EMBO reports

analysis

Can they think for themselves?

The coming generation of scientists has to learn more in school than simple fact memorising

Does a tomato have DNA in it? The average European adult would probably answer 'no'—only a genetically modified tomato has DNA in it—the average European secondary school pupil would most likely answer 'of course'. Given that children and young adults in secondary and higher education have a unique opportunity to develop critical thinking as well as assimilating facts, this chance must be better exploited to open their minds to the latest developments in science. Not only will it help many of them to get a job and contribute to the prosperity of Europe, but it will help all of them to understand better the fast-changing world we live in.

How well do we educate the youth of Europe in biology? According to TIMMS, the Third International Mathematics and Science Study, Europe is on average slightly less successful than the USA (see Table 1). But is such a study really meaningful? Surely what is more important is the quality of scientists that the education system produces (http://www.uni-giessen.de/~gf1002/vdbiol/timss2.html). Thus, instead of looking at the beginning of the life-long process of learning and discovery, perhaps we should focus on high schools and universities. And this is where the problems borne in secondary and higher education come home to roost. 'No one has taught them [PhD students] how to think,' remarked Jorge Moscat from the CBM Severo Ochoa in Madrid, 'in the first few years [in the lab] they need to be re-educated.' And his group attracts some of the most gifted graduates in Spain, he said.

At the heart of the problem is an over-concentration on the learning of isolated facts and too little integration of mutually beneficial fields such as biochemistry, physiology, molecular biology, plant and animal sciences. For example, no serious biologist would argue that a purely molecular approach to solving biomedical problems is likely to succeed.

Table 1.

Country	Percentage of correctly answered questions
Australia	63 (0.8)
Austria	65 (0.6)
Belgium	64 (0.7)
Bulgaria	64 (1.0)
Canada	62 (0.6)
Cyprus	49 (0.6)
Denmark	62 (0.8)
England	64 (0.8)
France	56 (0.8)
Germany	63 (1.1)
Greece	54 (0.6)
Hong Kong	61 (1.0)
Hungary	65 (0.7)
Iceland	58 (1.0)
Ireland	60 (1.1)
Israel	61 (1.1)
Japan	71 (0.4)
Korea	70 (0.4)
Latvia	53 (0.7)
Lithuania	52 (0.9)
Netherlands	67 (1.4)
Portugal	53 (0.6)
Romania	55 (1.0)
Russia	62 (0.7)
Scotland	57 (1.1)
Singapore	72 (1.0)
Slovakia	60 (0.6)
Slovenia	65 (0.6)
Spain	58 (0.5)
Sweden	69 (0.9)
Switzerland	59 (0.6)
USA	63 (1.1)

Results of the TIMMS (Third International Mathematics and Science Study) from 1995 (http://www.timss.org)
Pupils between the ages of 13 and 14 were asked 40 questions covering basic biology. Data from a more recent study in 1998–99 are not yet available.

The study of genomics has unequivocally demonstrated the need to integrate molecular studies with physiological and whole animal studies. However, as might be expected from the time-lag between developments in research and those in education, even at undergraduate level there is a preoccupation with molecular reductionism at the expense of integrative approaches. In a sense, this is a success story because it proves that the teaching establishment enthusiastically adopts important developments. But an integrated approach to biology teaching naturally breeds greater problem-solving ability, a quality that appears lacking in recent graduates.

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The problem of a lack of integration is also a horizontal one between all of the natural sciences. As Chris Leaver at the Department of Plant Sciences at Oxford University noted, in addition to many other shortfalls of the education system, biology teachers are usually zoologists who place too little emphasis on mathematics and the physical sciences. As computing and mathematics become an increasingly important tool in the interpretation of biological data, so the need increases for biologists who are as happy devising algorithms as with planning experiments in the lab. Ironically, among 16- to 18-year-olds taking biology in the UK, more than 50% do not study mathematics or a physical science. This is one of the problems that the Royal Society, an organisation that collaborates with the British Association for the Advancement

