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GUEST EDITORIAL

The challenges of teaching undergraduate biology

The introduction of programmes in both old and new universities and institutions that have taken up the cause of undergraduate (UG) biology is impacting its teaching in many positive ways. First, the newer curricula are enabling students of biology to have a wider and stronger foundation in other branches of science in their early years. Secondly, it is bringing the young UG students in more direct touch with active researchers allowing them greater opportunity to get a more hands-on approach, and actually feel the excitement of science. A third aspect, which is still not adequately appreciated, is that it brings about the possibility that active researchers would be able to use their trained research objectivity into the teaching process. The hope is, here, that it would bring out new changes in the way the subjects are taught. It is this third aspect, the aspect of possible changes in teaching that I wish to discuss and draw attention to some of the challenges.

One of the challenges in teaching a fact-ridden subject like biology is to be able to convey the discovery process of science. At the UG level, this also means that we need to make space for conveying the discovery process through landmark experiments with an element of history and even the personalities involved. For example, while teaching students about the three kingdoms of life – archaea, eubacteria and eukaryotes, it becomes more exciting when one discusses the discovery of Carl Woese more elaborately. How the discovery was made, the kind of tools that were used to carry out ribosomal RNA profiling, the seminal three-page paper in *PNAS* (Woese, C. R. and Fox, G. E., Phylogenetic structure of the prokaryotic domain: the primary kingdoms, *Proc. Natl. Acad. Sci.*, 1977), the reluctance with which the idea was accepted by the community, and how despite being nominated for a Nobel Prize, it was denied, because the work was not considered to be in the domain of Physiology or Medicine, and till today remains as one of the huge discoveries that did not win a Nobel Prize (Editorial, 'And the winner should be...', *Nature Reviews in Microbiology*, 2011). In addition, the philosophical approach of Woese and his way of doing science with the 'big picture' in mind, are wonderful methods to relate and learn. Similar examples no doubt exist in all areas of biology, and it helps to intersperse the traditional lectures with these stories of science.

A second crucial aspect is on deciding how much to teach of a subject and with what depth and width. The strong impulse is to insist on teaching as much as possible with the idea that the students must have strong fundamentals in all these areas before they graduate. In the process of good-intentioned loading (or overloading) of the fundamentals, the danger may well be that the student loses his/her love for the subject, that is critical for one to be able to learn by oneself and dig deep through one's own motivation. How much should one teach, and to what depth and width, is something we are continuously confronted with. How does one go about this task? It helps to remember Sri Aurobindo, the seer-poet, where in one of his writings that deal with the subject of teaching he writes, 'The first principle of true teaching is that nothing can be taught'.

There is also a need for greater participation of students in the teaching–learning process. This is the principle of 'active learning', where the student no more merely listens to an hour-long lecture, but is made to participate in the process. As the saying goes, 'Tell me and I will forget, show me and I may remember, involve me and I will understand'. Students often resist this, because sitting back and listening to a lecture is much easier. However, getting their participation is important. This could be either by group discussions, open questions, or other classroom assessment techniques such as the 'one-minute paper' (Stead, D. R., A review of the One-minute paper. In *Active Learning in Higher Education*, 2005). This becomes more difficult in larger groups, but films and videos, occasional 'reverse classrooms' where the lectures or interviews are given in advance, followed by an analysis of these are various approaches that can be possibly experimented.

One challenge here is to get the faculty also involved in this process of active learning and innovating during the teaching–learning process. The dictum that 'one is hired for teaching, but promoted for research' may be seemingly true. But the passion of the faculty for their research is what often causes a reluctance to invest too much time for classroom teaching. It is not surprising therefore, to find faculty prefering teaching their own specialized topics, to ease off 'this extra burden'. Administration and senior faculty need to be sensitive to the

needs of younger faculty to quickly kick-start their research programmes. To make it easier, perhaps, for the young faculty, one could consider a lighter burden for them in the first few years. Maybe lighter courses, a semester off, or more advanced courses that are in their own area of research in the first three years, could be one way of tackling this issue. It is also important to realize that there are not many born teachers. There are a few. But, for the rest of us, it is constant, evolving and progressing through experimentation, trial and error, and a constant striving that pay dividends with the eventual realization that teaching can indeed be very rewarding. Thus, it was only in my third attempt at teaching 'Microbial physiology and genetics' that I discovered that teaching the three kingdoms of life was most rewarding for both me and my students, when I presented the work of Woese from a historical story perspective. Eventually for each individual and for the institution at large, the need is to strike the right balance between research and teaching.

