science education

FOR THE FUTURE

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The school to university transition in science, technology, engineering and mathematics subjects

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This booklet summarises conclusions from a recently completed project, funded by SEED and carried out at the University of Glasgow, to ascertain what Scottish Universities believe is most important in the school education of students progressing to study science, technology, engineering, and mathematics (STEM) discipline areas at university. The project involved almost 200 individual academics, across all of Scotland's 13 universities. There has been a remarkable degree of consensus in their responses, with the same views emerging independently in very many different individual interviews and discussion groups. The Deans of Science & Engineering in Scotland have also endorsed these views. Our full Report can be accessed at ***http://www.gla.ac.uk/stem***

This booklet has been produced to communicate our views to science teachers across Scotland, and to local authority science advisers. We believe that the style of the science curriculum in schools has become constrained within an unhelpful mould, the character of which may have been influenced by views held by universities in the past. Much has since changed in science, and in society. Academics in STEM disciplines across Scotland's universities urge that the time is ripe for a fundamental change in approach.

The strap-line in the title of this booklet – *liberate teachers, engage pupils* – encapsulates the aspiration, which we believe could usefully be embraced as a guiding principle for change. Science is inherently intriguing, endlessly applicable and exciting, and it is of huge importance to everyone's life. We feel that the curriculum should be enabled to reflect these characteristics, and leave room for individual teacher initiative and pupil driven enquiry. As a university community we would wish to be as helpful and supportive as possible in working alongside teachers to enable such change.

The STEM disciplines represent a heavily interacting continuum at the research level and in the applications that underpin the whole infrastructure of our lives. We would wish to encourage the growth of more explicit and coherent links between teaching in the sciences, mathematics and the technologies, and we believe this is consistent with the philosophy underlying the Scottish Curriculum Review Group's *"A Curriculum for Excellence"* report.

1 Summary of views

The universities would strongly favour a less crowded, less assessment driven and more flexible curriculum for all levels of science courses, aimed to liberate and enthuse both teachers and learners.

We believe the national report, *"A Curriculum for Excellence"*, sets an ideal framework for a fundamental review of science education.

Falling numbers taking science Highers have serious implications for the supply of STEM-qualified graduates and for the future health of the science base and economy of Scotland.

A strong scientific literacy theme should form a vital part of school education for all pupils.

Developing personal study and work attitudes is important and needs to be considered in curriculum design.

Building key scientific skills should be a much stronger focus across the range of STEM subjects in school.

A seamless 3-18 curriculum is needed, avoiding current 'disconnects' in continuity and relative difficulty between different stages.

Mathematics provides a vital underpinning to students wishing to study STEM subjects at university. The curriculum should ideally build a mastery of basic techniques, particularly algebra. Topic content needs to be strengthened rather than thinned. Developing student skills in mathematics should be reinforced in the science curriculum.

The science subjects at school are viewed as overloaded and lacking in obvious relevance to everyday life: we recommend clarified and driving aims for school science education and we suggest that research on how to engage pupil interest should also be undertaken to inform a successful curriculum redesign.

It is important to build understanding of the core principles of the sciences; more themed or applications led approaches could be considered; more extended practical work and more in-depth and open-ended activities should be introduced.

The position and status of technological studies, the only school subject pointed explicitly to the world of engineering, needs urgent review; representatives from industry and the appropriate professional associations could be consulted to help with this.

Universities believe that the school computing curriculum gives a misleading impression of the nature of the discipline of computing science as studied in Higher Education.

The design of assessment, particularly in science, must be radically altered if the proposed shift in curriculum emphasis is to be realised.

Fruitful cross-curricular links should be explored amongst the sciences but also more widely with other subjects and in support of the key themes of enterprise, creativity and citizenship.

We tentatively draw attention to an approach, which might be investigated to improve the gender balance in some subjects.

