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SCIENCE FOR ALL[1]

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The situation of provision for, and achievement in, science in first- and second-level education in Ireland is reviewed and is considered unsatisfactory in a country in which the economy depends on workers who have skills in science and technology. Proposals are made for improvement. A vision for Ireland in 2015 of a knowledge-driven society, dependent on an economy founded on high value-added products and services and a society supportive of the benefits of scientific and technological developments, is presented. To make this vision a reality, considerable strengthening of postgraduate activities in research and development in Information and Communication Technologies and in Biotechnology will be required.

That we should be debating whether science should or should not be a core curriculum subject at the turn of the 21st century would be a matter of curiosity to members of the Belmore Commission, which in 1898 recommended the introduction of science for all students in national schools in Ireland (Commission on Manual and Practical Instruction in Primary Schools under the Board of Education in Ireland, 1898). Their recommendation was quickly acted upon, and science was incorporated into the revised programme for national schools [New Rules and Regulations (National Education), 1900-01].

Those guiding the emerging new state chose not to build on this scientific foundation. The Revised Programme of Primary Instruction introduced in 1934 (Department of Education, 1934) was narrowly conceived, with a strong emphasis on the teaching of Irish to the exclusion of certain parts of the programme inherited from the days of British rule. Science was sidelined. In 1943, the Primary Certificate Examination was made compulsory, but external examinations were limited to Irish, English, and arithmetic, further narrowing the educational range and outlook of primary education (Madaus & Greaney, 1985).

[1]Paper presented at Science Education in Crisis Seminar, Royal Dublin Society, 1 December 1999.

Nor did the new state choose to tell its children those interesting stories that could have made heroes and heroines of Irish men and women who achieved world-class distinction as scientists, mathematicians, or engineers. I cannot recall any teacher telling me of Rowan Hamilton and his work at Trinity College that laid the foundation for vector analysis, or of George Boole of Queen's College, Cork, whose algebra provided a foundation for modern computer sciences, or of George Johnstone Stoney who, in his remarkable work in atomic Physics in Galway and Dublin, was responsible for naming the electron. The founders of our state, being revolutionaries, were mesmerized, I suspect, by other revolutionaries and their revolutions. They chose to ignore those Irish people who achieved international distinction in the thoughtful world of mathematics, science and technology and determined instead to shape our heroes from the bloody skirmishes of past battles. Perhaps many of Ireland's distinguished scientists were perceived to be Anglo-Irish. Most were, of course, but there were notable exceptions, such as the Reverend Nicholas Callan, who did pioneering work in electricity at Maynooth. In any case, the new state chose to set scientists aside as new history books were written and the curriculum was revised to suit the political needs of the time. Far from grasping the opportunity of freedom and catching up with the industrial revolution that was bypassing us, science was downgraded, and a cold eye was cast on those with ambition and a desire to generate wealth.

These points were vividly demonstrated when, some time ago, I was invited to launch a new science school textbook in Limerick. It came as a surprise to most attending when I mentioned that until 1917, when the Mount Wilson telescope was built in California, the world's greatest telescope was in Birr. When built in 1845, it was an international focal point for scientists who travelled to the centre of Ireland to marvel at what was being discovered, as its three-ton mirror and forty-foot tube scanned the night sky. Few managers of a national curriculum could have so effectively concealed such a story from its people.

The indifference of the state to science remained until recently. I chaired the Curriculum and Examinations Board for seven years in the 1980s and, when we were designing the Junior Certificate course to replace the Intermediate and Group Certificate courses in 1989, I found myself in a minority in wishing to include the new science syllabus as a core requirement for all. The core subjects common to all schools remained as Irish, English, mathematics, and civics. The government of the day was under no real pressure to take science seriously. Our universities produced a surplus of engineers and scientists, many of whom went abroad, and the skills of school-leavers who went directly into manufacturing

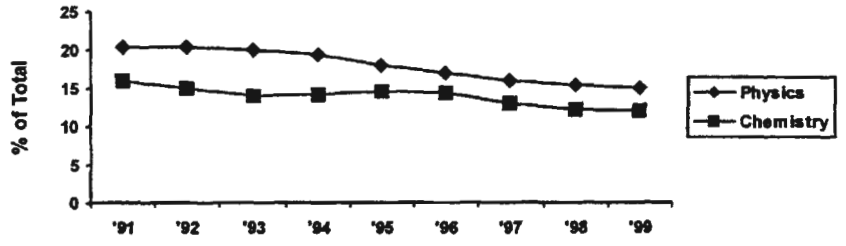
industry appeared adequate for the rather routine tasks most were asked to perform.

