Science in Second Level Schools

Summary

Science education is a vital part of the modern school curriculum. In a society which is increasingly based on science and technology, young people require a knowledge and awareness of science, technology and mathematics whether they progress to further study in the sciences or to other studies and careers.

As never before, science and technology are at the heart of issues in everyday life. The school system must reflect this changing environment by making changes to courses and processes at an appropriate rate.

The Irish Council for Science, Technology and Innovation is concerned that Ireland may not be in a position to take a full part in the emerging knowledge-based society. Among the causes of this concern are the falling proportions of students in physical sciences, skills shortages in sectors of Irish industry, above average proportions of lower grades in some science subjects, gender imbalances in the uptake of some sciences and many issues related to student assessment and to the provision of facilities in schools.

In this Statement, the Irish Council for Science, Technology and Innovation makes specific and actionable recommendations on science education to Government, the education and business sectors and others, under four headings, including:

Recommendations

Developing and implementing timely policy

1. A system of rolling reviews of all science, technology and mathematics (STM) subjects should be introduced with specified timescales for review and implementation of new and revised programmes;
2. The development of curricula and the design and execution of pupil assessment should be brought under one organisational structure in order to ensure consistency of objectives;
3. Subject choices and the factors influencing them should be monitored, in an international comparative framework, and periodic surveys of pupils' mathematical and scientific competences should be conducted using internationally comparable methods;

Teacher recruitment, training and retention

4. The Minister for Education and Science should provide special scholarships for graduates of physics and chemistry to encourage them to enter teacher training;
5. New promotional positions, such as Head of Science, should be introduced;
6. Special postgraduate courses for teachers should be introduced to provide opportunities for school staff to acquire additional qualifications in the teaching of the physical sciences;
7. All second level schools should have designated and properly equipped laboratories funded by the Department of Education and Science. Improvements in provision should be measured against a published specification of standard facilities, resources and staffing;
8. The provision of third level science education for teachers should be co-ordinated through a Centre for the Teaching of Science;

Teaching and assessment

9. School-based practical assessment should be implemented within three years;
10. Procedures should be introduced to address the problem of the relatively high proportion of students attaining the lower grades in some science subjects;
11. Science courses should be reviewed with the aim of making science more relevant and attractive to all students;
12. New Leaving Certificate science subjects, geared to meet the broad range of student needs, should be developed and implemented;

Environment for education

13. The private and public sectors should increase their efforts to promote awareness of, and interest in, science and technology through interactions with schools;
14. The Minister for Arts, Heritage, Gaeltacht and the Islands and the Minister for Education and Science should establish and provide ongoing support for a network of science centres;
15. The Minister for Education and Science and the business sector should put in place grant schemes and sponsorship arrangements to encourage informal science education activities and
16. The Minister for the Environment and Local Government should make a special allocation of funds for the public libraries to enable them to acquire science and technology materials.

Science in Second Level Schools

Introduction

In this statement, the Irish Council for Science, Technology and Innovation (ICSTI) makes specific and actionable recommendations to Government, the education sector, the business sector and others on improving science education, and also technology and mathematics education, in second level schools.

In formulating these recommendations, ICSTI has held discussions with a wide range of representatives of the education community and beyond. It has also drawn on the findings of the ICSTI report, Benchmarking School Science, Technology and Mathematics Education in Ireland Against International Good Practice, and the Benchmarking Database which supports that document.

In that benchmarking study, STM (science, technology and mathematics) education in Ireland is compared with that in four other countries (Scotland, Finland, Malaysia and New Zealand) under a common set of criteria. Arising from the study, ICSTI identifies three key issues affecting the quality and effectiveness of STM education. These are:

1. **How to develop and implement STM education policy on a relevant time-scale;**
2. **How to recruit, train and retain high quality STM teachers, particularly in the physical sciences and mathematics and**
3. **How best to teach and assess STM.**

These issues in STM education might well be said to be issues affecting school education in general. However, there are several reasons why they are manifested in more acute form in STM education:

- the importance of science and technology in so many major questions facing contemporary society is increasing;
- science and technology are changing rapidly and school curricula must respond at an appropriate rate;
- demand is increasing in the labour market for young people with scientific, technological and mathematical skills;
- opportunities in manufacturing and services are becoming more attractive for those who might otherwise be drawn to teaching STM subjects and
- student interest in the physical sciences is waning despite the increased need for understanding of the impacts of science and technology.