Project conclusions

2 A curriculum for excellence

We believe that a fundamental and comprehensive review of the science curriculum is needed, and we greatly welcome the priority given to addressing science education under the Review process initiated by the publication of *"A Curriculum for Excellence"*.

- *The Curriculum for Excellence* principles[1], which emerged as our own work was nearing completion, appear to us to be remarkably compatible with, and in sympathy with, our own recommendations for STEM (science, technology, engineering and mathematics) subjects.

[1] Report of the Curriculum Review Group, SEED, November 2004, available at: *http://www.scotland.gov.uk.library5/education/cerv.pdf*

3 The science curriculum

We have great respect for the commitment and professionalism of science teachers in Scottish schools and acknowledge the pressures under which they work. We are aware of the huge efforts which are exerted to ensure that science courses are robustly specified and assessed. We feel, however, that the science curriculum itself is seriously out of step with modern requirements. We are concerned about:

- negative trends in uptake in science and technology subjects in the upper secondary, and the difficulty in attracting applicants to university courses, particularly into physical sciences, engineering and computing science;
- the degree to which curricula are topic-knowledge dominated and assessment driven;
- the very limited extent to which the relevance of science to modern life, and the nature and public importance of science 'issues,' are brought out;
- 'disconnects' in the progression of science education, such as between primary and secondary, and in the marked increase in difficulty, relative to other subjects, between Standard Grade and Higher.

It is very important for school science to attract and prepare the young people who will become future professionals in STEM areas or members of a technically skilled workforce. It is also, however, vital to ensure that the future population as a whole has a broad understanding of the significance of science and can assess intelligently the public policy issues and dilemmas, which must be resolved in funding and regulating science. We strongly believe that any review of the school curriculum should embrace this full range of national needs. A well developed understanding of the contemporary significance of science is important both for student entrants and for the wider population whose views will greatly influence the ways in which our disciplines, and the economy, will progress in Scotland.

- We therefore recommend that a strong theme of "scientific literacy" should be introduced in to science courses for all pupils.

The university community* believes that science education at school should be designed to:

- build an appreciation of the historical and future significance of science and technology;
- generate interest and engagement in STEM subjects;
- build a basic understanding of the major ideas and principles of science;
- give an up-to-date view of selected areas of science, addressing some contemporary issues;
- engage interest and enthusiasm in pursuing STEM based careers, both academic and vocational;
- build scientifically useful skills in deploying knowledge and observation to explain and predict phenomena.

We would urge that these aims should be reflected at all stages in a new and coherent design of science provision for all age groups and streams of different ability and interests.

We recognise that a comprehensive curriculum redesign along the lines we advocate will be a far from trivial exercise. On the one hand we think that the current science curriculum in schools is overloaded and on the other hand we argue below for a range of new thrusts and exercises. Without very careful and detailed planning this could result in yet more over-crowding. It will be a major challenge to produce a curriculum which meets the above aims, with adequate scope and time for individual teacher initiative and more open-ended pupil investigation.

3.1 Improving attitudes and key scientific skills

Overlaying all of our more subject specific conclusions are three major pleas, to encourage:

- a strong focus on developing attitudes to education and work, nurturing

*Whenever an * appears, more information under the appropriate heading can be obtained from our full report obtainable at: *http://www.gla.ac.uk/stem*

perseverance and self-driven initiative, and recognising the longer term value of learning other than as a means to overcome a specific assessment hurdle;

- much more emphasis on the key scientific skills areas of
  – numeracy and basic mathematical skills
  – literacy' developed in a scientific context
  – problem solving, particularly in more open and extended applications;
- an approach to the curriculum that is much less knowledge based and assessment driven, accepting as a consequence a significant relaxation in the volume and comprehensiveness of assessment.

Attitudes*

During our interview and discussion process, attitudes emerged as perhaps the most important priority of all. Students require the interest and motivation to apply themselves to their studies and they need persistence and perseverance to achieve their goals at university as they do in school. Pupils today seem to be assessment driven rather than interest led and it appears that league tables, published in the press, encourage this attitude. It is hoped that the Curriculum Review exercise can encourage a more interest led and actively engaging curriculum, rather than one preoccupied with assessment.

