attend the Annual Scientific Meeting of the Australian Society for Microbiology.

Eligibility requirements:

• Applicants must be a member of the ASM of 12 months’ standing at the time of application.
• Be employed full-time, part-time or sessionally.

Application requirements:

• Current curriculum vitae.
• A letter of recommendation from the applicant’s head of department confirming involvement in and commitment to a teaching program.
• The names and contact details (including email addresses) of two referees.
• A brief synopsis of the applicant’s area of interest in education.

Award conditions:

The synopsis would provide the basis for a poster presentation or participation in a session organised by the Education Special Interest Group at the ASM Annual Scientific Meeting.

The award consists of:

• Certificate to be given at the ASM Awards Ceremony at the Annual Scientific Meeting.
• Up to $1,000 in travel expenses for the recipient to attend the ASM Annual Scientific Meeting.

Closing date for application:

Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.

ASM Vic Skerman Student Prize

This ASM-sponsored prize is awarded annually to a student member of the Society who has contributed, while enrolled as a student member of the ASM, the best review article to the Society’s journal for the period 1 July to 30 June in any year.

The award consists of:

• Certificate to be given at the ASM Awards Ceremony at the Annual Scientific Meeting.
• $500.00 cash prize.

Award conditions:

The applicant must submit a 50-word summary of their CV with their application.

Closing date for application:

Please send applications to Michelle Jackson michelle@theasm.com.au by 31 March 2010.