Finding the right balance in the delivery of undergraduate biology programs: a personal perspective

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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 [1]. 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*[2]. 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

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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.