This situation has changed utterly in the past decade. The surplus of science and engineering graduates and technicians has been absorbed as a result of Ireland's remarkable success in attracting mobile foreign high-tech investment, and as existing enterprise moves from the industrial to the knowledge era. A serious shortfall now exists. Radical measures are being taken in third-level education to significantly increase the output as a result of unprecedented growth, particularly in Information and Communication Technologies (ICT). The First Report of the Expert Group on Future Skills Needs (1998) estimates that there will be an annual need for an additional 8,300 scientists and engineers. With an annual output of 3,600 engineering and computer science graduates and 2,500 technicians, which includes the government's initiative in 1997 to substantially increase output, an annual shortfall of 2,200 is identified. This is broken down into an annual shortfall of 800 engineering and computer science graduates and 1,400 engineering and computer science technicians. This large shortfall projection was based on a high growth scenario. So successful have we been in recent years in developing the high-tech sector that despite every effort in the third-level sector to boost output, the shortfall is likely to be greater rather than less than predicted. The figures highlight the challenge for those responsible for national development and also the great opportunities for young people in science, engineering, and technology.

There has been remarkable discontinuity between policies and activities in the school system and opportunities in the economy. The percentages of students sitting Physics and Chemistry in the Leaving Certificate Examination have declined sharply (Figure1). Perversely, the percentages of schools that offer Leaving Certificate Physics and Chemistry have also decreased somewhat between 1994 and 1997 (Figure 2). The Irish Council for Science, Technology & Innovation (ICSTI) has advised the government of its concern, and states in graphic terms that 'the falling numbers taking Physics and Chemistry is potentially the biggest long-term threat to Ireland's ability to develop as a knowledge-based society' (ICSTI, 1999a).

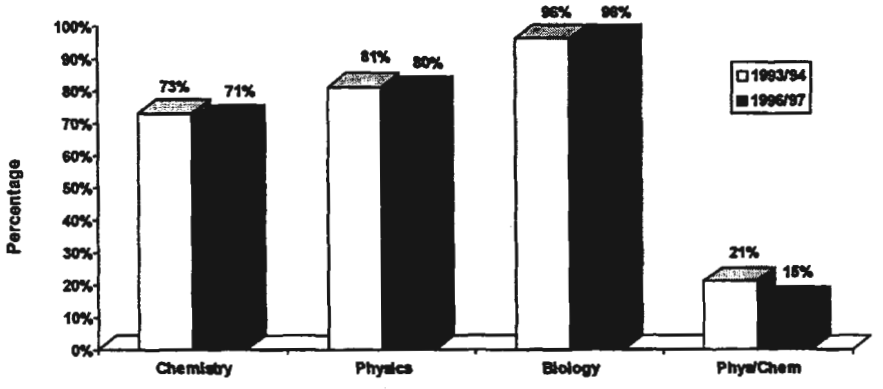
In the past, the Department of Education operated without much interaction with the Department of Industry and Commerce. Since manpower surpluses existed in almost every area, the Department of Education could afford to be relaxed about the speed with which it generated and implemented educational policies. For example, in the case of recommendations on science in both first and second levels, implementation has lagged by nine years. In a world where use of the Internet is doubling every 100 days, delays of this kind have no place.

FIGURE 1
PERCENTAGES OF STUDENTS TAKING PHYSICS AND CHEMISTRY IN THE LEAVING CERTIFICATE EXAMINATION, 1991-1999



Source: National Council for Curriculum and Assessment

FIGURE 2
PERCENTAGES OF SECOND-LEVEL SCHOOLS THAT OFFER LEAVING CERTIFICATE SCIENCE SUBJECTS.



Source: National Council for Curriculum and Assessment

The next generation of young people all require a basic scientific competence and the curiosity, understanding, creativity, and sensitivity in scientific matters called for in the knowledge age. Every level of education, from first to fourth level, must be examined and adjusted to meet the needs of a new generation of Irish people. In the past, we have spent far too long consulting and talking about change. Much speedier responses must be achieved in the national interest. There is a sense in which we can be said to be facing a national emergency and in the short-term it will be necessary to call scientifically literate people out of retirement so that the necessary expertise is available within our school system to ensure that the next generation is scientifically literate.