Key scientific skills

University lecturers were concerned that scientific skills* were poorly developed. We believe that key skills should be progressively and coherently developed throughout primary and secondary schooling. It is also believed that cross-referencing throughout the STEM curriculum could enhance these skills. The Higher Still reforms appear to have disappointed in their aim to improve core skills[2].

Skills meriting focussed attention for those interested in STEM careers are summarised below.

Numeracy:

- Confidence and reliability in arithmetic calculations, including handling fractions.
- Applying proportion.

[2] Roger Mullin, *'Insight - An Evaluation of the Higher Still Reforms'*, SEED, 2003, available at *http://www.scotland.gov.uk/insight/*

- Appreciation of the relevance and significance of scale.
- Estimating and assessing the reasonableness of an answer.
- Assessing the relative significance of risks of different levels.

Mathematical skills:

- Basic mathematical skills, particularly competence in algebraic manipulation.
- Understanding of indices, logarithms and exponentials.

Literacy:

- The ability to articulate ideas in extended writing.
- Grammar, spelling and the correct use of language so that communications can be clear and accurate.

Problem solving skills:

- Tackling problems in unfamiliar contexts.
- Working on problems in more extended contexts.
- Breaking down problems into logical steps.
- Comprehending the nature of the problem.

Practical skills:

We would strongly advocate an increased and insurgent role for practical work. Extended practical work and good demonstrations can enthuse pupils, whilst adding distinctive and important contributions to a science education. Practical programmes are important to:

- build skills in manipulation, observation and analysis;
- aid understanding of science principles;
- communicate the excitement of investigative science;
- connect science teaching and the real world.

3.2 Views on the current curriculum*

Mathematics

The content of school mathematics makes an important contribution to success in a wide range of Higher Education disciplines, including the physical sciences, engineering,

computing and mathematics. Teachers in the biological sciences also stress the rapidly increasing importance of mathematics in underpinning their disciplines.

- We believe it important to aim to strengthen and consolidate mathematical attainment throughout the curriculum and we advocate that this task should be supported through relevant applications in other subjects as well as in the mathematics classroom itself.
- University teachers believe that essentially all of the current content of Higher grade mathematics is important. For all students studying STEM subjects at university a mathematics curriculum would ideally ensure familiarity with logarithms, exponentials, calculus and trigonometry and knowledge of basic statistics would also be very useful. This could build upon what has already been introduced in Standard grade and Intermediate courses.
- Our participants would wish future students to be more skilled in the techniques and aware of the applicability of mathematics. Universally, they would wish to see greatly improved skills in algebraic manipulation.
- Many argue for more development of statistics, which is currently only available beyond Standard grade as an option that has the consequence of excluding very important other topics. A number of colleagues also advocated the potential value of additional geometry.
- The concept of a 'single 3-18 curriculum' in mathematics is welcomed. It is felt that current connections between different stages of school may be poor, and that some pupils may "mark time" in S1 and S2.
- While this report deals with students progressing to STEM subjects at university we would like to see courses developed for all ranges of ability and interest which will help enhance mathematical attainment for all pupils.
- To help encourage more pupils to be successful at mathematics it is recommended that alternative (and perhaps more applied) teaching and assessment methods should be investigated both for the most able and for those progressing more slowly.
- Mathematics should be exploited in other areas of the school curriculum, reinforcing confidence and competence and an appreciation of its value.

- Many pupils could perceive mathematics as remote from everyday life: if more connections were made it may help improve interest and help students appreciate its relevance.

