Biology Education in a Rapidly Changing Scientific and Socio-economic Context

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Across Europe there is a number of serious problems in biology education, as EMBO's experience of organising international biology education workshops for 6 years shows. These problems are not universal, but they are experienced by a large fraction of teachers (possibly most teachers) of biology at secondary level in most European countries. A non-exhaustive list includes: overloaded and outdated curricula, outdated text books, insufficient time to cover contents, insufficient "real" practical work, limitations of the scope of biology, the perception of biology as a "soft" subject, inappropriate pedagogy, lack of encouragement of teacher creativeness and independence, lack of teacher enthusiasm, lack of formal continuous teacher training, and, finally, a lack of student enthusiasm for the subject – which results from many of the preceding problems.

As organisers of education workshops, we treat secondary school biology teachers as scientists, because we consider a scientist to be someone who is professionally knowledgeable about science and its methods, and can communicate science. Our common goal as biologists, therefore, is to improve on all of the problems mentioned above. But there are certain priorities that should be concentrated on, and from which other improvements will follow almost automatically. For instance, if biology teachers are treated more as true professionals, then they must be provided with the means for professional development, and that means updates, or regular training opportunities, in their subject matter, its methods and pedagogy. Researchers and other scientists in institutes and universities are a vital part of this improvement. Currently many are engaged in a voluntary capacity, with little or no financial recompense. This service, however, has to be financed and expanded, if it is to be sustained and meet demands. Ultimately it is all about demonstrating that teachers are important, and are cared for. That in itself can help enormously to improve teacher moral and enthusiasm, but independence and creativity have to be encouraged too, and the necessary time made available in crowded teaching programmes.

As if that weren't enough, these changes need to be made against trends that make them even harder, but even more necessary: an increasing amount of knowledge to be covered, more concentration on attaining good exam results, a bewildering array of non-curricular information sources (e.g. websites, Internet portals, etc.) and falling enthusiasm for science in general among young people.

The last observation leads us to view biology education in the context of other developments in science and society. From 1998 onwards Europe has a greater scientific output per year than the USA (number of publications in scientific literature). But we can hardly afford to be complacent (neither can the USA, in fact), because research shows that probably in all European countries, students of age 15 are not keen on school science, and do not see a career in science and technology as attractive. In terms of biology, we should be concerned for at least three reasons: 1) a negative perception of science leads students to choose biology for the "wrong" reason ("soft" option); 2) other scientific disciplines important to biology are underrepresented; 3) the rate of production of science globally is increasing, arguably driven by biology and recently emerged new research areas: at the very least we need to ensure that young people are aware of what is going on and can appreciate something of its significance. Indeed, in Europe, the productivity of the life sciences (in publications per year) is greater than any other scientific field.

The "information explosion" happening in biology – driven by "-omics" technologies and new branches of biology – has consequences for research and education, and puts more emphasis on the importance of how biology is taught in school – both for those wishing to study it at university, and those who will be consumers of the "new" biology in future. The division is not trivial, because biology has become so complicated these days that some educational systems (e.g. the UK) have developed two kinds of course: science for further study, and science for citizenship.

As far as university study, and later research, in biology are concerned, transdisciplinarity plays an increasingly important role. In modern biology, subject boundaries are rapidly being crossed, new disciplines made, new integrative insights and knowledge created. This requires minds that are open and knowledgeable in a number of scientific areas. Already at school level, biology classes can introduce some of the basic concepts of this "new" biology as a horizon-expander for those who are curious enough to want to go into tertiary study. Systems biology is one such area. It basically integrates information from smaller areas of research to understand how systems – from biosynthetic pathways up to environmental phenomena –

work. Furthermore, it can be used to introduce a range of important modern advances in biology that have great societal relevance, from molecular medicine to molecular evolution. But it also enables a tantalising new technology: “Synthetic biology” Systems biology is also interesting from the point of view that it excellently demonstrates that whereas computers can help us generate massive amounts of data, it is ultimately bright human minds that will make the breakthroughs in understanding its significance and power. These bright minds need to be cultured starting at school.

Molecular evolution, despite its formidable-sounding name, is something that can be easily understood by most people, and can easily be taught. Essentially it is the principle that genes and gene products (proteins) mutate at rates that allow them to be used as molecular clock with faster or slower rates of ticking – a bit like the way words mutate in European languages from a common stem, hundreds or thousands of years ago. This then allows us to draw evolutionary trees that are better at predicting the true relationship between species than comparative anatomy, physiology or embryology. However on inspecting national biology curricula across Europe, we find that in no more than 20 % of curricula is molecular evolution specified to be taught.

Solutions to introducing new biology to school teaching are not easy. They must incorporate several features, or explore certain ideas. Some concepts are so easily inserted into curricula (e.g. molecular evolution), that they should appear across the board. To save space, they can be used to introduce other concepts such as molecular medicine (via genomics and proteomics which are important in molecular evolutionary studies), and even things as basic as why animal models are useful in research on human diseases. Other topics might be introduced by making a part of the curricula “open” for new research: an experiment being tried at the Weizmann Institute in Israel. Of equal importance is that teachers meet each other regularly to discuss new research (e.g. reported in Nature or Science), and how they can mention it in their lessons; regular interactions with researchers can be very helpful in this respect. And finally this brings us to the matter of teacher training again. Curricula and text books are mere objects, and will always be out of date, but teachers are the living breathing transmitters of knowledge, thinking and enthusiasm. The importance of bringing teachers together for regular in-service training with the help of scientists at institutes and universities must be generally recognised as a critical part of the recipe for improvement.