SCIENCE IN PRIMARY SCHOOLS

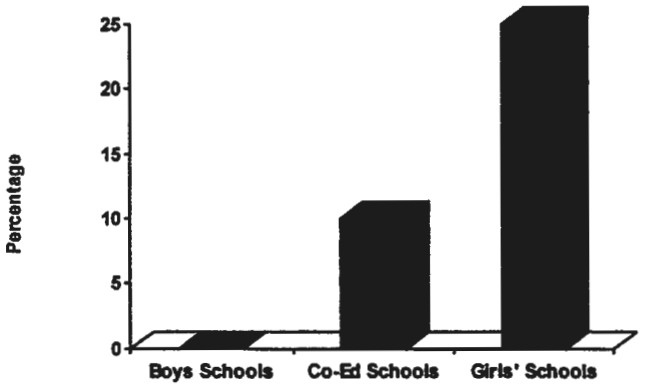
Following a review in 1990 (Primary Education Review Body, 1990) and a White Paper in 1995 (*Charting Our Education Future*, 1995), a revised primary-school curriculum (National Council for Curriculum and Assessment, 1999) is currently being phased in. Science makes a welcome, if modest, reappearance on the curriculum, after being sidelined in 1934. Its reintroduction, however, is somewhat tentative. It is not an independent subject, by contrast with many developed countries, but part of Social, Environmental and Scientific Education. The programme has four strands: living things; materials; energy and forces; and environmental awareness. It is expected that approximately one hour per week will be devoted to science. This modest start must only be seen as such, if we are seriously committed to preparing our young people for the opportunities of the knowledge age.

I am sure that the government would wish to do more, but there are serious logistic impediments. The principal one is the shortage of primary teachers who are scientifically literate. A review of primary teacher education is underway, but one does not need to await the report to realize that a crash programme is immediately necessary in teacher preparation courses to ensure that a large proportion of graduating new teachers are equipped to play a leading role in introducing and developing science. A major programme of inservice education in the primary curriculum began in late 1999; if it is to be effective, considerable effort will need to be directed towards providing primary teachers with the necessary scientific expertise to fill the void that exists in schools. It is also worth considering the idea of attracting into the primary teacher workforce mature people who already have a scientific or high-tech background. The graduate programme for teacher preparation provides an obvious route.

It is surprising that the state still permits secondary schools to operate even if they teach no science of any kind. A secondary school in Ireland meets its obligation to the Department of Education and Science if it provides 'science; or a language other than Irish and English; or a subject of the Business Studies Group' (Department of Education, 1997, p. 7).

Although all but ten schools in the country offer science at junior-cycle level, the core of the Junior Certificate does not have to include a science subject and, as a result, some students complete their studies and get their Leaving Certificate without ever having studied any science subject. The situation is worst in all-girl schools where some 25% of pupils do not study any science subject at the Junior Certificate and almost all of these go on to complete the Leaving Certificate without a science subject. The situation is better in co-ed schools and best in boys' schools where almost all study a science subject, at least at Junior level (Figure 3).

FIGURE 3
PERCENTAGE OF SCHOOL LEAVERS WHO DO NOT STUDY SCIENCE, BY SCHOOL TYPE



Source: National Council for Curriculum and Assessment

For many the dye is cast on entering secondary school. If a science subject is not taken in the Junior Certificate, it is difficult or impossible for most to take one in the Leaving Certificate. This sequence of events precludes significant numbers of students from considering a wide range of third-level studies and

career options. Too late, many students realize that they have fallen into this hidden trap within the school system. As a matter of priority, it is necessary to remove the trap and require all Junior Cycle students to study science as a core subject. This is the norm internationally and our current arrangements represent a remarkable anomaly.

Students who take science at the Junior Cycle are exposed to a curriculum that is heavily weighted towards Biology and the soft sciences. The Department of Education and Science believes that this has an adverse effect on the uptake of Physics and Chemistry for the Leaving Certificate and has asked the NCCA to address the matter urgently. The bias towards Biology permeates the Irish educational system at all levels. We need more of the hard sciences and less of the soft sciences. The majority of those who go into science teaching have backgrounds in Biology. Only 14% of science students studying the Higher Diploma in Education in 1998-99 had a Physics background, and 23% a Chemistry background, compared to 63% who had a background in Biology. As at primary level, the shortfall in teacher expertise at second level requires attention which may involve financial incentives and special promotional opportunities for teachers of science.

In most developed countries, unlike Ireland, external examinations are not held at the end of lower secondary or compulsory education (West, Edge, & Stokes, 1999). Student assessment is school-based, which allows students do more project and experimental work, be more creative and involved. In the absence of these activities, the excitement of science is greatly diminished. The case is similar in music, where study of the theory is rather dull if not enriched and reinforced by playing an instrument. Development of the Junior Certificate examination to incorporate school-based assessment could greatly enrich the learning process in all subjects and especially in science (see Department of Education and Science, n.d.). The dominance of the written terminal examination and the emphasis on theory are perhaps the greatest deterrents to students in following scientific careers. Students are denied the excitement of experimental work while being exposed only to the drudgery of preparation for the written examination. It is hardly surprising then that, according to figures supplied by the National Council for Curriculum and Assessment, of students who take Ordinary Junior Certificate Science, 40% decide not to take a science subject in the Leaving Certificate, while for those who take Higher Level Science, the figure is 20 percent.

