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Engineering Education at Second Level in the Republic of Ireland: Provision and Developments*

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This paper reviews the provision for engineering education in second level education with particular reference to the Leaving Certificate. The aims, functions, structure and cohort of the Leaving Certificate are identified. The scope and diversity of occupational roles in the area of engineering is reflected by the diversity of curriculum provision for this area across subjects and programmes. The subjects comprising engineering education are identified and aspects of the associated skills and knowledge provided for are reviewed. New educational programmes introduced at upper secondary level have had and will have a positive impact on engineering education. Finally, a number of issues related to engineering education are discussed including progression to higher education and gender issues.

INTRODUCTION

ENGINEERING EDUCATION at second level in the education system of the Republic of Ireland forms part of the general education of second-level students. This level of the education system has experienced and continues to experience substantial curriculum change during the 1980s and 90s. The educational developments at second level have impacted significantly on provision for, and development of, engineering education.

Engineering as a career or profession has no clear profile in Irish society as compared, for example, with medicine. Most students will have met doctors and other medical staff in various capacities but many will not have met engineers or engineering technicians. The distinction in the healthcare sector between different occupational roles is reasonably clear to students. However, in the case of engineering it is not. Most would have difficulty describing what engineering is, let alone distinguishing between occupational branches of engineering. In terms of public perception, engineering is simply an indistinguishable component of the built environment.

This is reflected in second-level schools where it is possible to identify a range of subjects that contribute significantly to the education of students who gravitate towards engineering as a career but there is no direct link between engineering-related subjects at second level and engineering courses in third level. In this context, engineering mainly draws upon Mathematics, the physical sciences and the technology subjects. At junior cycle, the associated subjects are Mathematics, Science, Materials Technology (Wood), Metalwork, Technical Graphics and Technology. In the senior cycle, the relevant subjects are Mathematics, Applied Mathematics, Physics, Chemistry, Physics and Chemistry, Construction Studies, Engineering and Technical Drawing.

In outlining provision for and developments in engineering education, this paper firstly reviews the structure of second-level education with particular reference to the Leaving Certificate. It identifies the aims, functions, structure and cohort of the Leaving Certificate. Developments at senior cycle are briefly discussed. Then the subjects that contribute to engineering education are identified and aspects of the associated skills and knowledge are reviewed. The contribution made by new educational programmes introduced at senior cycle (upper secondary level), namely the revised Leaving Certificate Vocational Programme and the Leaving Certificate Applied, is discussed. The transfer from second to third level is briefly discussed. Finally, issues related to engineering education at second level, including gender, are reviewed.

AN OVERVIEW OF POST-PRIMARY EDUCATION

The schematic diagram in Fig. 1 shows the structure of the Irish education system. The second level or post-primary sector consists of secondary, vocational, community and comprehensive schools. Students are generally twelve years of age on transfer from primary schools. Post-primary education consists of a three-year junior cycle followed by a two or three-year

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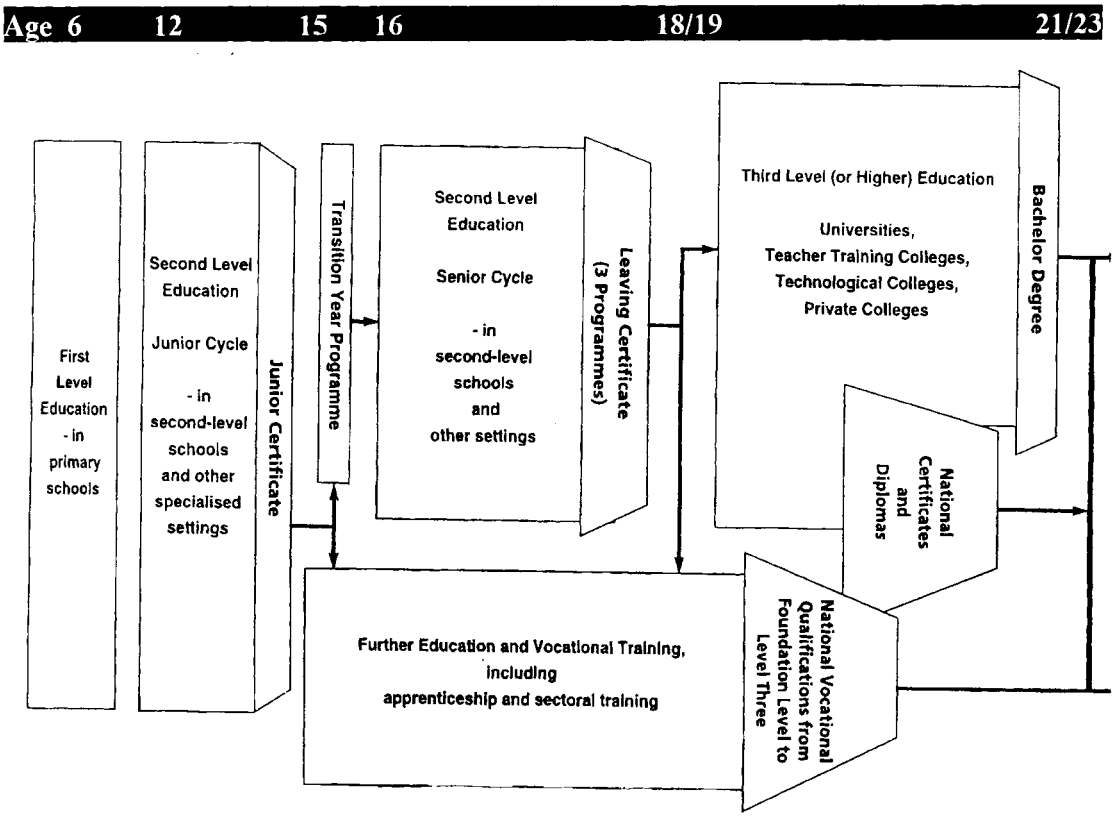

Fig. 1. A schematic view of the Irish education system [1].

senior cycle. The Junior Certificate, a state examination, is taken after three years. It was introduced in 1989 to provide a single unified programme for students aged between twelve and fifteen years [2, p.16]. At senior cycle there is an optional one-year Transition Year Programme followed by a choice of three two-year Leaving Certificate programmes [2, pp. 15–19].