Knowledge within science education

Within the core sciences we urge that much less emphasis is given to specific detailed knowledge. Our stance on this key issue deserves careful explanation. It is of course a key characteristic of science to attach great importance to knowledge and evidence. Science is, however, fundamentally about interpreting the implications of, and assessing the validity of, knowledge. It also identifies, and then pursues, what is unknown. Science develops central conceptual frameworks, and laws and models of behaviour, which allow us to organise and inter-relate knowledge, to make predictions about properties and behaviour, and to design new or improved devices or methodologies. Learning in science is not fundamentally about committing large volumes of factual information to memory and proving later that this can be regurgitated. In relation to knowledge the priorities for school science curricula are:

- to instil a respect for valid factual knowledge as the cornerstone of all scientific analysis;
- to build a knowledge of central principles and models applicable in the subject area of study, and grow understanding of ways in which these can be applied;
- to achieve a general appreciation of the state of knowledge underlying chosen topics of study, and an ability to access, select and evaluate detailed relevant information as required.

The specialist sciences

Various reports[3] have concluded that science subjects at school are overloaded and there is a belief that the amount of material to be covered leads to very superficial learning. Decluttering the content of school courses will be warmly welcomed by the universities* so long as pupils can gain the skills and techniques of science combined with a knowledge of the fundamental underlying principles. Applying the methods and the principles of the sciences also offers an ideal platform to develop numerical, mathematical, literacy and problem solving skills as well as analytical skills.

[3] *'Why Science Education Matters; Supporting and Improving Science Education in Scottish Schools'*, Scottish Science Advisory Committee, 2003.

We would wish to support a redesigned science curriculum that could provide a range of courses that would meet the appropriate educational objectives whilst being exciting, relevant and also challenging to pupils at all levels.

- Courses should have an inbuilt mechanism for rolling change to avoid growing obsolescence and a need for major review every ten to fifteen years.
- Teachers should be given more scope and space to enthuse pupils about the subjects studied and not so driven by the assessment process.
- We believe it is very important that the science curriculum engages the interest and enthusiasm of young people: we recommend that the international ROSE survey should be used in Scotland and should partially inform the design of new curricula.
- Extended practical work and good demonstrations can enthuse pupils, whilst adding their own distinctive educational value.
- It has been shown[4] that pupils are interested in science topics in the news and wonder why they are not covered in schools. Introducing topics open to debate would also significantly enhance understanding of the nature of science, and bolster the development of scientific skills.
- There should be a strand throughout school science focussed on scientific literacy so that all pupils are given the opportunity to study and debate wider ethical and moral issues relating to science.

[4] *'Beagle Reignites School Science'*, BBC News Monday 22 December 2003. *'New Science for Young Citizens'*, BBC News 9 January 2003, available at: *www.bbc.co.uk/l1hi/education/264275.stm*

The table below regroups our recommendations on the science curriculum.

Perceived issue	Recommended response
Fact filled static curriculum	"Free up" the curriculum, de-clutter to concentrate on core principles, study fewer topics in more depth, introduce 'science for all' and discuss controversial issues. Above all involve the pupil. Investigate the introduction of more themed or application led curricula to interest and motivate the learner. Place more emphasis on developing core skills. Consider the balance between integrated and single disciplinary curricula in the sciences.
Assessment driven culture	Reduce assessment and make assessment serve rather than lead curricular aims. Trust and give weight to teacher-led assessment. Place more emphasis on overall achievement across all subjects studied as a measure of general educational success. Take account of conclusions from research on assessment.
Externally marked experiment dominating limited practical experience	End external moderation of practical. Introduce more practical work, particularly in chemistry and biology. Include more extended exercises.
Compartmentalised knowledge	Form links with other subjects in the school curriculum (thereby also improving core skills). Link science with real life and careers. Consider an integrated project. Develop the strong contribution that science can make to enterprise, creativity and citizenship.
Pupils not active in learning - but to an extent 'force fed', tutored to pass exams, not encouraged to think and form opinions, or to relate to subject.	Pupils should be encouraged to learn and study independently and also to work in teams, and be encouraged to form and express opinions. More extended and relevant practical work should be undertaken. Research what pupils find interesting about science and adjust curriculum in response, perhaps through use of the ROSE questionnaire.
Disjointed school curricula	Construct a single coherent '3-18 curriculum' related to clear developing and unifying aims.