It has been noted that there is a great difference between the rhetoric and the reality of the Junior Certificate programme. We have much to learn from countries such as New Zealand and the Netherlands where rich and stimulating

science programmes at Junior Cycle have been developed. Teachers are given more freedom to be creative leaders of their science programmes and those students who are curious and creative have an opportunity to develop these vital talents and excel in a way they may not on the written examination.

SCIENCE IN THE LEAVING CERTIFICATE

The percentage of schools offering science subjects for the Leaving Certificate Examination rather than increasing, as one would hope, is in fact declining. The percentage of students taking a science subject in the Leaving Certificate Examination is even more rapidly declining. While the issue is one with which many developed countries are grappling, the problem is particularly acute in Ireland because of the remarkable new opportunities for scientifically competent graduates. Urgent and radical remedies are called for in the interest of the students and in the interest of Ireland's future development as a knowledge-based society.

From the Leaving Certificate students' standpoint, optimising CAO points is the most pressing issue and it is perceived, with some justification, that studying Leaving Certificate Physics and Chemistry is a demanding activity, the syllabus is overcrowded, and the examinations are harshly graded. Since there is no assessment of practical work in the examination, the exciting practical component of the syllabus is usually downgraded or removed in the school, leaving only the drudgery of preparing for the written examination.

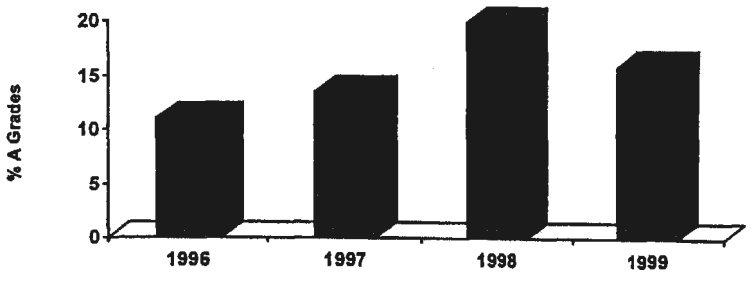
Agricultural Science is the exception. There is a school-based practical examination, and grading of the examinations has been less harsh than in Physics and Chemistry. It may be no coincidence that there has been a 23% increase in students taking Agricultural Science during the past decade. Students sitting for the Leaving Certificate Examination must sensibly judge where their efforts might best be rewarded, and it is generally perceived by students and teachers that studying Geography, Home Economics, and Biology, whether you are interested in the subjects or not, is going to produce more CAO points than studying Music, History, Higher Level Mathematics, Chemistry, or Physics.

Examination Reform

The arbitrariness of the Irish examination and grading system which produces such a wide variation in results between subjects, and from year to year, has persisted for so long that many assume nothing can be done about it. The reality is that the standardization of grades within and across subjects is one of the few initiatives that can be taken quickly and at insignificant cost within the

Department of Education and Science. The need for reform is illustrated in Figure 4 which shows the variation in A grades awarded in the Junior Certificate Science (Higher) Examination over a four-year period.

FIGURE 4
PERCENTAGE OF STUDENTS OBTAINING A GRADES IN JUNIOR CERTIFICATE SCIENCE, HIGHER, 1996 TO 1999



Source: National Council for Curriculum and Assessment

The number of students who sat the examination in each year exceeded 35,000. With such a large sample it is in practice unrealistic statistically to justify any but the smallest variation of a few percentage points in grades from year to year. Such a variation could reflect real differences in national science achievement. But this is hardly the case: in a 24-month period the percentage of A grades awarded almost doubled, and in a subsequent 12-month period decreased by 25 percent. A lottery situation exists for students in all our national examinations and the current arbitrary arrangements are demonstrably unfair. If one sat the Junior Certificate science examination in 1998, one stood a much better chance of receiving an A grade than if one sat it 12 months or 24 months earlier. Such arbitrariness has no place in a national examination system.