Junior cycle

The junior cycle curriculum leads to the Junior Certificate examination. All students must take Irish, English and Mathematics, one other prescribed subject and two other subjects from the approved list. In vocational schools, students must take one of Technical Graphics *or* Art, Craft, Design *or* Home Economics *or* Business Studies. In secondary schools, students must take History and Geography. In community or comprehensive schools, the compulsory common core of subjects has not been defined. History and Geography are not compulsory but are usually studied by students. Apart from these requirements schools may provide any of 24 subjects approved for recognised junior cycle students.

It is clear that, with the exceptions of Mathematics in all schools and, possibly, Technical Graphics in vocational schools, Science and/or a technology subject are not compulsory in the junior cycle. There is a policy objective, as set out in the Department of Education and Science's White Paper *Charting our Education Future*, that Science or a technology subject be part of the programme for all students [3]. To date, this objective has not been implemented. The technology subjects at junior cycle are Materials Technology (Wood), Technology, Technical Graphics and Metalwork. The provision of such subjects in the different school types is shown in Table 1.

The participation rates for the same subjects in the 1996 Junior Certificate examination are shown in Table 2. Examinations are mainly offered at two

Table 1. Provision of Junior Certificate Subjects in second-level schools 1995/96 [4, pp. 46–59]

Subject	Total	Secondary	Vocational	Community/ comprehensive
Mathematics	748	445	227	76
Science	737	445	216	76
Materials Technology (Wood)	477	181	222	74
Technology	194	110	57	27
Technical Graphics	532	239	218	75
Metalwork	311	38	199	74

Table 2. Candidates in engineering-related subjects in Junior Certificate Examination 1996 [4, pp. 85–96]

Subject	Total	Ordinary level	Higher level
Mathematics	57 916	34 087	23 829
Science	59 031	19 337	39 694
Materials Technology	15 499	5 514	9 985
Technology	3 129	848	2 281
Technical Graphics	18 765	9 873	8 892
Metalwork	9 364	3 151	6 213

levels, Higher and Ordinary. In the case of Mathematics, in both the Junior and the Leaving Certificates, an examination is also offered at foundation level. The number of students who sat foundation-level Mathematics in 1996 was 9,065 [4, p. 89]. The table shows participation in Science to be quite high but participation in the technology subjects to be generally low, particularly for girls. This has inevitable consequences, in terms of uptake of engineering-related subjects, as students move from junior cycle to senior cycle.

A root and branch revision of the junior cycle curriculum was undertaken in the 1980s when new syllabuses were developed in most subjects to reflect the changing needs of students, the education system and society and the transition from provision for two state examinations—the Intermediate Certificate and the Group Certificate—to the present Junior Certificate. The general trend in the new syllabuses was towards greater relevance, flexibility and potential for students learning in more active ways. The hope was that these aims would be reflected in the assessment modes and techniques employed in the examination of the Junior Certificate. The latter did not prove to be the case with the result that opinions are divided on the degree of success of the Junior Certificate as an educational programme. The National Council for Curriculum and Assessment (NCCA), whose brief it is to advise the Minister for Education and Science, is currently conducting a review of the junior cycle within the context of which these issues are being researched and addressed.

Most engineering-related subjects were revised during the 1980s. Revised syllabuses were introduced in Mathematics in 1987, in Science in 1989, and in Materials Technology (Wood) and Technical Graphics in 1991. A new general subject titled Technology was introduced in 1989. These syllabuses provide students with a basic foundation in the relevant disciplines. The revision of the subject Metalwork was deferred. Students currently taking this subject nominally pursue the original syllabus although the lack of revision has not precluded evolution and development of the subject and this is reflected in the examination of the subject whose parameters bear little resemblance to the original syllabus.

The deferral of the revision of Metalwork at junior cycle reflected concern at the number of technology subjects offered at junior cycle. At one point it was envisaged that the new subject, Technology might subsume some of the other technology subjects. In 1993, NCCA outlined its policy on the future of the technology subjects at junior cycle [5]. The Council proposal is that given the common nature of developments in the technology subjects at junior cycle towards incorporation of basic treatment of the relationship between design and technology, towards use of a wider range of materials, skills and processes, and towards the development of the problem-solving capacity of students, a merging of some aspects of this range of subjects would be appropriate:

> 'Council proposes that these developments be coordinated and developed further through the specification of a common syllabus framework for the development of the various technological subjects which would accommodate the internal dynamic of these subjects, maintain standards and traditions and ensure that all pupils in the area of technological education are exposed to a common core set of experiences . . . The new syllabus framework . . . should be structured over three years on the basis of a common core and extended specialist options.'

The provision of specialist options would retain the potential for schools, where chosen, maintaining an emphasis on the materials of wood and metal. While remaining a policy of Council, these proposals have not been implemented to date.

Senior cycle

The option of a three-year senior cycle was introduced in 1994. Students who take this option study a Transition Year programme followed by one of three Leaving Certificate programmes—the established Leaving Certificate, the Leaving Certificate Vocational Programme (LCVP) and the Leaving Certificate Applied. In general, this restructuring of senior cycle is aimed at encouraging a greater number of students to continue in full-time education after the compulsory school-leaving age. To this end, it was seen as necessary to provide a range of programmes suited to a broader range of student abilities, intelligences and interests than the traditional, 'academic' established Leaving Certificate.