The Minister for Education and Science has acknowledged the need for intervention in relation to some of these issues. The £15 million package of aids to science teaching in second level schools, announced in Spring 1999, aims to ensure improvements in laboratory facilities and in professional development for science teachers, and to support immediate implementation of agreed revisions of science syllabi.

The Minister has expressed concern about the falling proportions of Leaving Certificate students taking science subjects and instituted some changes in examination format to reverse that decline.

The Minister has also instituted reviews of various aspects of the school system, including the review of Junior Cycle and the examination of the relationship between second and third level, through the Points Commission.

The Irish Council for Science, Technology and Innovation stated recently, in the Technology Foresight Overview, that “the falling number [of Leaving Certificate students] taking Physics and Chemistry is potentially the biggest long-term threat to Ireland’s ability to develop as a

knowledge-based society". The Council welcomes the Minister for Education and Science's initiatives, but believes that much remains to be done to ensure that science subjects are taught and assessed in a manner which matches their central importance for Irish society as a whole.

The following recommendations on science education are presented under the three issues identified through the Benchmarking Study, along with a fourth – the environment for education – which encompasses wider issues of culture and society affecting the education system and the place of science subjects within it.

Developing and Implementing Timely Policy

The Benchmarking Report identifies the first key issue in STM education to be:

How to develop and implement STM education policy on a time-scale that meets the rapidly changing needs of an emerging knowledge-based society, while continuing to meet individual students' long-term needs and ensuring a high level of ownership among the social partners.

The time-scale of policy revision and implementation is especially relevant in STM education because of the pace of change in the economic environment, in the approaches to and understanding of science and technology and in the developments and applications of technology. The continuing, and potentially worsening, skills shortages in S&T-based industry have been identified as a major national concern. In the 1998 Budget report, the Department of Finance stated that "the most immediate (risk to the current favourable outlook for Ireland) arises from emerging shortages of both skilled and unskilled labour. If not dealt with, these shortages have the potential to bring the current strong growth phase to a premature end". Employment opportunities rooted in S&T developments are currently not being fully availed of. The education sector is being called on to address this issue through a number of initiatives in higher education, vocational training and elsewhere.

Schools have a role to play in this too. But as changes in the content or process of STM education take years to affect the pattern of entry into the labour market, it is vital that delays in determining and implementing necessary changes in curriculum and assessment are kept to a minimum.

ICSTI believes that STM education plays a dual role. It prepares some students for further studies and careers in S&T-based occupations and prepares all students to play an active part, as citizens, in a society that is increasingly shaped by developments in science and technology. The present STM education system is fulfilling neither of these functions satisfactorily. The need to simultaneously fulfil both should inform a comprehensive and continuing review of syllabi for STM subjects.

The current process of syllabus revision involves all the major stake-holders. This increases the sense of ownership of changes, but can contribute to delays in making relatively minor adjustments. Delays arise too in implementation. The content of the revised Leaving Certificate syllabi for physics and chemistry was completed in 1994 and the syllabi are being implemented with effect from the school year 1999-2000 and taught in schools from September 2000. Such delays seriously affect the necessary syllabus revision process.

ICSTI recommends that the partners in the process of syllabus revision, notably the Department of Education and Science, examine how that process can be streamlined, for example through the setting of specific time limits for completion, implementation and review of changes. ICSTI further recommends that a system of rolling reviews of all STM subjects, on a phased basis, be put in place.

Rationalisation is needed too in the relationship between curriculum development and assessment. It is essential that changed objectives in the design of curricula be fully reflected in the manner in which students' performance is assessed. A shift towards greater emphasis on 'problem-solving' approaches, for example, can be jeopardised by a continuing reliance on terminal examinations that test memory of 'correct', factual answers. ICSTI recommends that the development of curricula and the design and execution of pupil assessment be brought under one organisational structure in order to ensure consistency of objectives. This has been a declared intention of education policy at various times: ICSTI urges that it now be given effect.

Continuing review of changes in curriculum and assessment and of how they are taking effect in schools should be an integral part of the policy process. In this connection, it is also important that those designing curricular and assessment policy and practice understand how and why students exercise subject choices. Some work has been done in analysing and addressing any imbalances between boys and girls in the uptake of science subjects at Leaving Certificate. As the overall proportion continues to decline, the need for monitoring, and for well-founded action, becomes more urgent.