Laboratory courses can often excite students in their early years towards research in biology. But here again, there are many challenges. First, there needs to be an effort towards ensuring that every student is performing or participating in every experiment in a hands-on manner. This seems obvious, but can be difficult at times, when resources (consumables and equipment) are limited. And perhaps, here is where we can innovate – either staggering the experiments or using inexpensive or alternate reagents and materials, to ensure that this becomes possible. There are also many biology teaching journals that have experiments that one could adapt to one's own curriculum. Some of these are quite imaginative. In many cases, the duration of the experiments and the need to capture the key essentials in the duration of a few hours are a challenge, and require significant planning. A flexibility in the course structures is therefore required. Many scientific societies which include the Genetics Society of America, the American Society of Cell Biology and the American Society for Biochemistry and Molecular Biology lay great emphasis on UG teaching and the journals often carry new ideas and thoughts that can be adapted to our laboratories. A second approach towards teaching laboratories is to carry out experiments in a project mode. Some years ago the journal *Science* carried a series on innovative experiments in colleges. One of the award-winning entries was 'DNA barcoding from NYC to Belize' (Harris, S. E. and Belino, M., *Science*, 2013), which was a year-long curriculum that had several different aspects of biology associated with it. This included biodiversity, field ecology, sampling, molecular biology, sequencing and simple bioinformatics such as BLAST. Indeed, to capture the diversity of biology and the diversity in approaches to study biology is one of the challenges, not only in the laboratories, but in the foundational courses as well. In another example of a course in project mode, was the synthesis of the first artificial yeast chromosome (Dymond, J. S. *et al*., Synthetic chromosome arms function in yeast and generate phenotypic diversity by design. *Nature*, 2011). It involved the participation of a large number of UG students, who became the main force propelling this well-designed programme. It also led to a new UG course (Dymond, J. S. *et al*., Teaching synthetic biology, bioinformatics and engineering to undergraduates: the interdisciplinary build-a-genome course. *Genetics*, 2009). As our faculty design new curricula, they must also explore the options of publishing their experiments in some of these journals. These may be experiments in terms of the laboratory design, or experiments in the way the course is structured or taught. Finally, one hopes that we would soon see some forums for teachers to exchange ideas in teaching, as well as share failures and common problems. It would be beneficial and should catalyse further innovations in both old and new institutions.

A benefit that is likely to emerge out of this research-cum-teaching environment is the involvement of the graduate students and postdoctoral fellows in the teaching process. Graduate students and postdoctoral fellows can be encouraged to be involved in some of the UG teaching. The involvement could be as either laboratory tutors, or tutors for theory courses where they participate in some measure. Despite the investment in time, the advantage of such an involvement is that it opens up another window of opportunity for these researchers, with the recognition also, that teaching can be as creative an enterprise as research on the bench. And one hopes that at least some may find their true calling in the teaching profession.

In India, there are some additional issues while teaching UG students that need to be dealt with. First is the fact that students who join often lack sufficient proficiency in both spoken and written English. Since a single course in English is going to be inadequate to address this problem, how can good reading and writing be built into at least some sections of our courses is something on which we need to give sufficient thought. In addition, with a wide spectrum of students, coming from a wide variety of backgrounds, it is important that we continue to remember to strive to ensure that no student is left behind.

There are indeed many challenges regarding UG teaching. One hopes that with the new generation of teachers, researchers and research students incubating together in a research-cum-teaching environment, in the years to come, we will witness great strides in the UG teaching of biology.

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