Furthermore, this revision was also seen as underscoring a merging within the curriculum offered to senior cycle students of the liberal education and vocational preparation traditions within education and the false dualisms of academic versus vocational, theory versus practice, and education versus training that their separation has given rise to in our education system [6]. This merging of the best aspects of the liberal and vocational traditions was viewed as increasingly relevant to a society and economy whose Government and other representatives espouse the merits, for our young people, of a broadly based education with a significant vocational focus rich in skills and attributes such as those of motivation to learn throughout life, a good standard of

literacy, numeracy and communication, critical thinking, teamwork and career development.

The established Leaving Certificate

The established Leaving Certificate offers students a broad, balanced education while incorporating some potential for specialisation towards a particular career orientation. Student performance in the Leaving Certificate examination can be used for purposes of selection into further and higher education.

The arrangements for students taking subjects in the established Leaving Certificate are clearly outlined by the Department of Education and Science [7]. For students taking the established Leaving Certificate, 'the approved course for recognised senior pupils must include not less than five of the subjects specified of which one shall be Irish'. There are 31 specified subjects listed and these are assigned to groups. The subjects which we have identified as most closely associated with engineering education fall within the Science and Applied Science groups. With regard to these groups, it is recommended that 'each pupil should take at least three subjects from the group of subjects for which he is best fitted, and at least two subjects from outside that group'. There are some limitations to the freedom of choice in this context especially in the case of subjects where there is common syllabus material.

In reality, this grouping of subjects seems to have little relevance to the decisions schools and students are making in providing and taking subjects respectively. It is arguable that most Leaving Certificate students see themselves not as undertaking a 'programme' of education incorporating a 'grouping' of subjects but as undertaking a selection of relatively independent subjects. A further difficulty related to the current list and grouping of subjects is its predominantly academic nature. It reflects a bias in favour of particular forms of knowledge and understanding namely the linguistic and logical-mathematical. Much curriculum development currently taking place on the established Leaving Certificate is aimed at introducing a more balanced schedule of subjects in the future.

The process of reviewing the subject syllabuses of the established Leaving Certificate commenced in the early 1990s. Some revised subjects have already been introduced to schools, some such as those of Physics and Chemistry are awaiting implementation, others such as the technology subjects, including Engineering, are in the final stages of preparation. The brief established for course committees embarking on the revision of subjects provides an indication of the common features of course revision across all subjects. These include:

- to provide articulation with and progression from the Junior Certificate course;
- to cater for the variety of human needs with particular reference to the vocational, further education and training aspirations of students on completion of the Leaving Certificate programmes;
- to achieve greater congruence between the aims and objectives of syllabuses as specified and the modes and techniques used to assess student attainment;
- to be sensitive to aspects of Irish and European culture, to gender equity and to the relationship with other subjects in the school curriculum.

The incorporation of these emphases within revised subjects has implications both for the direction the established Leaving Certificate might take as an educational programme in future years and for its relationship with other senior cycle programmes.

The Leaving Certificate Vocational Programme (LCVP)

The LCVP can be described as an educational intervention in the established Leaving Certificate which results in an enhancement of that programme. The enhancement is of a vocational nature preparing students for further and continuing education, for the world of work and for the business of making a living. The focus of the programme is on students taking greater responsibility for their own learning, becoming more innovative and enterprising, communicating well, working in teams, accessing and using technology.

The LCVP requires that students, while taking the established Leaving Certificate in the usual way, ensure that two of the subjects chosen comprise a vocational subject grouping (e.g. Engineering and Physics) from the list of 13 specified. Students must also study a continental language but most significantly they take three Link Modules in Enterprise Education, Preparation for Work and Work Experience. The Link Modules are assessed, the results achieved recorded on the Leaving Certificate results sheet and they can be used to generate points for the purposes of progression to third level.

The LCVP was introduced to schools in its present format in 1994. In the school year 1998–99, this programme was offered in approximately 460 of the 770 or so post-primary schools. This involves over 30,000 students in the programme. The subjects associated with engineering education are central to the LCVP and their enhancement through linkage with the activities associated with the Link Modules has given rise to impressive experiences at school level of students applying knowledge gained through those subjects to life and work-related projects and investigations.

The Leaving Certificate Applied

The Leaving Certificate Applied, introduced in 1995, is a discrete, alternative programme to the established Leaving Certificate. It is pre-vocational

by nature, aimed at those students who do not wish to proceed directly to third level education and for those whose aptitudes, needs and intelligence are not fully catered for by the established Leaving Certificate. The Leaving Certificate Applied student is predominantly engaged in work and study with an active, practical, task-based orientation.

The programme is structured around three elements: Vocational Preparation, Vocational Education and General Education. Within these elements courses comprised of a number of modules are taken. For example, within the element Vocational Education a course in Mathematical Applications is taken and courses such as those of Information Technology, Engineering, Construction and Manufacturing can be chosen. It is an innovative programme in terms of what students learn, of the methodologies employed in the learning process and of the ways in which student achievement is assessed.

In the school year 1998–99, this programme was offered in almost 200 post-primary schools and other educational/training centres to over 8,000 participants. There is considerable scope within the programme for subjects associated with engineering education mainly within the context of education and training of young people for work at apprentice level and progression to technician level in engineering-related industries.

ENGINEERING AND THE SENIOR CYCLE CURRICULUM

One of the difficulties is distinguishing those components of engineering education which are rooted in academic education and those which are rooted in technical education. There is an excellent treatment of the history of technical/vocational education in Coolahan [8]. Traditionally, engineering education has been seen primarily in terms of subjects but this is an incomplete picture. Nonetheless, one of the main patterns in the past thirty years is of increasing provision of science and technology subjects and this has lead to increased participation.

