# From School to University – a report on the transition from secondary school biology education to university in Europe

## Introduction

This report results from contributions made at EMBO's 5th International Workshop on Secondary School Biology Education "From School to University" on 11 – 13 May 2006 in Heidelberg, Germany. It addresses aspects that might be improved in biology education at secondary level in Europe by analysing the transition from school to university.

While Europe is making significant efforts to increase percentage national GDPs spent on research and development, young people in secondary schools tend to hold science and technology in low regard either as a subject of study or as a career. In contrast, in developing nations, a qualification in science is believed to open doors into the 21st century and into Western economies[1]. This problem must be tackled in Europe at a variety of levels, for example via practising scientists communicating with the young, and by promotion at policy level of science as an exciting endeavour. Above all, the education system must play a leading role. The interface between school (especially at secondary school level) and university is key in this respect.

## Is there really a problem in biology?

In many European countries, mathematics and the physical sciences are suffering a crisis of falling enrolment at secondary and university level. The reverse is often reported of biology. But, ironically, biology is suffering as a by-product of the increased number of students, many of whom regard it as a relatively easy, "soft", science. Yet compared with other sciences, new knowledge and technical approaches are arising in biology at a much higher rate, and one that is accelerating extremely fast. The increasingly cross-disciplinary nature of the biological sciences, and the rising flow of data from genomics, proteomics and bioinformatics are making many branches of biology increasingly quantitative and rooted in physicochemical principles. Students have never had to cope with such an increase in information to be learnt, and the importance of developing the skills of critical thinking, numeracy and analysis has never been greater. Ensuring quality, rather than quantity, of students studying at university is, therefore, the primary concern for biology.

## Participation and performance in secondary and tertiary education

In most European countries, over 70% of young people graduate from upper secondary education (e.g. Baccalaureat, Abitur or A-levels)[2]. A substantial proportion goes on to tertiary education at university or similar establishments, representing between 1/3 and 4/5 – depending on the country – of the population of undergraduate student age. Graduation failure rates of 40% and above (which include drop-out before graduation and examination failure) are not uncommon, and in some countries may be as high as 50 – 60%. Failure rates for sciences are generally not known, but are assumed to be related to the overall figure. High failure rates represent a waste of resources and time. The reasons for failure are mainly:

- The course did not match the expectations of the student.
- The student did not match the expectations of the course, lacking life and social skills, and the ability for autonomous information retrieval and learning.
- The student did not enter university with the aim of gaining an academic qualification (i.e. university was merely a stop-gap option).

Set against this background, entry rates to university continue to rise in most of Europe. Since it is widely reported that the quality of students gaining upper secondary qualifications remains largely unchanged, or is even declining, some universities find themselves so preoccupied with compensating for the deficits of secondary education that their role as tertiary education providers is compromised. In extreme cases, tertiary education is done mainly in doctoral programmes.

## What universities need from schools

Conclusions

- There should be more interdisciplinarity between biology and other sciences at school, and a requirement for the parallel study of chemistry and/or mathematics for those wishing to study biology at tertiary level.

- Expectations of biology as a subject of tertiary study and research should not be limited by the strict requirements of secondary education qualifications.
- Students should develop skills of autonomous learning, critical/analytical thinking, and life/social skills before leaving school.
- Initiative, flexibility and creativity of teachers should be promoted, as these qualities are crucial for motivating students.
- An appreciation of the method of science and mechanisms of scientific progress should be viewed as a central requirement for all citizens.
- The contextualising of science via historical perspectives, role and perception in society, science current affairs and science-inspired drama should be considered an important part of a general science education.
- Textbooks should culture creativity and thinking beyond the prescribed curriculum, thus broadening horizons to more current research and ideas.
- Teachers should be supported in regular in-service training in order to keep up with developments and use new resources.

## Parallel scientific ability

Not only are fewer young people studying mathematics, physics and chemistry as primary interests, but those sciences are not sufficiently studied as supporting disciplines to biology. Indeed, in many educational systems biology may be studied at university without another science subject having been taken at secondary level. University teaching staff report that such limited scientific background does not prepare students adequately for the study of modern biology. At a later stage in the career ladder it tends to produce scientists who are scientifically under-equipped to deal with the challenges of their discipline.