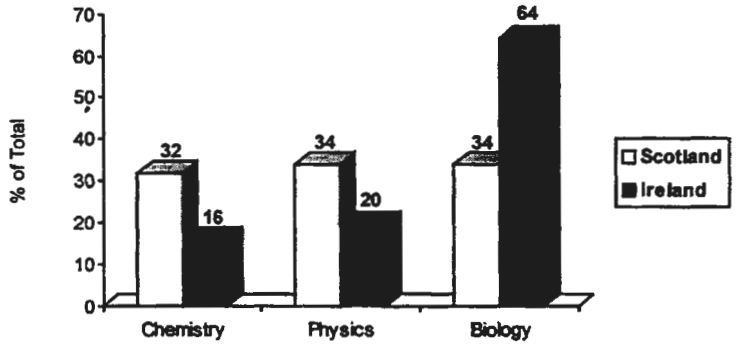
It is quite straightforward to remove this whimsy from the process. There is good reason to consider basing grades on a normal distribution curve for all subjects at all levels. This move would give a consistency to results across subjects and from year to year, and eliminate most of the annual variation between results in examinations. An A grade would then mean something specific, for example, that one was amongst the top 15% of students taking the examinations.

The demands of all subjects and all examinations should be constantly adjusted in a co-ordinated way so that students are not encouraged to gravitate towards subjects that are perceived as easy, but to select subjects because of personal interests, abilities, and ambitions. An examination exit poll of a sample of students could easily provide the information necessary to do the tuning each year. Addressing this issue does not so much depend on funding, as the will to do it.

Imbalance Between Science Subjects

The large majority of those taking science for the Leaving Certificate choose Biology. This represents an imbalance of our own creation in Ireland. In Scotland, for example, equal numbers of candidates are attracted into Physics, Chemistry, and Biology (Figure 5).

FIGURE 5
PERCENTAGES OF STUDENTS TAKING CHEMISTRY, PHYSICS, AND BIOLOGY IN SCHOOL LEAVING EXAMINATIONS, SCOTLAND AND IRELAND



Source: National Council for Curriculum and Assessment

Were I to choose I would prefer to have a student studying one of the hard sciences, such as Physics or Chemistry, rather than one of the soft sciences, such as Biology. If there has to be an imbalance, it should be towards Physics and Chemistry, which provide a more rigorous scientific foundation and a more suitable background for current opportunities for many years ahead in Ireland. It is important that active steps be taken to correct the imbalance and to encourage students to opt for Physics and Chemistry rather than for Biology.

New Leaving Certificate 'Science'

In addition to correcting the imbalances between Physics, Chemistry, and Biology and making these subjects more attractive, there is good reason also to cater for the large number of students who would benefit from a more broadly based programme in the sciences. I have in mind the introduction of a new subject in the Leaving Certificate called just 'Science', that would build on a core science programmes at the junior-cycle level and prepare for work and life in a world that is increasingly science-driven. Modified versions of the existing Physics, Chemistry, and Biology programmes could cater for those who wish to specialize. This approach has worked well in other countries.

The new Leaving Certificate 'Science' programme, dealing with the fundamentals, would contain a wide range of material that is relevant, interesting, and exciting. There would be a written examination but performance records relating to laboratory and project work undertaken in the school during the course would contribute significantly to the overall examination grade. Special financial and other incentives would be necessary to prepare and augment the teaching community. Incentives, such as matching funding arrangements, should be provided to stimulate collaboration between schools and enterprise in the catchment area. Exchange of personnel between schools and enterprise would also build desirable bridges.

It is encouraging to know that new Leaving Certificate syllabuses have been developed in Agricultural Science, Biology, Chemistry, and Physics, and that these will be implemented on a phased basis from September 2000. It is also encouraging that they have been designed so that teaching will be practically and experimentally based and emphasize to some extent the investigative process. A new infrastructure will be required in each school to support the necessary new emphasis on practical work in both science and technology. Government has demonstrated a clear commitment to provide the necessary funds and the challenge now lies at the door of the educational community in responding to a matter of profound national strategic importance. However, the fact that there is no commitment to practical assessment of this work creates an obvious dichotomy between the objectives of the course and its implementation.

Misuse of the Term 'Technology'

The term technology has been used widely and inaccurately in the Irish educational system to describe craft courses. This may have been done on the assumption that materials technology may sound more attractive than woodwork. Certainly, the teaching of crafts is both desirable and important, but it serves no good purpose to misuse the term technology, which is often

described as the 'application of science to the solutions of problems'. It frustrated me when I was chairing the NCCA to realize that subjects that were essentially craft-based were being described as technology subjects without sufficient change in their content. The balance between craft and technology in the curriculum must be altered to reflect the changes taking place in the workplace. There is a need to give new focus to the technology curriculum. Craft-based subjects should continue to be taught, but should be correctly described as craft subjects and not as technology.