Selected biology teaching resources on the Internet

- European Initiative in Biotechnology Education: http://www.rdg.ac.uk/EIBE/
- Microscopy resources for schools: http://www.microscopy-uk.org.uk/schools/mainscol.html
- British Library, UK, Living Worlds: http://education.bl.uk/
- BUBL (Bulletin Board for Libraries) http://bubl.ac.uk/link/c/cellbiology.htm and http://bubl.ac.uk/link/g/geneticseducation.htm
- Freie Universität Berlin, biochemical resources: http://userpage.chemie.fu-berlin.de/~biocheag/resourcen.html
- Das deutsche Internet-Verzeichnis: http://dir.web.de/Wissenschaft/Naturwissenschaften/Biologie/
- Universität Bamberg, biology teaching resources: http://www.uni-bamberg.de/~ba2ap1/GENERAL/education/www/resources/biology.res.html
- Universität Hamburg: http://www.rrz.uni-hamburg.de/biologie/b_online/kritik/hoturls.html
- BIODIDAC, Canada (anglophone/francophone): http://biodidac.bio.uottawa.ca/
- CNRS, France: http://www.snv.jussieu.fr/bmedia/
- Le Village, CyberBio: http://le-village.ifrance.com/cyberbio/
- Projet Biotope: http://perso.club-internet.fr/eflorent/index.htm
- Biologie Amusante: http://wwwusers.imaginet.fr/~pol/BIO-AMUS.html
- The virtual library: http://vlib.org/Biosciences.html
- Biopharmaceutical Technology Centre, an excellent source of information and links to other resources: http://www.btci.org and http://www.btci.org/resources/Resource.htm
- Access Excellence at the National Health Museum: http://www.accessexcellence.org/
- University of Wisconsin links: http://www.wisc.edu/zoology/links/web_biology.html
- About; the human Internet, an ecology site with updating camera shots: http://ecology.about.com/science/ecology/
- The Natural History Museum in London: http://www.nhm.ac.uk/
- The American Museum of Natural History: http://www.amnh.org/
- The National Museum of Natural History (Smithsonian): http://www.mnh.si.edu/
- Boston Museum of Science: http://www.mos.org
- Animation of gene splicing: http://www.hypercosm.com/showcase/gene-splicing/index.html

of Science to improve public understanding and education of science, intends to tackle in its recently devised education programme.

As computing and mathematics become an ever greater tool in the interpretation of biological data, so the need increases for biologists who can master them

The education system in the UK, where a new curriculum for 16-to 18-year-olds is just being introduced, has drawn widespread criticism for its science curriculum. But in terms of the graduate biologists it produces, it need not hold its head in shame. In comparison, German graduates fare much worse in skills such as reading and assimilating research papers. They are trained in 'recipe reading' rather than creative thinking, noted Patricia Kahn, editor of the publication of the International AIDS Vaccine Initiative, who taught graduate students at the University and the EMBL in Heidelberg. She added that it is remarkable that Germany produces any good scientists at all given the 'factory system' in which they are reared—a learning framework built around the memorisation of facts and practically no contact with professors. In secondary school education, Germany could also do better, but here at least there is at least one energetic initiative underway: The Life-Sciences Lab in Heidelberg, brain child of Thomas Schutz, a biologist working at the Deutsche Krebsforschungszentrum, who is coordinating an engaging calendar of events. In addition to opportunities for the public to learn more about science, Schutz, in collaboration with interested scientists, has devised a holiday academy. A group of school children selected in competition with others from the region will work for a week on projects of their own design in a genuine research laboratory. The indefatigable Heidelberg biologist also plans a seminar to bring scientists and teachers together, and to discuss continuing education of biology teachers, a matter of some urgency.

For continuing education brings new ideas and inspiration into the classroom. It is an uncommon pupil who is not affected by a teacher's enthusiasm for his or her subject. It is an all too often heard complaint of parents that their children simply are not interested in school subjects. And it is depressing to think that on entering school, the fascination that most children have for things that creep, crawl and wriggle can turn into apathy. Class sizes are clearly one reason; teachers cannot give each child enough attention, and this is where multimedia can help. However, the hardware needed to equip a school satisfactorily is in general too expensive for a publicly funded education system. A recent report revealed that only 6% of PCs in German schools have a CD-ROM—the figure elsewhere in Europe can hardly be better. Fortunately, many excellent Internet sites—often hosted by museums and visitor centres—offer an abundance of teaching resources for free. Predictably, most of the web resources in biology are hosted by US institutions and universities.

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Inspiring and educating young scientists is something that we cannot leave to chance, given the indisputable connection

between scientific research and economic growth. In Israel, whose economy is firmly based on science and technology, this link is clear to those officials responsible for education. That is why in recent years a minor revolution has taken place in their education system; not surprisingly it addressed the very problems that still trouble Europe. Firstly, the curricula were rewritten to place more emphasis on integration between the science curricula. Secondly, teachers participate in continuing education through a network of regional centres, which they attend one day a week. For this, they are rewarded with an increased salary. Teachers are important after all, as we have yet to recognise in Europe. Finally, a core curriculum was established for all subjects, not just the sciences. The Israeli Ministry of Education liaises very closely with academics in universities and provides them with a budget for the development of teaching materials. However, as Benjamin Geiger, chair of the steering committee responsible for the reforms and professor at the Weizmann Institute, conceded, Israel is small—1.2 million children attend school—and hence activities can be coordinated easily. Since Europe is large, there is an even greater need for a similar revolution. But given that many countries do not yet have a national curriculum, the possibility of a pan-European curriculum seems a little remote at the moment.

The task of planning curricula and teaching them is not likely to become easier. An ever-increasing number of factors need to be considered. The expert panels who design curricula must include many different professionals, among them practising scientists, educators, social scientists and ethicists. The new knowledge and concepts that arise in research must be complemented by consideration of their ethical, social, environmental and economic impact. These are topics that must be tackled not only in science, but across the whole curriculum, as the Wellcome Trust recently recommended in its concepts for a national curriculum in England. What a challenge. Teachers have never been so valuable.

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