Technological studies

We are concerned about the decreasing national uptake of Higher technological studies, and about the low esteem in which this subject is sometimes held. It is important that the profile of engineering is raised in schools as too few qualified engineers are being generated in Scotland. Pupils should be made aware, in school, of the career options open to engineers.

There appear to be no easy answers as to how technological studies can be made more popular. There is debate about how to balance "academic" and "vocational" aims. Perhaps this terminology is itself misleading: it might be better to think in terms of supporting developing "professional" and "technical" interests. There are also discussions of the potential merits of taking a more "thematic" approach, and concerns about inadequate resourcing of equipment. It would be useful to draw industry and professional bodies fully into discussion on ways to address this serious problem.

The *Curriculum for Excellence* Report advocates activities that span several disciplines and it may be that one way to raise interest in technology would be to work towards better integration with the science subjects. For example it is instructive to note how electronics is approached at Higher level: the emphasis is on "knowledge and understanding" and "problem solving" in physics, and on "design and construct" in technological studies. It would seem important for pupils to be able to integrate all of these perspectives.

Computing and information systems

Higher mathematics is regarded as a better predictor of ability to cope with a computing science course at university than is a Higher in either computing subject. Of the two courses Higher computing is regarded as the more relevant from the point of view of HE. The skills that professional computer scientists require are to:

- think analytically;
- think abstractly;
- take an everyday problem and break it down into smaller parts;
- work quickly and accurately;
- look at different ways of solving a problem;
- fault-find.

Lecturers, while appreciating that the principal purpose of the Higher is not to prepare pupils for study at university, thought that opportunities are missed to develop the skills and abilities required to study computing science further.

From a university perspective the Higher computing units on computer systems and software development seem overly knowledge based. It is also suggested that more emphasis could usefully be given to what a computer can do rather than how it works.

It is concerning that there appears to be a problem in attracting well-qualified graduates to the teaching profession and also in keeping the skills of existing staff up-to-date in this rapidly developing discipline.

4 Cross-curricular links

Linking across the curriculum is strongly advocated in the *Curriculum for Excellence* report, and we believe this could be of major benefit. There should be more integration across the sciences themselves, to prevent duplication, to reflect the cross-disciplinary applicability of basic principles, and to recognise that research frontiers and major industrial applications are largely at the boundaries between the sciences. We believe that cross-curricular activity could greatly enhance pupils' school experience.

- We would wish to see more coherence and cross-referencing between science and technology.
- Very productive links can be developed, to reinforce mathematical and numeracy skills by their timely application within science.
- Literacy skills can be enhanced in expressing scientific arguments in extended writing.
- Skills in logical analysis can be exercised in studying science issues, alongside parallel efforts in other subjects.
- The STEM disciplines should play distinctive roles in cross-curricular themes such as enterprise, creativity and citizenship.

- Links could also valuably be exploited between the sciences and subjects such as geography, history and modern studies: for example, climate change is relevant to science, geography and modern studies.

5 Science for all

We* believe it is important to provide a significant "science for citizenship" theme for all school pupils. This should address:

- the profound impact of science on modern lifestyles;
- science issues that appear in the press today.

The basic science that dominates current schooling is deterministic and feeds the idea that there is only one correct answer to any science question. Science topics aired outside of school tend to have no "right or wrong" answers and are very much topics for debate, generally hinging on:

- judgement of the reliability and completeness of evidence to help us make the best choices;
- assessment of the risks against the benefits involved in the different choices.

It is important that all our young people have some understanding of how science has transformed our lives and can continue to be of benefit to us in the future if correct and informed decisions are made. Young people should feel able to participate in debates on subjects of controversy, with some sense of the background and of the balanced analysis required to make informed judgements.