VISION FOR IRELAND IN 2015

The first Technology Foresight exercise conducted by Ireland was undertaken in 1998. During the course of an intense twelve-month exercise, the Irish Council for Science, Technology and Innovation (ICSTI) brought together some 180 of the best minds from industry, the public sector, and the scientific and engineering communities to consider Ireland's needs as it evolves towards becoming a knowledge-based society. The Technology Foresight exercise was spearheaded by eight broadly-based expert panels under the guidance of a taskforce chaired by Brian Sweeney, Deputy Chairman of the Council and Chairman of Siemens Limited, Ireland. The panels addressed the following areas: Chemicals and Pharmaceuticals; Information and Communication Technologies; Materials and Manufacturing Processes; Health and Life Sciences; Natural Resources (Agri-food, Marine, Forestry); Energy; Transport and Logistics; and Construction and Infrastructure. The exercise concluded that the Irish economy should be repositioned to be widely recognized internationally as a knowledge-based economy and innovation-driven society. If this is to happen, quantum shifts in policy are called for and the redirection of funding, to ensure that the national foundations are strengthened in the appropriate areas and an apex of world excellence is created to fill a void that the Technology Foresight exercise identified.

ICSTI worked to produce a vision for the year 2015 of a knowledge-driven Ireland, believing that national well-being in a knowledge-based society will depend on an economy founded on high value-added products and services and a society supportive of the benefits of scientific and technological developments. The characteristics of Ireland in the year 2015 functioning as a knowledge-based society are seen by ICSTI (1999b) as follows:

> a significant proportion of industry has become technology-based, and robust in the face of international market developments;
>
> an export trade in R&D and technology services in certain niches has developed;

Ireland has developed a substantial number of large and small indigenous technology companies that are internationally competitive;
Ireland has become a sought-after location for advanced technology firms to perform R&D, interact with the Irish STI system, and produce and export innovative goods and services;
industry, universities, and state institutes constitute a vibrant research partnership, particularly in the key enabling technologies;
access to the best international knowledge has become widespread, as has collaboration with the research base in Europe and the US, especially through the diaspora;
the Irish labour market can now meet the high tech expertise needs of the productive sectors;
higher standards of living are being enjoyed by ever-increasing numbers of people;
Irish researchers have become world renowned in niche technological areas;
attractive employment opportunities now exist for researchers in science and engineering disciplines, and leading Irish researchers around the world have been encouraged to return;
venture capital has become more widely available to technological innovators;
Ireland's infrastructure, particularly in telecommunications and transport, has come into line with the needs of an advanced technology economy;
Irish society has become fully aware of the economic and societal benefits of scientific and technological development.

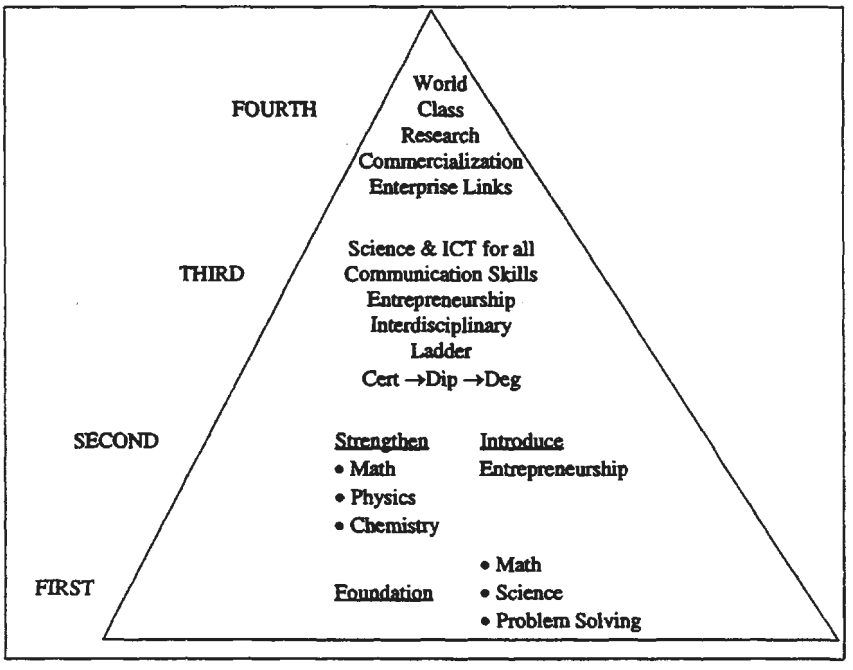
In considering the achievement of this vision, each of the eight panels recognized that the development of human capital is fundamental to Ireland's success. Characteristics of Ireland's population in the year 2015 were identified by ICSTI as follows:

well-educated across a range of disciplines and comfortable with science;
a broad base of numerate citizens;
entrepreneurial and adaptable, including a basic technical competence;
cross-disciplinary capabilities, including environmental understanding;
innovation management capability;
professionals with high-level specialities;
world-class R&D expertise in companies and research centres.

