August 2010

Scottish Science & Engineering Education Action Plan

Teaching Excellence Initiative

Input from the Deans of Science & Engineering

We welcome fundamental review of science education following CfE principles and in pursuit of excellence. A step change is indeed required if Scotland's ambitions for its future success are to be realised. Key issues are:

- ***to develop a well-connected approach across STEM education as a whole***
- ***to enhance and deploy mathematical skills across the board***
- ***for the driving aims to be: to engage learners, to build key skills, and to understand and draw from core concepts***
- ***to study a wide range of topics to illustrate the scope and power of science, set in the context and referenced back to the driving aims***
- ***to ensure that assessment is designed to reflect the driving aims***

The Deans of Science and Engineering in Scotland welcome the invitation from the Cabinet Secretary to engage with the Action Plan Advisory Group in discussions on teaching excellence. We believe this is an important area, and a critical one for Scotland's future relative prosperity in the face of rapidly advancing technology and an increasingly competitive global environment.

The STEM context

It is becoming ever more important to ensure a well-connected approach across STEM education as a whole.

- Modern science is thoroughly quantitative; it is difficult, if not impossible, to understand scientific concepts without a solid grounding in numeracy and mathematics. At school level we believe this has not been adequately recognised. For instance, academic bio-scientists have been keen to emphasise that Biology is itself a mathematical subject.

- Nowadays, many of the research frontiers of science depend on interdisciplinary insights and collaborations. This applies in areas such as biomedicine, nanotechnology, environmental science, renewable energy and space exploration. In reviewing the last 25 years the journal "Physics World" recently commented on a remarkable change: at the start of the period most research physicists worked almost exclusively with other physicists, whilst now the great majority are working in partnership with chemists, biologists and/or engineers. The Royal Society of Chemistry has highlighted a corresponding change.

- It is important to stress that these comments do not mean that we are seeking for teachers to cease being subject specialists – their depth of knowledge is critical to future success. What we do hope for is that the cross-disciplinary connections should be explicitly recognised, and indeed highlighted, wherever relevant, because all STEM subjects are interdependent. As a result, all opportunities should be exploited to reinforce and deepen concept and skills development across teaching in the STEM disciplines.

Driving aims for science education

We understand that the remit of the Advisory Group covers teaching in the sciences and hence what follows is set in that perspective. We would have somewhat different but complementary comments to make about teaching in mathematics and the technologies.

We would argue that the driving aims for excellence in science education should be:

i. to engage interest in science, in its scope, power and significance, and to engage active participation in studies

ii. to build the key skills sets in applying science, notably including numeracy and mathematical skills, critical thinking, logical analysis of information, problem analysis & solution, practical observation & measurement, the testing of ideas and the explanation of results and conclusions

iii. to develop and progressively deepen understanding of the key concepts and story lines of science, as the framework upon which topics of study are explained

iv. to explore a wide range of specific applications, selected to address the above aims as effectively as possible, studied in a learner active way, designed to raise interest and to provide challenge and attainable achievement at different levels for students at different levels of current capability

Flexibility and relevance

There is a huge range of potential application topics through which science education can be delivered, many supported by excellent materials on the websites of learned societies and other bodies, both in the UK and internationally. Whilst overall programmes have to be planned to build the key skills and concepts, it is the wealth of applications covered that establishes the importance of science to current and future lifestyles, and excites interest in the challenges and successes of science and in its potential for rewarding careers.

Within the constraints of following a coherent overall programme ensuring progression in skills and conceptual understanding, teachers should be free to select specific application topics judged likely particularly to interest a class, or where the teacher may be able to communicate their own interest and enthusiasm.

Extracting full value from external inputs

The range of educational, industrial and other organisations offering support for school science is one of the clearest signals of wide-spread recognition in the post-school world of the need to enhance the impact of school science education. Whether via the support of Science & Engineering Ambassadors or through the rich variety of experiences, events and competitions offered by external bodies, it is important to find ways to link such inputs to the core curriculum. This may involve work to prepare for, and to follow up such inputs. It would also involve some dialogue with providers geared to maximise the value added by such initiatives.