ICSTI recommends that procedures be put in place for a system of continuing monitoring, in an international comparative framework, of subject choices and of the factors influencing them. Another element of this approach should be periodic surveys of pupils' mathematical and scientific competences by internationally comparable methods.

Teacher Recruitment,Training and Retention

The Benchmarking Report identifies the second key issue in STM education to be:

How to recruit, train and retain high quality STM teachers, particularly in the physical sciences and mathematics.
In view of the strong demand from industry for graduates in STM disciplines, particular incentives are needed to attract such graduates into teaching and, once they have entered the profession, to retain them. In recent years, quotas for science graduates on postgraduate education courses have not been filled.
ICSTI recommends to the Minister of Education and Science that special scholarships be provided, for an initial five-year period, for graduates of physics and chemistry entering teacher training.

As a further measure to improve the professional status of science teaching, but also to ensure a better match of teacher skills and curriculum requirements, it should be obligatory that those teaching STM subjects at Leaving Certificate level have relevant qualifications.

ICSTI advocates that promotional positions (e.g. Head of Science) be introduced and that special postgraduate courses be provided for teachers to give them the opportunity to acquire additional qualifications in the teaching of the physical sciences. Other courses could equip participants for laboratory management and curriculum leadership. Additional incentives for teachers could include award schemes for outstanding achievement, e.g. as an adjunct to the Young Scientist and Technology Exhibition.

ICSTI also recommends to the business sector that it seek ways to support best practice in STM teaching, e.g. through paid-for placements in industry and/or universities. Short-term placements could be held during vacations and long-term placements as sabbaticals for a term or a year.

Poor laboratory facilities are a major disincentive to teachers, just as they are to students. The Department of Education and Science recently completed a survey of school laboratory resources and the Minister has indicated that a major programme of investment to modernise school laboratories will be implemented.

ICSTI requests that the survey of laboratory facilities be published as a baseline against which future improvements can be measured. A further programme of investment must be implemented to ensure that all second level schools have designated laboratories and that resources are available to replace equipment as needed.

In view of the particular significance of computer facilities for teaching STM subjects.

ICSTI recommends that a programme of investment be established, following the present Schools IT 2000 programme, to ensure that schools can maintain and upgrade facilities and resources for information and communication technologies (ICTs) as needed.

For all science and technology laboratories, a specification of standard facilities and resources should be published against which provision can be measured. By setting a baseline standard it will be possible for teachers and schools to identify their needs and to request support.

Science teachers are often over-burdened with the management of laboratory and technology facilities. In order that teachers can concentrate on the content and methods of their teaching, ICSTI recommends that the specification incorporate standards for the provision of staff for science teaching. Specifically, teachers' assistants to supervise laboratories and computer facilities should be included in that provision. The level of provision of support staff by the Department of Education and Science, which is an implicit action arising from the specification,

could, for example, be dependent on the number of pupils taking science subjects at Leaving Certificate in a particular school.

Expansion of the present range of in-career development courses at third level, for updating teachers' knowledge and skills, and the establishment of a continuing review of teachers' needs for in-career supports are required. Science education courses and lectureships now exist in several third level institutions. ICSTI recommends that third level science education activities be co-ordinated through a Centre for the Teaching of Science, as proposed in the Council's Technology Foresight report. This centre - perhaps established as a network - would be a resource for teachers, schools, Science Resource Centres and Education Centres, providing a range of short courses and degree programmes in science education and research-based information on new materials and methods in teaching science. Proposals should be sought by the Minister for Education and Science from the third level sector on a Centre for the Teaching of Science with a commitment to establish the centre on a specific time-scale.

ICSTI acknowledges the enthusiasm and commitment of the subject-specialist teachers' associations and the contribution they have made, on a voluntary basis, to pressing for improved standards in science education. The Minister for Education and Science has recognised the role of the Irish Science Teachers' Association (ISTA) by appointing leading ISTA representatives to public bodies within the education system. ISTA members will also be key resource teachers supporting the implementation of syllabus change in physics and chemistry. ICSTI recommends that the ISTA be further encouraged and supported through the allocation of a grant to fund a full-time officer. The proposed Centre for the Teaching of Science would be a suitable location both for the officer and an ISTA office.