A high-skilled base is an essential foundation for the knowledge-based economy. This means investment in people and science in primary, secondary, and third-level education and subsequently in the workplace through continuous

professional development in the context of a 'life-long learning' approach. Flexible, highly trained and technically capable staff is a key component of agile, competitive, and successful companies. The Irish workforce must in future be able to balance traditional literacy and verbal skills with an equal competence in science and technology. ICSTI concluded that science and technology subjects must be an integral part of the curriculum at all levels from primary to third level. Pupils should have a good grounding in mathematics at primary level, and most pupils should acquire an ability in Physics and Chemistry at second level (see Figure 6).

FIGURE 6
A SCHEME FOR EDUCATION AND TRAINING



SCIENCE AND ENGINEERING AT THIRD LEVEL

At third level, while shortages exist, the Council is impressed by the initiatives being taken by the state in partnership with institutes of technology and universities in responding to needs and opportunities. Funding has been provided across the third-level sector to address the new opportunities, and the

National Development Plan (1999) highlights in a most remarkable way the commitment of Government to education and training at all levels, but especially in addressing skills shortages.

STRENGTHENING THE FOURTH LEVEL

While good progress is being made at third level, a major deficit is identified by ICSTI (1999b) at fourth level. During the past decades, as Ireland geared itself to respond to the opportunities and needs of the industrial era, prime focus was directed towards strengthening and developing degree and sub-degree programmes in universities and institutes. The efforts were most productive and the high standing of Irish graduates with bachelor, diploma, and certificate qualifications is recognized internationally. The ready availability of skilled people, combined with tax incentives, proved central to Ireland's bid to woo mobile international investment, and to achieving our unprecedented economic success. The universities and institutes have served Ireland well and have contributed much to that success.

But as living standards and earnings rise, it becomes difficult for Ireland to compete as a location for basic manufacturing operations. Ireland must plan for a future in which the lower end of manufacturing activities will gravitate from Ireland to countries with lower labour costs, such as those in Eastern Europe. To survive and prosper, Ireland must move up the economic value chain and gear itself to excel in the development and production of knowledge-based products.

Embedding the multinational and developing indigenous high-tech enterprise are Ireland's challenges for the next decade. The Technology Foresight exercise concluded that there are two strategic technologies that will contribute to improving innovation across all sectors of the economy: Information and Communication Technologies (ICT) and Biotechnology. ICSTI has advised the Government that while it is necessary to strengthen postgraduate activities in research and development across the board, it is vital, if we are to secure a good future for Ireland, that we achieve world-class standing in research and development in key niches within these two vital areas. A small country must make choices and these two areas are identified as the most crucial to national success across a wide range of endeavour.

While Ireland is already the world's largest exporter of software after the United States, it has no corresponding centre of software research of world standing.

The Council has concluded that an incremental approach will not ensure that Ireland achieves a leading competitive position in key areas: a quantum leap both of policy and investment in human capital and infrastructure is necessary, if

Ireland is to be recognized as one of Europe's leading locations for knowledge-based investment.

World-class standing and reputation in niches of ICT and Biotechnology must be achieved. The first step has been taken by Government in the National Development Plan and the Council is pleased that its recommendations of April 1999 have been acted upon so fully by Government (Table 1). Table 2 shows the allocation of the industrial provision. This full response of Government to ICSTI proposals marks a watershed in Ireland's development and the start of a new era where Ireland's neglected and rundown research capability will be strengthened across the board, and research centres of world-class standing in key areas of ICT and Biology will be created.