From the academic tradition, subjects such as Mathematics, Applied Mathematics, Physics, Chemistry and Physics & Chemistry contribute to the development of engineers. From the technical tradition subjects such as Engineering, Technical Drawing and Construction Studies would lead students to courses and careers in engineering. It should be noted that there is no subject such as Computer Studies/Information Technology currently available for certification at Leaving Certificate level although such a development is under active consideration by the NCCA at present.

Engineering-related subjects in the Leaving Certificate

Broadly speaking, academic education was carried out in the secondary schools and technical education in the vocational schools. The development of comprehensive and then community schools in the 1970s and 1980s drew on both traditions and this is evident in subject provision within the different school types. Provision in existing science and technology subjects varies between schools types as shown in Table 3.

Research has shown that subject take-up is dependent on three factors [9, p. 153]:

- provision—whether or not the school offers the subject;
- allocation—manner in which a subject is allocated to students within schools;
- choice—individual choice of a student whether or not to take subjects which are offered.

As the data above demonstrates, Mathematics is provided in all post-primary schools and provision varies for the other subjects. A number of additional factors affect the provision of subjects within a school—the expertise of the staff, availability of the room and equipment required for workshops or laboratories, and the money required to resource the subjects on an annual basis. The tradition of the school as outlined earlier also plays an important role. The size of school affects the provision of the sciences and the technology subjects [10, p. 120]. It follows that schools wishing to extend the provision of these subjects would find it difficult from within existing resources and are dependent on gaining suitable support from the appropriate authorities.

Participation also depends on allocation policies within a school. Almost all schools require students to take Mathematics at Leaving Certificate level. Schools may require students to have taken the appropriate Junior Certificate subject

Table 3. Provision of Leaving Certificate subjects in second-level schools 1995/96 [4, pp. 60–63]

Subject	Total	Secondary	Vocational	Community/ comprehensive
Mathematics	739	443	222	74
Applied Mathematics	216	169	26	21
Physics	597	388	140	69
Chemistry	544	401	83	60
Physics & Chemistry	126	67	49	10
Construction Studies	405	151	187	67
Technical Drawing	512	233	208	71
Engineering	306	39	196	71

and/or achieved a specific grade in the Junior Certificate before they may take the subject for the Leaving Certificate. Such allocation policies may reflect the cognitive demands of the subjects or the numbers permitted in the laboratories or workshops. Thus Junior Certificate subject provision and participation, as outlined earlier, can affect Leaving Certificate participation.

Finally, choice of subjects by students is the key factor in determining participation at Leaving Certificate level. Students' choice of subjects is usually determined by their interests and abilities [9, p. 298] but it is also affected by family tradition [11], third-level points requirements, gender, student perception, and maybe teachers [9, p. 295]. Students' subject choice appears wide but it is constrained by the factors of provision and allocation identified above. Subject participation in the 1996 Leaving Certificate is shown in Table 4. Foundation-level mathematics has been omitted.

This is a snapshot of the participation in these subjects. However, such participation is not static. The numbers taking the Leaving Certificate have increased over recent years and the numbers taking the different subjects varies. The proportion of candidates taking Mathematics at Higher Level has increased in the past few years. The numbers taking Chemistry and to a smaller extent Physics has been falling in the past ten years. This seems to be balanced by an increase in the numbers taking Biology, a science subject not usually considered relevant to engineering education. Participation in Engineering, Construction Studies and Technical Drawing has been increasing slowly.

These patterns have been in part affected by the process of curriculum change and development in these subjects. Most of the subjects are either revising or have revised the courses in the light of the developments at junior and senior cycle. Developments in Mathematics are discussed in some detail as all students take the subject and it is required for entry to all engineering courses in further and higher education.

In Mathematics, there are three levels, Higher, Ordinary and Foundation. All three Mathematics courses are assessed by two written terminal examination papers. The Foundation level, introduced as the Ordinary Alternative level, was revised and renamed in 1995. The Higher and Ordinary level courses were recently revised. The revisions were aimed particularly at making the demanding Higher level course both shorter and less intimidating and thus increase participation at this level [12, p. 44]. The data in Table 4 shows that these developments have resulted in some measure of success as 5,662 students sat the Higher level examination in 1991 [13].

Table 4. Participation in 1996 Leaving Certificate by subject and level [4, pp. 101,107]

Subject	Total	Ordinary level	Higher level
Mathematics	47 848	38 378	9 470
Applied Mathematics	1 347	129	1 218
Physics	9 193	2 763	6 430
Chemistry	7 316	1 399	5 917
Physics & Chemistry	1 238	416	822
Construction Studies	6 867	2 261	4 606
Technical Drawing	7 194	4 095	3 099
Engineering	4 725	1 776	2 949

The Higher and Ordinary level courses are similar in structure. However, the courses differ in both the target groups and the emphasis for the students. The Higher level course is aimed at the more able students i.e. students who are able to study academic mathematics and may follow advanced mathematics courses on leaving school. It is recommended that emphasis be given to problem-solving, abstracting, generalising and proving mathematical concepts [14, p. 5]. The Ordinary level course is essentially a service subject i.e. 'providing knowledge and techniques that will be needed in future for their study of scientific, economic, business and technical subjects' [14, p. 16]. Students following the Ordinary level course would have limited exposure to abstract mathematics and a particular emphasis would be the maintenance of basic skills and the use of mathematics.

The foundation-level course developed from the Ordinary Alternative course which aimed to offer 'lively, relevant and mathematically meaningful education to those who do not require . . . the 'specialist' content of the Ordinary course' [12, p. 44]. In 1996, the number of students who sat the Ordinary Alternative Mathematics examination was 5,398 [4, p. 5]. The Foundation level course is aimed at students who may proceed to further and higher education in areas in which specialist mathematics is not required. It aims to 'provide students with the mathematical tools needed in their daily life and work and (where relevant) continuing study' [15]. The 'intelligent and proficient use of calculators' is an integral part of the course.