In our full report we discuss ways in which a *Science in Society* strand could be offered as a core component in the curriculum, right through to S5 level. The *Science in Society* theme might aim[5] for students to be able to:

- appreciate and understand the impact of science and technology on everyday life;

[5] *http://www.21stcenturyscience.org/newmodel/literacy.asp*

- make informed personal decisions about things that involve science and technology, such as health, diet, use of energy resources and technology;
- read and understand the essential points of media reports about matters that involve science and technology;
- reflect critically on the information included in, and omitted from reports;
- take part confidently in discussions with others about issues involving science and technology.

To re-emphasise, we believe it hugely important within a coherently re-planned secondary science curriculum to address the relevance of science to society and how issues of controversy must be faced. This should fit naturally within the broader agenda, progressively developing the major ideas of science, and building scientific skills and competences.

6 Assessment

In the course of our discussions assessment* has been identified repeatedly as a critical area of concern. It is generally believed that school courses are assessment driven. We feel that the current assessment regime adversely influences the nature of the education delivered, and pupil attitudes to learning and to the subject itself. There is also international research evidence[6] that shows repeated testing could cause relative under-achievers to perform less well.

Students at universities seem more assessment driven than previously and "getting a degree" seems much more of a motivational drive than an interest in the specific subject. Many in Higher education believe that their own assessment regimes have become over-burdensome, and that one factor which has driven this has been the growing reluctance of entrants to exert effort on any aspect of a course where its direct relevance to assessment credit is not immediately and directly obvious.

We have become aware that universities, through their specification of entry

[6] *http://www.bctf.bc.ca/alert/archive/2002-03/2003-04-30.html*

requirements, could themselves be thought to be an obstacle to significant reform at Higher and Advanced Higher levels. We have consulted on this issue and can assert that our project participants would not object to changes in assessment that substantially reduced the burden imposed and led to much less detail-oriented examination papers. Nor would they be upset if not all corners of the topic curriculum were always addressed.

We would support a more relaxed and adventurous approach to assessment in schools. It could be healthy and appropriate to include scores from teacher-set and internally marked exercises, allowing a fair degree of initiative within some general guidelines, and supported only by a "light touch" mechanism for moderation. These could enable more open ended and extended exercises to be undertaken. For example, a report on a scientific topic could make the curriculum more relevant and interesting and at the same time enhance literacy skills in producing a structured and coherent piece of extended writing.

However it is redesigned, it is of primary importance that assessment reflects, and encourages engagement with, the full range of desired skills, knowledge and understanding being developed in the course. The fact that it is more challenging to assess these broader thrusts should not be allowed to get in the way. Whilst suggesting that alternative in-course assessment exercises might play a useful role in producing better balanced assessment, we would also stress that any such moves should not run counter to addressing over-assessment.

Scotland's project *Assessment is for Learning*, managed by Learning and Teaching Scotland appears to have made major advances through using formative assessment in making pupils more eager to learn and in helping teachers to address identified difficulties. Their final report[7] identifies very positive feedback on the extent to which the project improved pupil learning, motivation and attainment. Most of the research was centred on primary schools and S1-S2. It would be of interest to investigate the effect of similar initiatives for pupils in S3-S6.

Assessment structures and design must substantially alter if the shift in emphasis

[7] *http://www.scotland.gov.uk.library5/education/ep/aldps.pdf*

proposed for the school curriculum is to be realised. There will need to be a change away from the examination of mainly factual material to a type of assessment which will consolidate understanding and develop skills as well as measure achievement.

- We would encourage changes made to this end and would support less comprehensive and less burdensome assessment.
- We would in general welcome arrangements liberating teachers to exercise much more individual initiative and professional judgement in selecting different optional topics or applications: we believe our recommendations as a whole encourage this and may indeed require it.
- In this context we would also welcome, where appropriate, significant weight being given to teacher-led assessment placing more trust and initiative in the hands of teachers through a "light touch" approach to moderation.
- We have reviewed statistical evidence from universities and find that the relative performance of students at degree level is only relatively weakly correlated with the strength of their school leaving qualifications: there is no need to regard the form of the current school assessment model as sacrosanct because of its reliability as a precise predictor for university admission judgements.