Topical and controversial topics

Science should not be presented and perceived as certain and fixed: outside of the classroom everyone is aware of the limitations of scientific weather forecasting. Science policy issues can often be controversial: benefits have to be weighed against risks, and ethical judgements may also have to be made. It is important to reflect these very important features within school science education. Relevant topics of current interest abound across the sciences, including climate change projections, GM crop development, nano-robots, nuclear power, STEM cell technologies, agrochemicals, etc. The aim of studies in such areas should be to give a balanced, and wherever possible, quantitative account. Science identifies the issues and the odds: policy decisions should be informed by the science but in the end they involve political and ethical judgements. A sine qua non for studying such issues objectively is that the "Numeracy" strand on probability and risk is developed effectively, in a coordinated cross-disciplinary way.

Science education for all

STEM education at school is important not only for those who will in due course progress to careers dependent on STEM skills, but also for the population as a whole. As a society we have to face up to numerous issues relating to the appropriate application of science. If such issues are to be treated rationally, the population as a whole needs to be strongly science literate, and numerate. This is a critical issue for a nation aiming to be in the vanguard in exploiting new science and technology.

The upper levels of science courses in schools should be designed and promoted as useful not only for progression to higher education in science subjects, but also as valuable for those pursuing other directions, providing useful understanding of science, alongside developing skills that are valuably transferable to study and careers in many other areas.

Over the 3 – 15 age range, science education should be designed to engage the whole ability range. In learner-centred mode this requires providing for different levels of challenge for the more and less able at any given stage, allowing positive achievement to be recognised from different starting levels of ability.

Courses at National levels 4 and 5 should be designed, not as the first steps in slowly going through the Higher syllabus, but as engaging and challenging courses at these respective achievement levels. These courses should be designed to support direct progression to work at junior technical levels in industry, whilst also boosting learner confidence and skills levels to allow subsequent entry to higher academic levels.

Addressing gender issues

Considerable gender imbalances in subject interest develop through the secondary years and into higher education. Women are hugely under-represented, particularly in physics, engineering and computer science. One characteristic of an excellent science teaching programme should be an explicit, and reflective, effort to address this position. There is evidence (from the ROSE study and elsewhere) that the choice of specific applications to study could influence the gender imbalance in interest. Topics of clear real-world and human significance are generally found more engaging by girls (whilst scoring quite well with boys also).

A separate gender issue to keep under review is the relative underperformance of males across education as a whole. We believe that science education, appropriately designed, should have the potential to help awaken engagement. This could be aided by the tuned approaches suggested above under "Science education for all," in addition to ensuring that a proportion of the topics studied are in areas that have been found to appeal particularly to males.

Links with numeracy and mathematics

The importance of numeracy and mathematics was stressed at the outset of this note. Using these skills in the course of science study should significantly enhance the science itself, whilst also reinforcing progress in mathematics. A coherent collaborative strategy should be adopted across teaching departments. Among strands that are important are sensitivity to scale, applying proportion, handling probabilities, using graphs effectively, handling equations and algebra, and manipulating units. At more advanced levels the emerging significance of trigonometry, coordinate geometry, vectors and calculus should not be hidden.

Links with engineering and technology

We would like to see opportunities developed to improve connections and cross referencing between science and technology teaching. It is widely recognised that there is a huge need to raise the profile of engineering, and an understanding of the importance and nature of this discipline and the attractive careers it supports. Science underpins engineering, and engineering is central to the applications of science that have so transformed prosperity and our way of life. The project *Engineering the Future* has begun to show ways in which engineering can be highlighted whilst studying science: this agenda should be developed further.

Assessment

It is widely held that the detailed structure and design of Higher Grade exams have heavily influenced the whole approach to teaching the sciences, and many claim that this applies from the beginning of secondary. Hence, getting the assessment "right" for the new generation of courses is of crucial importance. We should make it clear that from a university point of view, we would strongly support quite radical change. The whole spirit of *Curriculum for Excellence* is incompatible with the current model's reliance on recall of factual details and short taught "problem" procedures. The emphasis should be on demonstrating skills in applying an understanding of core concepts in new contexts. Questions should in general be more extended and more open. We appreciate that, for the sciences, a deal of trialling will be required to ensure that examinations and marking approaches are tuned to achieve the right standards, for each grade of award. Such change, however, is essential to raise the quality of science learning achieved.