Teaching Assessment

The Benchmarking Report on STM education identifies the third key issue to be:

How best to teach and assess science, technology and mathematics.
Evidence from the five countries in the benchmarking study showed that STM education practice was subject to continuing review and analysis. Specifically, there was a shift of emphasis from fact-based teaching to problem-based learning. The decline in the proportion of students taking science, particularly physical science, subjects at Leaving Certificate or equivalent level is an international phenomenon. Education research in this area is increasingly focused on how traditional modes of science teaching have contributed to this phenomenon.

In Ireland, this factor is compounded by the reliance on a single form of assessment, which, traditionally at least, has tested retention of discrete facts and laws much more than the capacity to reason and analyse. The teaching of science subjects in the senior cycle of second level education is significantly shaped by the forms of assessment. These militate against innovation in teaching. This examination-driven approach makes the teaching and learning of physics and chemistry more difficult.

Several science subjects have been made more inaccessible than necessary through the manner in which examination papers are presented. Students' perceptions that physics and chemistry are difficult have been reinforced over the years by the above-average proportion of lower grades in some science subjects at Leaving Certificate. On the welcome initiative of the Minister for Education and Science, some of these examinations were made more comprehensible, with immediate results, evidenced by reduced failures and better grades in physics and chemistry, in 1999. The wider problem remains: assessment is carried out on a very limited basis through terminal written examinations and the consequent restrictions on teaching remain.

Discussions have continued for several years on the feasibility and forms of practical assessment. There is now general agreement on the desirability in principle of practical assessment in science and other STM subjects. ICSTI is concerned that practical assessment be introduced at as early a date as possible. The Council is aware of implementation concerns and difficulties but it urges the Department of Education and Science to implement school-based practical assessment on a phased basis and, at the latest, within three years.

Serious concerns have been expressed by students, parents and teachers about the lack of comparability between the grades awarded in different subjects and the perceived discrimination against the science subjects. Currently, examinations and results are criterion-referenced against the requirements laid down by the Department of Education and Science through the Inspectorate. The examination grades are also compared with the achievement levels of previous years but not against those of other subjects. In order to address concerns that science subjects are being discriminated against, examination results for different subjects should be compared and procedures introduced to remedy the consistently above average proportion of lower grades attained by students in some science subjects.

The substance of courses needs to be reviewed to make science subjects more relevant and attractive to all, including those not intending to pursue third level studies. In Junior Certificate Science and Leaving Certificate Biology, Physics and Chemistry, there is a need for greater emphasis on the applications of science, on examining science in an historical, social and cultural context, and on scientific method and how current knowledge has been acquired. For Leaving Certificate, the inclusion of Science, Technology and Society in all revised syllabi is welcome. ICSTI urges that these and other improvements be made, with a view to subsequently making Science a required subject for completion of the Junior Certificate. This measure would ensure that all school students leaving at the earliest permitted age have studied science at some level.

Science in Second Level Schools

ICSTI believes that students would benefit from the inclusion of more science and technology elements in Transition Year, where the greater flexibility could be used to explore further the applications and the origins of scientific knowledge. ICSTI recommends that schools should be encouraged to incorporate more science into Transition Year activities and require all Transition Year students to achieve a basic level of competence in ICTs, which might be measured through the European Computer Driving Licence (ECDL).

Science provision for the Leaving Certificate is currently geared to the entry requirements of third level science or science-related studies. The range of choices and the design of the subjects tends to force students into one of two streams, scientific or non-scientific. The Council acknowledges the benefit to students of the Leaving Certificate Vocational Programme option, a course which gives emphasis to science and technology subjects in a context of social and practical applications. ICSTI believes there is a strong case for new Leaving Certificate science subjects geared to meet the broad range of student needs and that such courses should be developed and implemented. A course in General Science would cover a range of science topics and be provided for students not specialising in individual sciences. A course in Understanding Science, with a strong emphasis on the social and historical context and applications of science, could be of equal value to students opting for specific science disciplines and those who are not. A related course in Understanding Technology would focus on technological developments and their applications and their role in, and impacts on, society.

With the rapid expansion of the provision to schools of ICTs through Schools IT 2000, there are opportunities to make the teaching of science more relevant and attractive. STM subjects are particularly well served in the provision of educational software, courseware, and reliable Web sites. ICT-based services can also be used to support project-based and other forms of continuous assessment.