## School science curricula, resources and lesson content

Students often have mistaken expectations of biology at tertiary level because their horizons have been limited by the school curriculum. All students should develop the skill of autonomous learning ("learning to learn"), and be encouraged to think critically, analytically, and ask questions about biology. The (welcome) trend in Europe is away from lengthy and highly specified curricula to more elemental versions, often of no more than one or two pages in length. Curricula are variously administered completely at national level (e.g. France), partially at national level (e.g. UK and Finland), or primarily at regional level (e.g. Germany). More important are their content and the quality of the teachers who interpret them.

The UK system defines broad topic areas at national level and leaves course designers to develop courses around that core, and 4 examination boards to test accordingly.

By emphasising skills and providing interesting contexts for the biology content, the Salters-Nuffield Advanced Biology (SNAB) course (UK) has found favour with teachers and students. It takes an unconventional approach, starting not with cells and biochemistry etc., but with topics such as lifestyle, health, ethics, risk, correlation and causation to introduce biological concepts and knowledge[4]. It also acknowledges the need to assess, rather than merely teach, practical skills. Texts are complemented by a web-based learning environment, which provides downloadable paper resources and electronic tutorials, encouraging more autonomous learning[5].

In the Finnish system, broad requirements are laid down in a national (core) curriculum, the details of which are specified in local municipality-specific or school-specific curricula by local education providers[3]. Parents also have the opportunity to participate in drawing up the school's curriculum and in determining educational objectives. A hallmark of the system is the trust that it places in teachers. In order to teach science, Finnish teachers must take a university Master's degree course of at least five years, comprising study in science departments, and one year of pedagogical study at the department of teacher education. In general, biology teachers complete studies in two subjects, for instance biology as major and geography or chemistry as secondary subject. Allowing individuality of approach, initiative and creativity at the level of individual teachers also motivates students. Furthermore, flexibility of teaching method seen in Finland is increasingly recognised as addressing the needs of different learning types (so-called "Lerntypen").

Whatever the precise curricula, all sciences need to be taught as a component of general education for citizenship in a world that lives and breathes science and technology. Although this report does not specifically address science for citizenship, it recognises it as a priority equal to that of science for further study. In some countries (notably the UK) the two kinds of science are separately represented at curriculum level. Such an approach allows academic requirements to dictate the highest level to which science is taught at school, rather than more general 'social' criteria. However, this is not universally seen as a positive way forward, but often as a "dumbing down" of the syllabus.

Of crucial importance in science education is the teaching and discussion of the scientific method – how questions are identified and formulated, how they are researched, how results are interpreted/conclusions reached, and how models arise, are tested, and either superseded or confirmed by further studies. In the age of public interest and scepticism in science, such insights are as important for students who do not go past statutory minimum education as they are for those who go on to university science courses. It is also generally agreed (though not generally implemented) that science education should include the history, socio-historical context and philosophy of science. Analysing the science behind current affairs is a widely recognised formula for increasing students' interest in science, as is science-inspired drama (e.g. film or theatre). Such additions to the teaching plan are generally not formally recognised in curricula, nor are they universally addressed during teacher training.

Additional resources

Textbooks tend to set the standard (as in the USA), and in some places (e.g. UK) prescribe exactly what has to be learnt – and no more. They can easily be seen as the authoritative, or only, interpreter of the curriculum, resulting in little drive for teachers themselves to elaborate and extend the boundaries of the material they teach. The incorporation of additional elements, resources and experiences into the teaching plan is a necessary enrichment, and one that can help promote an informed enthusiasm for study.

There is an extensive array of resources at the disposal of teachers, from experimental protocols to information websites. Some teachers (particularly in well funded schools) do access, use and adapt such material in their lessons. However, an overriding concern for most teachers is the in-service training and support that they need in order get to grips with new material and decide what is good. Teachers generally do not have the time to reflect on teaching content and practice. Change must come through the establishment of communities of teachers motivated to undertake professional learning and exchange of experience with new resources, and demand the necessary time away from normal teaching. There needs to be support for such initiatives (e.g. teaching cover whilst on training). Furthermore, schools should make efforts to contextualise and enrich biology education by forming links to local/regional employers of biologists (e.g. industry, research establishments, hospital labs, public service agencies etc.).