TABLE 1
NATIONAL DEVELOPMENT PLAN 2000 - 2006
EXPENDITURE RECOMMENDATIONS, BY SECTOR

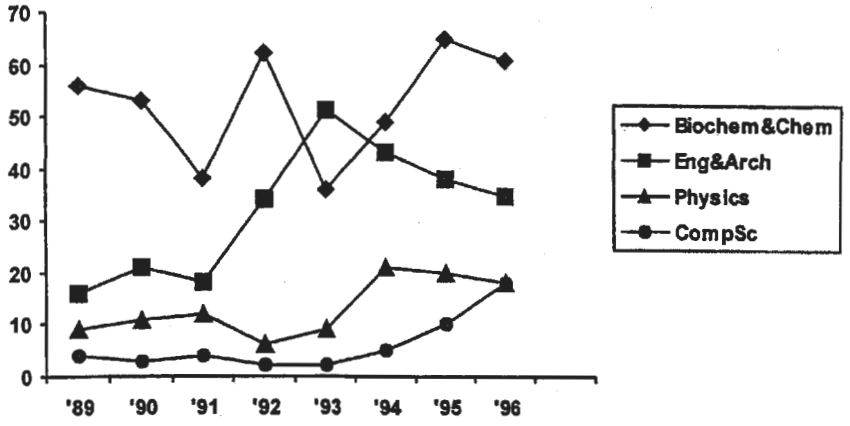
	£ million
Industry	1,186
Education & Science	550
Agriculture & Food	134
Marine & Forestry	50
Environment	14
	1,934

TABLE 2
ALLOCATION OF THE INDUSTRIAL PROVISION
IN THE NATIONAL DEVELOPMENT PLAN

	£ million
Technology Foresight	560
Regional Innovation	17.5
Human Infrastructure	17.5
Companies	381
Networks	210

Given the fragile and generally neglected state of research and development in Ireland, the challenge is great. Ireland's research effort must be reoriented and significantly strengthened. The number of doctorates awarded in key areas must be increased from its present low base (Figure 7). Post-doctoral activities must be dramatically increased, especially in areas of strategic importance.

FIGURE 7
NUMBER OF DOCTORATES AWARDED ANNUALLY IN SCIENCE AND TECHNOLOGY IN IRELAND, 1989-1996



Source: Hughes & McCormack (1999)

Where excellent centres of research exist in the targeted areas, such as the NMRC in Cork, strong support must be provided to ensure that the best minds are retained and attracted. Where satisfactory foundations do not exist upon which one can build, for example in the crucial area of software, a new start must be made. It will be necessary to call upon all available resources. Excellent opportunities need to be created in Irish universities for researchers and for a new blossoming of research.

Ireland has a unique reservoir of global talent. This reservoir must be tapped and the necessary incentives provided to attract home some of the best minds from many of the world's great universities and industrial laboratories. In building research centres in Ireland, the conditions and remuneration will have to match the best in the global marketplace. Contracts cannot be limited by the norms currently applied under public-sector remuneration guidelines if we are to attract and retain the world's best minds.

As Ireland considers how best to achieve world standing in research, it will be useful to consider the kind of institutional diversity that has been demonstrably effective in countries that have already achieved such standing. For example, in Germany, 80 Max Planck Institutes work in a variety of collaborative

arrangements with the universities in addressing Germany's research needs. The success of the Max Planck Society is based on the Harnach principle: research is built around research personalities of world standing, each supported by research teams, typically composed of 8 researchers, 8 students, 5 technicians, 1 or 2 secretaries, some visiting scientists and some fellows. There are many such teams within each of the Institutes. A particular team is dispersed when the team leader leaves or retires. In this way, there is steady renewal and reorientation of each Institute. The Germans are further strengthening their research effort by adding nine new Institutes to the existing 80. The new directors have been appointed, but locations have not yet been finalized. Individual universities and their communities are making presentations to the new Max Planck directors in an effort to attract the Institutes to their cities. While there is competition between the German universities and the Institutes it is a healthy competition for 'status in science'. A wide range of collaborative activities, exchange and joint appointments, between the universities and the Institutes balance this competition.

Other research institute models that have resulted in world-class achievement can be found in many developed countries, in the US, UK and France; but of particular interest are the initiatives of smaller countries such as the Netherlands and Israel, where the Weizmann Institute has made such a major national contribution.

While the institutional arrangements are important, they should be seen primarily as the means of providing the type of environment and support that will retain and attract the best researchers in the world, making them feel cared for and satisfied as they perform their work.

If Ireland is to make its mark internationally as an advanced nation committed to fostering knowledge-driven enterprise, world-class research centres equivalent to a Max Planck or a Weizmann Institute are called for, at least in the two key areas identified in the Technology Foresight exercise. Excellence is not achieved by half measures. A quantum leap is called for in terms of Ireland's vision and commitment to the task. There is one certainty when quantum leaps are involved and radical change is called for in the national interest: great opportunities and rewards will flow to those individuals and organizations that can respond quickly and flexibly.

As the new millennium dawns, a unique opportunity and challenge is presented to the established universities and institutions by the Government. The unprecedented levels of research funding called for by ICSTI in Technology Foresight are being made available to the research community. I have no doubt that the established institutions, together with whatever new institutions are created, as well as individual members of the research community, will respond

with enthusiasm in filling the void at fourth level, as Ireland prepares for the intense global competition of the knowledge age.

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