As is evident from the data in Table 4, Applied Mathematics is a minority subject with small numbers. It is a syllabus with a traditional academic approach to mechanics and is assessed through a written terminal examination.

The situation in the sciences is different. The present Chemistry syllabus was introduced in 1983 and the Physics syllabus in 1984. Practical work is an integral part of both courses but they are assessed by a written terminal examination. As a consequence of the developments in junior cycle and senior cycle policy outlined earlier, both syllabuses have been revised and await implementation. Each syllabus is offered at two levels, Higher and Ordinary, and comprises 70% pure science with the other 30% consisting of science for action, the applications of science and its interface with technology and scientific issues of concern to citizens. The vocational aspects of the subjects are emphasised and they are practically

and experimentally based. As part of the revision, it is proposed to assess practical work by means other than a written terminal examination. Physics & Chemistry is an older syllabus that is at present being revised following similar policy guidelines.

The technology subjects, Construction Studies, Engineering and Technical Drawing have been revised and developed as technical education spread from the vocational schools to the comprehensive and community schools. Construction Studies and Engineering are workshop-based subjects with a large practical element and are assessed by a written terminal examination, a practical examination and assessment of coursework and projects. The projects differ in that the Construction Studies project is usually chosen by the student whereas the Engineering project is set centrally by the Department of Education and Science. Technical Drawing is assessed by two terminal examination papers in drawing. As a consequence of developments at junior cycle all three subjects are being revised and a fourth subject developed, at present called Technology, to provide a range of technology subjects for schools and students in the senior cycle. The policy guidelines as outlined earlier for all senior cycle subjects apply and all four subjects reflect the thrust of the junior cycle subjects with core skills in drawing, workshop practices, basic electronics and health and safety as appropriate. The central theme of design and realisation using a wide range of materials is evident across all four syllabuses. A further aspect of the revision is the concern with developing 'gender fair' syllabuses. The revised syllabuses will be assessed in similar ways to the present syllabuses with some change of emphasis from the practical examination towards the project. Engineering proposes to retain the workshop-based practical exam while Construction Studies aims to subsume it in the project. These developments and revisions should be completed by next January 2000 and then the subjects will be available for implementation in due course.

Engineering in the Leaving Certificate Vocational Programme (LCVP)

Engineering-related subjects are central to the LCVP. The linkages which take place within this programme between the subjects of the vocational subject grouping and the Link Modules can give rise to rich inter-disciplinary and integrated learning experiences for students. The 13 vocational subject groupings currently specified give rise to 26 or so combinations of subjects for study, over half of which involve engineering-related subjects. Usually the grouping involves linking a technology subject such as Engineering with another technology subject or a science subject such as Physics. Where links can be established between the subjects related to subject matter, skills or processes and projects, they are encouraged. Further links can be established with the Link Modules and the enterprise, preparation for work and the work experience activities associated with these.

For example, where students take the grouping of Engineering and Physics with the Link Modules, they may have the opportunity to relate course material and projects between these two subjects, to base an enterprise activity in one or both subjects, to investigate a career in a related industry, visit that industry and typically invite visits from that industry or business to the school. They might also undertake work experience and work shadowing in related areas of employment, etc. In short, the LCVP provides increased potential for engineering as an inter-disciplinary field to be brought to life for students in active, interesting ways. However schools, like many third-level institutions, experience difficulty implementing inter-disciplinary dimensions of educational programmes and this has proven the case with the LCVP where greater success has been achieved to date in bringing the Link Modules and programme activities to life in schools than in exhausting the potential for linking subjects. Progress is being achieved but could be assisted by ideas coming from third level on potential areas for integration between the relevant disciplines of engineering.

Engineering in the Leaving Certificate Applied

The potential for integrated educational activity in engineering-related subjects within the Leaving Certificate Applied is even greater. In particular, on a regular basis, students undertake tasks which can comprise projects, investigations, production of artefacts, involvement in simulation processes, etc. Some of these tasks are based in the Vocational Education strand of the programme within which students must undertake a course in Mathematical Applications and two vocational specialisms which might include those of Construction/Manufacturing (including sections on construction practices, material science, graphics, and manufacturing), Engineering (including sections on engineering materials and manufacturing processes and engineering components, systems and services) and Technology (including sections on electrical understanding, water technology, change of state technology, and storage). These specialisms are pre-vocational by nature with much of the learning being workshop and project-based.

The advent of the Leaving Certificate Applied and its uptake by a limited but increasing number of students gives rise to issues related to the content and emphasis of some engineering related subjects of the established Leaving Certificate. The group of students taking the Leaving Certificate Applied includes those who, prior to its introduction, would not have proceeded to senior cycle and those who would previously have taken the established Leaving Certificate, and in doing so taken subjects which were perceived as more 'practical'—particularly the technology subjects.

Traditionally, these subjects, conscious of this grouping of less academically-oriented, largely male students, retained a significant emphasis on the practical, workshop-based dimension of their subjects. The question arises as to whether, into the future, the movement of a specific grouping of students to the Leaving Certificate Applied will result in a reappraisal, within the technology subjects of the established Leaving Certificate, of the balance between the practical, workshop-based dimension of subjects and that dimension based in knowledge and understanding and its practical application in the built environment.

Progression to Further and Higher Education

The pathways of progression to further and higher education in the engineering sector are difficult to discern from second level and this can lead to incomplete advice to, and preparation of students for entry to this sector. Students enter the sector at a range of levels e.g. through apprenticeships, certificate, diploma and degree courses. Also, there are a number of independent Post-Leaving Certificate courses within the further education sector, which aim to prepare students for entry to degree and diploma courses in engineering. The role of certificate and diploma courses in preparing engineering technicians is unclear to many teachers and students. The role of degree courses in preparing professional engineers may be clearer but understanding of the different types or branches of engineering may be lacking in many cases.