ICSTI has initiated the preparation and publication of a Directory of Science Teaching Resources, which notably includes many disc-based and Internet-based products and services. By undertaking this project with the National Centre for Technology in Education and the Irish Science Teachers' Association, ICSTI aims to support the teaching of science in schools. The development, effective dissemination and continuous updating of the Directory of Science Teaching Resources will depend on this partnership.

Many schools have, often through the commitment of individual teachers, developed imaginative and effective means of engaging pupils' interest in STM subjects. ICSTI encourages schools more advanced in STM education to share their experience and, where appropriate, their resources with other schools, through subject specialist teachers' associations and the Education Centres, and requests that the Department of Education and Science supports such initiatives. The proposed Centre for the Teaching of Science would further facilitate these interactions.

Environment for Education

Science and technology have an increasing importance in major questions facing contemporary society, yet they are widely regarded as the preserve of experts who are removed from the arena of everyday public debate and social interaction. The organisational and professional forms of science and technology education and work contribute to this sense of distance. The school system plays an important role in making science and technology, its workings and outputs, more accessible. With the help of the scientific community, it can do more to encourage young people, their parents and teachers to engage with science and technology, and to promote an understanding of the contribution of science and technology to cultural, economic and social development.

Public awareness of science and technology is weak, in particular awareness of how scientists and technologists work and how science and technology exercise their influence on everyday life. This contributes further to the distance mentioned above, and undermines the efforts of many talented and dedicated teachers in enthusing their students about STM subjects and in retaining their interest. Thus, initiatives in both the private and public sectors to increase awareness of, and interest in, science and technology must form an integral part of the effort to improve STM education. This can be achieved by science-based industries, professional bodies and third level colleges engaging more actively with the education community, for example, through supportive interactions with teachers, through open days and in providing work experience.

This should not mean that such public awareness initiatives are aimed exclusively or primarily at school students, or geared specifically to school curricula. A positive, or at least open, disposition towards science and technology among parents and among teachers of all subjects will be a key factor in improving the status of and attitudes to science in schools.

One of the potentially most valuable initiatives to be undertaken could be the development of science centres. Several proposals for a national science centre have been actively promoted over the past decade, but none appears close to realisation. Ireland remains one of the few European states without a major science museum or science centre. In the United Kingdom, several new science centres, including a major centre in Belfast, are being established as part of a millennium initiative.

ICSTI, as stated previously[3], favours a ‘distributed’ model for science centres in Ireland, that is, a network of smaller centres, each with its defined brief within the broad field of science and technology, each with its own links to companies, colleges and schools in the region, but all sharing design, development and maintenance facilities. ICSTI urges the Minister for Arts, Heritage, Gaeltacht and the Islands and the Minister for Education and Science to proceed quickly in putting a science centre network in place.

The value of informal science education activities in promoting young people’s interest in science and technology has been amply demonstrated in other countries by science centres, science fairs and science shows. There is limited experience of such activities in Ireland but the positive reaction of teachers and pupils to such initiatives supports the case for larger and wider investment in, and sponsorship of, such ventures. The ScienceWorks Roadshow and the Science Bus of the Centre for Talented Youth in Ireland take science shows to primary schools and the Galway Science Festival, as part of Science Week Ireland, has attracted large numbers of young people. ICSTI recommends to the Minister for Education and Science and to the business sector that they actively encourage informal science education activities through grant schemes and sponsorship arrangements.

The public library network has received welcome attention recently in view of its potential role in facilitating wider access to online information services. These services include many with educational value, notably in the range of STM subjects. The libraries can play a larger role in helping to create a supportive environment for school science through the purchase of up-to-

date materials. ICSTI recommends that the Minister for the Environment and Local Government make a special allocation for the public libraries to enable them to acquire science and technology materials.

Scientists, technologists and engineers also contribute to creating the environment within which school students participate in their education and exercise their subject choices. Some of the responsibility for students finding science subjects unattractive, or failing to see the career opportunities that taking those subjects might open up, lies with those who give guidance to students and provide information to schools on careers. Those providing careers information and guidance must ensure that it reflects the exciting opportunities which are open to young people with STM qualifications at all levels. Some responsibility for the attitudes of young people must also lie with the science and technology community. Many students cannot identify relevant role models in science-based occupations. This is due in some part to the low public profile of scientists. ICSTI urges scientists, engineers and technologists and their professional organisations to become more active in public affairs.

ICSTI made this recommendation in its statements on Science in Primary Schools (may 1998) and Science, Technology and Innovation Culture (November 1998).

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Currently two vacancies