7 Gender issues

In several subjects there is a quite marked imbalance in the male to female ratio. In some areas this is quite expected, although not necessarily desirable. For example very few girls take technological studies and only about 25% of those taking Higher physics are girls. Rather more surprising is the low female participation rate in computing science courses at university where typically only about 10-15% of students are women and it has been found that their drop out rate is also higher. Yet, on both counts, these gender disparities are not found to anything like the same degree for those entering computing courses for the first time at postgraduate level.

It has been discovered that women come to computing with different motivation and teenage experience than men and if courses are designed more with their interests

in mind and if people of like computer experience are initially grouped together, the females will perform well and indeed increasing numbers will enrol for courses. Research on this has been carried out at Carnegie Mellon University[8] where they have subsequently increased women's enrolment from 7% to 42% in five years.

At school the gender imbalance in computing is more marked at Higher than at Standard Grade. Whether the lessons learned at Carnegie Mellon University are directly transferable to a school context is an open question but pilot initiatives might usefully be encouraged selecting more diverse applications or sub-dividing classes by gender.

Technological studies seems to be losing its appeal for boys also and so the problems here are not just related to gender. A questionnaire, issued to school pupils a number of years ago, was designed to see what were the perceptions of boys and girls of the word "technology". The boys responded in the expected way naming computers, tanks, planes, robots and space age ideas. Girls, on the other hand, responded mainly in contexts of society, the environment, health, welfare and making lives better and safer. Again it may well be that perceptions might be influenced through careful choice of the range of applications introduced at school in all school subjects so that both sexes are attracted to different subjects.

Over the years there have been many initiatives to encourage more women to pursue engineering and physical sciences, such as those under the WISE banner, but all with little effect. We feel the work at Carnegie Mellon on computing may have provided an important new insight into the issues which could be applicable across many subjects*.

8 Numbers taking science Highers[9]

Between 1995 and 2003 the numbers sitting the three main sciences have fallen by over 20%. Higher human biology has grown in uptake: however, biology and human biology taken together still show a net decrease of 13%. There is even greater concern about the decrease in the proportion of pupils taking two science Highers at one sitting from 13% to 9% in four years. Many lecturers believe that pupils do not appreciate

[8] *http://www-2.cs.cmu.edu/-gendergap/*
[9] *Statistics available from: http://www.sqa.org.uk.* Also our final report, pp34-37.

the full career and earning prospects open to those who take degrees in science and engineering and would wish to see career relevance highlighted at school. The numbers of students enrolling on physical science and engineering courses at university continues to fall and several universities have cut their chemistry departments. At the same time Scottish industry thinks that it will have a shortage of engineers and also physical scientists in the future because we are not training enough of our own people either at graduate or apprentice level. There is also an approaching shortage of school science teachers. The country needs more pupils to become interested and enthused by science and engineering in schools, and would want to encourage more pupils to take more than one science subject to Higher level.

Physics is a high uptake Higher in Scotland (in 2002 ranked third, after english and mathematics). In Europe and elsewhere uptake of physics is smaller and numbers are falling even more rapidly. Research has shown that Standard Grade physics has been very popular in Scottish schools because the course adopts an applications led approach that pupils appear to enjoy[10]. Pupils seem then to want to study the subject further and progress to Higher physics. Here, however, they come across a more classic type of curriculum: not many are enthused to pursue physics or engineering at university. The introduction of a similar applications led course at Higher may help sustain interest and encourage more to pursue their studies further at university. The chances of gaining a pass at Higher in chemistry and biology with a credit pass at Grade 2 at Standard grade are about 33%. In other subjects the chances of a pass are much greater. Better progression pathways between Standard grade (or whatever the replacement qualification) in the sciences and the Higher need to be established.