Entry to apprenticeships requires Junior Certificate qualifications in Mathematics and Science or a technology subject. In recent years many qualified Leaving Certificate students have taken up apprenticeships. Admission to certificate and diploma courses generally requires a pass (grade D3) in Ordinary Level Maths and either English or Irish. Direct entry to degree courses generally requires a grade C3 in Higher Level Leaving Certificate Mathematics. One of the engineering-related subjects may also be required. It is evident that the critical subject for entry to further and higher education in engineering is Mathematics. Studies have indicated the importance of Mathematics as preparation for the study of engineering [10, p. 123]. The role of the other engineering-related subjects as preparation for further and higher education is unclear given the lack of requirements for entry. However, there is evidence that studying these subjects at second-level is important in preparing students for engineering [10, p. 18].

One of the characteristics of Irish Mathematics education in the senior cycle is that, by international standards, both the Leaving Certificate Higher and Ordinary Level Mathematics courses can be considered specialist courses i.e. appropriate for those who wish to use Mathematics as part of further studies e.g. in Science, Economics, Engineering and Technology [12, p. 39]. Thus, even though the number of students qualified for entry degree courses is quite low (see Table 4), the number of students qualified for entry to engineering-related courses is high. However, as Ordinary Level Mathematics (along with English and/or a language) is used as a standard entry qualification for third level these students are also qualified for a wide range of other non-engineering courses.

Where engineering courses run by the Institutes of Technology and the universities and jobs in engineering companies seem distant from schools, the engineering profession can seem amorphous and diffuse. Thus perceptions of engineering can be based on very little experience. Without appropriate guidance and preparation students may either fail to consider engineering-related courses or choose courses for which they are unsuitable. The impact of information and communication technologies and related further and higher education courses may also need to be considered.

MAIN ISSUES IN ENGINEERING EDUCATION AT POST-PRIMARY LEVEL

The main issues related to engineering education at post-primary level are multi-dimensional and inter-related. They include the need from an educational as well as from the economic and societal perspectives to increase student participation in science and technology education, including engineering education. A fundamental educational issue directly related to increased participation is that of gender—how can we ensure that more girls participate in science and technology education? Curriculum provision is also an issue—its appropriateness, its relevance, its implementation, its resourcing. Finally, as this paper has frequently suggested, the ongoing clarification of the role, nature and purpose of engineering education and its relationship to the engineering profession is of great importance in curriculum planning in relation to this area, in school planning for subject and programme provision and in planning a student's future.

Increasing participation in science and technology education

The Irish education system has often been criticised, both internally and externally from bodies such as the OECD, for the over-academic nature of its curriculum. As this paper has illustrated, this imbalance is being addressed through the reform of the curriculum at both primary and post-primary levels. A key indicator of imbalance is the relatively small levels of uptake by post-primary senior cycle students of science (excluding Biology) and technology-based subjects. From the perspective of the aim to provide a broad and balanced curriculum, this fact is problematic. Increasingly, from the economic and societal perspectives it is potentially even more critical.

Table 5. Candidates in engineering related subjects in Junior Certificate Examination 1996 [4, pp. 85–93]

Subject	OL male	OL female	HL male	HL female
Mathematics	16 807	17 280	11 623	12 206
Science	11 966	7 371	19 458	20 236
Materials Technology	4 787	727	9 374	611
Technology	556	292	1 607	674
Technical Graphics	8 832	1 041	8 032	860
Metalwork	2 864	287	5 942	271

Scientific and technological developments comprise major elements in a changing world. The pace of these developments and the related pace of change is ever increasing. From a societal perspective, there is a strong case to be addressed for education to develop in young people the aptitudes, skills, knowledge and understanding to engage with, respond to and participate in change or, at the very least, not be marginalised by it or left in its wake. Greater exposure to the scientific process and to the creativity associated with scientific discovery, greater access to and comfort with developing technologies are central to the educational development of students to meet the challenge of a changing society.

From an economic perspective the issue of the 'skills shortage' looms. The Irish Government established the Business, Education and Training Partnership in 1997 'to develop national strategies to tackle the issue of skills needs, manpower forecasting and education and training for business' [16]. The Partnership has established that, in the context of Ireland's progress towards a high skill economy, a need will exist for up to 8,300 technologists (approximately half of whom would be engineering professionals and technicians) on an annual basis between 1997 and 2003. There will also be a further substantial demand for skilled and semi-skilled operatives in the IT sector. Currently, the number of technologists entering the labour market on an annual basis is around 6,100 leaving a shortfall of over 2,000. Increasing the participation of post-primary students in science and technology subjects is one medium to long-term measure that can be taken to meet this demand. Critically, this implies increasing interest in and knowledge and understanding of science and technology subjects among students (particularly girls), parents and teachers at all levels of our education system. This brings those working in education face to face with what has proved to be one of its most intractable challenges—increasing participation of girls in science and technological education.

Girls and engineering education

The take-up by girls of engineering-related subjects reflects the factors of provision, allocation and choice mentioned earlier. Irish schools are a mixture of single sex and co-educational schools. The single sex schools are mainly secondary schools and tend to provide the scientific subjects that might prepare students for engineering. Girls' schools tend not to provide subjects such Metalwork or Construction Studies. The co-educational schools are vocational, community/comprehensive and/or secondary schools and tend to reflect the technical or academic tradition of these school types and tend to conform with patterns as shown in Table 3.

The participation of girls in engineering-related subjects in the Junior Certificate is shown in Table 5. Foundation level Mathematics is omitted.

All students take Mathematics, the majority of girls and boys take Science but few girls take the technology subjects. The pattern is continued in senior cycle as the 1996 Leaving Certificate data shows in Table 6. Foundation level Mathematics has been omitted.