## *What schools need from universities and academia*

Conclusions

- School <> university links should be strengthened with a view to further education of teachers, extra-curricular opportunities for students, and better career guidance.
- Networks of teachers, students and university research departments should be established.
- Links between schools, industry and universities should be established, in order to improve the scope and quality of biology education.
- Particularly able students should be given the chance to participate to some extent in tertiary courses before enrolling full-time in tertiary education.
- National academic societies should help schools diversify and contextualise biology education, and develop new teaching resources.
- The reverse flow of experiences and information from past students, now in tertiary education should be exploited to enrich the learning environment at school.

Schools and universities working together

Academia should (and in many locations does) play an active part in the continuing education of school teachers. Greater interactions between schools and universities at the level of career guidance and information about the science of biology in research and application are also of mutual benefit. The transition from secondary to tertiary education involves a long period of adaptation for many students. It is vital that tertiary education requirements, aspirations and expectations are presented and discussed in as part of career advice at school. Several examples of structured and sustainable programmes of interaction exist, e.g. CusMiBio in Milan, Italy[6], where school students and teachers are involved in extra-mural experiences in theoretical and practical science in which young graduates play an important role.

It is also important that universities contribute to secondary education in a way that takes note of and exploits cultural aspects of the region. At European level it would be helpful to establish a network of tertiary education institutions that interact with secondary schools in order to share experiences. For a few particularly capable and motivated students, university material is already within their grasp whilst at school. Initiatives that develop in association with university departments may even be able to offer certain students advance access to tertiary science courses, easing them into the academic environment in a controlled way. The Ort-University Project at the Hebrew University of Jerusalem is a pilot scheme aimed at the gradual "academisation" of secondary science studies[12]. It enables particularly capable students to undertake the first university science courses whilst still at secondary school. At present, 70 students from the 8$^{th}$ – 9$^{th}$ grades are enrolled. Starting with partial participation in the academic course they are able to obtain a BSc degree in 5 years, three of which overlap with their last years of secondary school. At international level, a networked project known as the 'Network of Youth Excellence' promotes involvement of specially gifted secondary students in tertiary education and science research via sustainable teacher–researcher links[13]

## Extramural initiatives and services

Europe has a multitude of institutional initiatives and services for biology education at the level of schools, school-academia interactions and totally extramural education projects and establishments. In Germany alone there are around 200 teaching laboratories, and numerous networks of teachers, students and scientists: from "Stützpunkt-Schulen" (schools that actively interact with scientists and develop new teaching resources), through foundation-supported activities such as the Bosch-Stiftung's NaT-Working[7] to large teaching laboratories such as Xlab in Göttingen[8]. The UK recently set up a series of science learning centres[9] and is also home to the National Centre for Biotechnology Education[10] – a centre that acted as a model for the famous Dolan DNA Learning Centre (USA). Although national biological societies have an important role to play (e.g. teaching resources, careers guidance) – and can strengthen the link between schools, industry and academia[11] – it appears that very few teachers have contact with national academic societies. Former students also become a potential external resource, but one that is almost completely overlooked. A reverse flow of information from students who have gone to university back to the schools and teachers can bring new ideas, resources, experiments and enthusiasm to the classroom. The Researcher in Residence scheme from the UK is one example of this in operation[14].

## Epilogue

Of particular importance in strengthening the education system as a whole is the maintenance of the central role of school as the place where curiosity is first cultured and developed. External education initiatives, while vital, should not assume the role of school teachers, but rather develop collaborations with them, and involve them also at a creative level if possible. From career advice to opportunities for extra-curricular learning, structured and sustainable collaborations between secondary schools and tertiary education establishments have the potential to strengthen the education pipeline as a whole. Interactions between schools, scientific societies, industry and society at large can support the education chain vertically and horizontally: providing new teaching resources, and contextualising biology as a fascinating subject, source of many useful applications and provoker of profound social debate. School probably represents an opportunity for a larger number of educational experiences than at any time thereafter in life. We are generally only realising a small fraction of them.

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