Can they think for themselves?

The coming generation of scientists must 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—whereas 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 TIMSS, the Third International Mathematics and Science Study, Europe is on average slightly less successful than the USA (see Table I). 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 bio-

Table I. Results of the TIMSS from 1995 (<http://www.timss.org>)

Country	Percentage of correctly answered questions ^a
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)

^aStandard deviation is given in parentheses. 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.

medical problems is likely to succeed. 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 often 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 they are planning experiments in the lab. Ironically, among 16- to 18-year-olds taking biology in the UK, over half 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

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://www.users.imagnet.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.btc.org> and <http://www.btc.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>

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

As computing and mathematics become ever greater tools 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 hang its head in shame. In comparison, German graduates fare much worse in skills such as reading and assimilating research papers. They are trained in 'following recipes' rather than creative thinking, noted Patricia Kahn, editor of the *IAVI Report*, a publication of the International AIDS Vaccine Initiative, who taught graduate students at the University of Heidelberg. She added that it is regrettable that German Scientists are stifled by the 'fac-

tory 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 'Heidelberg Life-Sciences Lab' (<http://www.brains.de> and <http://life-science-lab.xmachina.de>), brain child of Thomas Schutz, a biologist working at the 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 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

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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.

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, inspired by a report from a national committee, headed by Professor Haim Harari, President of the Weizmann Institute. Not surprisingly it addressed the very problems that still trouble Europe. First, the curricula were rewritten to place more emphasis on integration between the science and technology curricula. Secondly, teachers, in growing numbers, participate in continuing education through a network of regional training 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 is being devised 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, Professor at the Weizmann Institute, who was involved in the implementation of this reform, conceded, Israel is small—1.2 million children attend school—and its education system is centralised, and hence activities can be coordinated relatively easily. ‘But the implementation of such a comprehensive reform is a slow and difficult endeavour,’ he added, ‘and it is still way too early to evaluate its success.’ 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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The discovery of functional genomics

EU announces new funding approach for European research

The one consistent aspect of the European Community's science funding policy to date has been that it has not had any difficulty in changing its direction or priorities with each Framework Programme. And in the wake of heavy criticism of the current 5th Framework Programme—by scientists, review panels and science lobbyists—for its heavy emphasis on applied research, the commission finally seems to be willing to revamp its funding policy. If the informally leaked details for a new experimental approach for funding and managing research projects in functional genomics—to start as early as the middle of next year, and to be absorbed into the 5th Framework Programme—are indeed true, the EC will have demonstrated an ability to react quickly to new developments as well as widespread criticism. Furthermore, if this new initiative can be regarded as a pilot project for the 6th Framework Programme, it means that the next programme, sched-

uled to start in 2003, will better reflect the wishes of European scientists than the current one does.

The new initiative will focus more directly on research in functional genomics as a component of the 5th Framework

the flexibility that is required to respond to this gap and have already pre-announced, at a number of small meetings, their intention for a new approach to support European research in the field of functional genomics.

If this new initiative can be regarded as a pilot project for the 6th Framework Programme, the European Commission has shown a commendable willingness to respond to criticism

Programme. This area has not been emphasised in the current programme because of the extensive period of negotiation that was required to put the programme together. The EC's 5-year plan simply was not able to reflect the most recent and important developments in this field, i.e. the sequencing of the human genome, and a growing number of other species. Happily, they have shown

Previously, the standard EU response to such a dilemma would simply have been to change the wording in the working programmes slightly to make functional genomics a target for applications for research funding. However, in this case the EU is going much further, introducing a new style of selection and targeting. Although the details may change again by the time that this issue of *EMBO reports* is