Many girls do not have the opportunity to take subjects such as Metalwork or Engineering because it is not provided in the schools they attend. However, within schools where they are provided girls may not be permitted to choose such subjects. They may not satisfy the pre-requisites laid down by the school and priority may be given to boys, particularly in the technology subjects. Finally, there is evidence that where girls have free choice, they tend not to choose Physics, Applied Mathematics or the technology subjects.

Table 6. Participation in 1996 Leaving Certificate by Subject and Gender [4, pp. 97–106]

Subject	OL male	OL female	HL male	HL female
Mathematics	17 982	20 396	5 305	4 165
Applied Mathematics	124	15	1 015	203
Physics	2 337	426	4 480	1 950
Chemistry	890	509	2 893	3 024
Physics & Chemistry	358	58	517	305
Construction Studies	2 153	108	4 443	163
Technical Drawing	3 937	158	2 921	178
Engineering	1 701	75	2 862	87

Chemistry is taken fairly equally at both levels by girls and boys. This is shown in Table 6. However, if taken by girls the engineering-related subjects tend to be taken at Higher level, especially the sciences.

Higher level Mathematics, Chemistry, Physics and technology subjects are not generally part of the culture of either girls or indeed girls' schools. There is evidence that these subjects are chosen only if there is a clear need for the subjects as a preparation for a future career or if the student can gain good points for third-level entry. This may be due, in part, to the perceived difficulty of the subjects as noted in the literature [17, pp. 19–21]. These attitudes effectively exclude girls from considering engineering as a career. Thus girls' participation rates in these subjects are an issue for both second level and engineering education.

Initiatives to encourage girls into science, engineering and technology

As part of the concern about participation rates in science, engineering and technology a number of initiatives have been developed to encourage girls to choose senior cycle subjects which will give them options in this career area. Some of the interventions are structural, i.e. aimed at providing girls with senior cycle subjects not previously available. Others provided a range of educational experiences outside of those often available to girls. Yet others provide supporting material both for the classroom, laboratory or workshop for teachers and students and for guidance counsellors working with students.

The major structural intervention has been the *Physics and Chemistry Intervention Project.* This project, funded by the Department of Education and Science, started in 1985 with the aim to increase the provision of Leaving Certificate Physics or Chemistry as part of the curriculum in girls' schools. The project has made a significant impact in increasing the provision of Physics and Chemistry and there has been a substantial increase in the number of girls taking Physics and Chemistry. It is now in a dissemination phase with two main elements—the establishment of Science Resource Centres and the preparation of comprehensive resource materials for teachers [18].

Another project focused on girls' attitudes to new technologies in the Junior Cycle. *Futures* (*Girls into Technology*) was funded by the Department of Education and Science and the European Union. Material was developed for use with junior cycle or Transition Year students which aimed to develop girls' confidence and competence in technology, to heighten students' awareness of gender stereotyping and to encourage students to reappraise traditional subject/career choices. Modules were developed by teachers in participating schools in Computers, Electrics, Communications and Design & Make. This material, along with two further modules in Art and Geography was published in 1992 and is in use. Schools are free to use the material as appropriate [18].

These curricular interventions have been complemented by a number of other interventions aimed at encouraging all students to consider a wide range of careers and girls in particular to consider engineering. A summary is provided in the Appendix. These initiatives aim to encourage girls to choose senior cycle subjects that will give them options in the area of science, engineering and technology. However, the impact that the engineering sector has made on girls' perceptions of suitable careers has to be questioned.

Changing patterns of participation in engineering related subjects

All of the above initiatives have had some impact on schools and the participation of girls in engineering-related subjects. In particular, the *Physics and Chemistry Intervention Project* has changed the provision of these subjects for girls in single-sex schools. A recent review of strategies for attracting girls into science, engineering and technology suggests that successful strategies maintain and increase girls' participation in these areas. Such strategies include enrichment activities through pre-school and out-of-school experiences, use of role models and single-sex environments for the teaching of some subjects e.g. physical sciences and information technology. Other strategies include reviewing teaching practice, classroom environments and considering the nature of school science and technology. International evidence suggests that such interventions need to be part of the ongoing process of education if girls' participation rates in engineering related subjects and careers are to increase. We are reminded that 'the world of science, engineering and technology is still, in the main, a masculine domain' [17, p. 26].

CONCLUSION: ENGINEERING EDUCATION IN THE CURRICULUM

Throughout the 1980s and 1990s the Irish education system at both primary and post-primary levels has experienced a significant degree of curriculum reform. At primary level, the turn of the century will witness the introduction of a new curriculum with a firm emphasis on science and technology education as part of the basic education of all children. At post-primary junior cycle, the introduction of the Junior Certificate in the 1980's has resulted in new syllabuses for subjects characterised by relevance, flexibility and greater potential for students learning through activity. The senior cycle, following developments in the 1990's, is characterised by choice in the range of programmes available to students and by the new balance and merging achieved between the liberal academic tradition and that of vocational preparation. In all these developments the

abiding aim has been to retain the most valuable aspects of the 'academic' curriculum and enhance that curriculum by providing more opportunities for students to encounter practical applications of learning through activities relevant to their current and future lives. Curriculum reform has contributed to an increase to approximately 85% in the number of students who remain in school beyond the compulsory school-leaving age of 15.

On the basis of the developments outlined above, a significant degree of consistency and commonality should be achieved over the coming decade between the aims of education in general and those of engineering education in particular. In other words, trends in curriculum development should generally prove conducive to more effective engineering education. The engineering sector should have access to a larger pool of well-educated students than at any time in the past.

The degree to which the changing curriculum and schools can respond to the more specific objectives of engineering education depends, at least in part, on the clarity with which those objectives are articulated and the extent to which they mirror the perceived variety of educational needs of those students engaging with the engineering sector at different levels—apprenticeship, technician, professional. As this paper has indicated, the perception at second level is that the scope and nature of engineering education and its specific objectives have not been fully clarified and the third level engineering sector has an important role to play in clarifying these more specific objectives.