Mike Tomlinson, who chaired the 14-19 Review in England and Wales, said recently[11] that if science education is to recover from its downturn in popularity among students, the country must once again trust its science teachers. He stressed that any science curriculum should have:

- ethical and moral discussion as part of lessons, alongside the development of scientific knowledge, ie there should be a better balance between scientific literacy and scientific competence;
- a reduced burden of summative assessment and improved assessment for learning;

[10] Norman Reid and Elena A Skyrabina, *'Attitudes Towards Physics'*, Research in Science and Technology Education, Vol 20, No 1, 2002.
[11] *http://www.21stcenturyscience.org/asp/printable.asp?strPath=/news/n0000000874.asp*

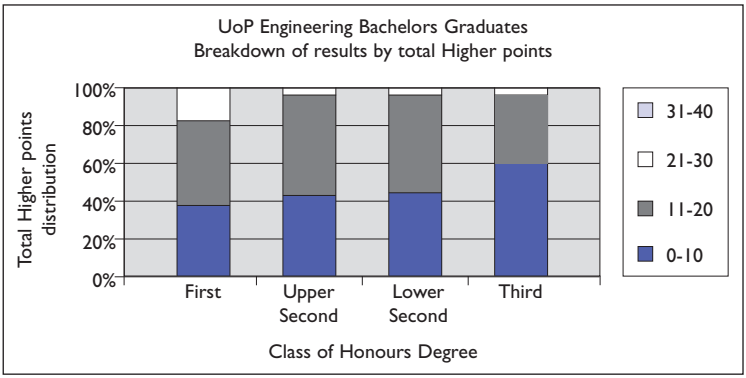
- more time for teaching and learning;
- a more intelligent system for public accountability in education, at present only what is measurable is valued;
- more subject specific CPD for teachers.

Our project participants clearly agree.

9 School results as a predictor of university performance

We have been told at several universities* that school results are a far from perfect predictor of relative performance at degree level. We have confirmed this with studies of our own at Glasgow and Paisley universities.

We think it is important to emphasise this: relative abilities as measured by performance at one stage in education are not set in stone. Most university lecturers can quote cases of previously poorly-performing students suddenly "taking off" academically.



The most dramatic illustration we have seen of this is shown in the chart above, based on an analysis of 947 engineering and computing graduates from the University of Paisley. Over 30% of first class graduates had a school leaving 'UCAS point score'

of under 10 (grades A, B and C at Higher give 6, 4 and 2 points respectively). The generally accepted explanation is that It is only when students become seriously engaged with their studies at a later stage that they can suddenly make huge progress. Within this lies a powerful and encouraging message for the potential positive results of a curriculum review designed better to engage pupil interest and effort.

10 The way forward

Since the publication of the *"Curriculum for Excellence"* report, we have discovered that our views are shared by the Executive Committee of ASE (Association for Science Education) Scotland. We share with them a keenness to contribute collaboratively to help ensure that the unique opportunity offered by the Science Curriculum Review is successfully exploited. We have also met with a small representative group from professional bodies and industry and believe that they too would wish to join collaboratively in providing supporting and coherent input. This Review promises to be groundbreaking in the extent to which it may be driven by an overview of the needs of science education as a whole and for all. If the style of the curriculum is to change in the ways envisaged, it will involve topics, which are beyond the career experience of currently practising teachers. We believe our university network, working in a collaborative and supportive role can:

- provide access to an impressive range of expertise;
- help assure the robustness of any new curricular structure adopted;
- use our strong links with industry and institutions to marshal constructive input;
- contribute collaboratively to the development and delivery of CPD for teachers.

We believe that the Review is of great importance to the future of the Scottish economy and society, and we would wish to do all we can to assist. We would welcome comments from any reader of this report who might wish to comment on or contribute to our on-going efforts. The website indicates how contact can be made. Further detail, and information on the evidence underlying our conclusions, can be found in our full report at: ***http://www.gla.ac.uk/stem.****