The challenge related to second-level education is twofold. Firstly, to provide an effective educational foundation for entry to all three strands of engineering—apprenticeships, technician and professional engineering. Secondly, to address the issue of how guidance counsellors, subject teachers, parents and students can determine suitability for courses and careers in engineering. Engineering as a career competes with all other career areas, many of which are more visible, and more clearly understood, by students, parents and teachers.

REFERENCES

1. *Ireland: Vocational Education and Training; a Guide*, Dublin: Leonardo da Vinci Ireland (1997) p. 16.
2. Department of Education and Science. *Brief Description of the Irish Education System*, Dublin: Communications Unit, Department of Education and Science (1998).
3. Government of Ireland, *Charting our Education Future*, White Paper on Education, Dublin: Stationery Office (1995) p. 49.
4. Department of Education, *Statistical Report 1995/96*, Dublin: Stationery Office (1997) p. 89.
5. NCCA, *A Programme for Reform—Curriculum and Assessment Policy Towards the New Century*, Dublin: Stationery Office (1993) p. 42.
6. Richard A. Pring, *Closing the Gap—Liberal Education and Vocational Preparation*, London: Hodder and Stoughton (1995).
7. Department of Education. *Rules and Programme for Secondary Schools*, Dublin: Stationary Office (1996) pp. 7–10.
8. J. Coolahan, *Irish Education: Its History and Structure*, Dublin: Institute of Public Administration, (1981) pp. 85–104.
9. D. F. Hannan, et al., *Schooling and Sex Roles: Sex Differences in Subject Provision and Student Performance in Irish Post-Primary Schools*, Dublin: ESRI (1983).
10. Denis McGrath, *School Performance and Engineering Education.* Dublin: NCEA, (1996).
11. Richard Breen, *Subject Availability and Student Performance in the Senior Cycle of Irish Post-Primary Schools*, Dublin: ESRI (1986) p. 92
12. Elizabeth Oldham, 'Mathematics in the Senior Cycle: The New Leaving Certificate Courses', *Studies in Education*, **8**, (2).
13. M. O. Martin and B. L. Hickey, *The 1991 Leaving Certificate Examination: A Review of Results*, Dublin: NCCA (1992) p. 50.
14. Department of Education, *The Leaving Certificate Mathematics Syllabus* (*Higher level and Ordinary level*), Dublin: Stationery Office.
15. Department of Education, *The Leaving Certificate Mathematics Syllabus* (*Foundation level*), Dublin: Stationery Office, p. 5.
16. Chris Horn, *Building on Ireland's Skill Opportunities*, paper presented at the Business, Education and Training Partnership Forum, Dublin (1998).
17. M. Vlaeminke, F. McKeon and C. Comber, *Breaking the Mould: An Assessment of Successful Strategies for Attracting Girls into Science, Engineering and Technology*, London: Department of Trade and Industry (March 1997) pp. 19–21.
18. Department of Education and Science, *Promoting Gender Equality in the '90s*, Dublin: Department of Education and Science.
19. DIT, *Engineering, Passport to a Challenging Career*, video (1994).
20. Irish Times: Anything you can do, I can do better, *Education & Living*, 14 October 1997, p. 13.
21. *Suitable Jobs for a Women*, Dublin: WITS (1993), p. 5.
22. NCEA, *Engineering Your Destiny. Engineering a Career*, video (1997).
23. *The Worlds of Engineering*, Science, Technology and Innovation Programme: STI Awareness, CD-ROM (1997).

Additional reading material

Patrick Clancy, Selection for college: some implicatons for second level, *Compass*, **19**, (2) 1990, pp. 7–21.

NCCA. *Curriculum and Assessment Policy Towards the New Century*, Dublin: NCCA (1993).

NCCA. *Assessment and Certification in the Senior Cycle: Issues and Directions, a Consultative Paper*, Dublin: NCCA (1994).

M. Ní Choileáin, and P. Keaveney, *Make the Right Choice! A Guide to Leaving Certificate Subjects*, Dublin: Folens (1997).

APPENDIX

Initiatives to encourage girls into science, engineering and technology

In addition to the structural interventions outlined the following initiatives have occurred:

- The Department of Education and Science produced a range of posters and leaflets aimed at encouraging all students to consider a wide range of careers and girls in particular to consider engineering.
- Dublin Institute of Technology, Bolton Street ran a NOW (New Opportunities for
- Women) project from 1993 to 1995 which reviewed girls' and women's access to engineering courses. As part of the project, there were workshops for girls in the Transition Year Programme. These ran for a morning a week for ten weeks and were both over-subscribed and highly popular with the students. Boys wished to attend such workshops. A video, aimed at girls, focusing on engineering as a career was produced by the project in 1994 [19].
- A similar initiative for girls in the Transition Year Programme was run by Carlow Institute of Technology in 1997 [20].
- Women in Technology and Science (WITS), a voluntary organisation of women working in science, engineering and technology, has run a series of role model days for girls since 1992 which exposes students to a wide range of different occupations including engineering. In 1993 a Role Model booklet was produced which includes occupations such as Chemical Engineer, Civil Engineer, Computer Software Specialist, Electrician (Technical Trainer) and Telecommunications Test Engineer [21]. In 1997, this booklet was complemented by 'Stars, Shells and Bluebells' a book which recorded the lives of women scientists and pioneers. This work has been supported by the Department of Education and Science.
- Other recent initiatives in engineering include the production of a video by the NCEA, aimed mainly at girls, to encourage students to think of Engineering as a career [22]. The STI Awareness campaign has supported the production of a CD-ROM highlighting different careers and career paths in engineering [23]. Most of this material has been circulated to schools for use as the schools consider appropriate by guidance counsellors, subject teachers and students.

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