The Bologna Declaration and Engineering Education in Europe

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1. General

In considering the Bologna Declaration[1] and its implications for engineering education we must first examine the historical evolution of engineering education and how it has responded to influences in the past.

The process of putting in place a system of education to produce engineers was first established in the French Ecoles Politechniques and the Ecole Centrale des Arts et Manufacture, following the French Revolution over two hundred years ago. The process included competitive entry by examination, a strong foundation in science and mathematics, mastery of the engineering sciences, the art and practice of current technologies and finally their application to engineering design and decision making[2]. New institutions were created and developed which engaged in engineering education and gradually departments of engineering were established in many European universities. In Ireland the first engineering school was established in Trinity College, Dublin in 1835.

2. Models of Engineering Education:

2.1 The UK/ Ireland Models

During the nineteenth century in England, society was subjected to a range of dramatic influences. Legislative changes in the English Parliament in relation to land ownership resulted in the migration of thousands of peasant farmers to the cities. The growth of the modern city at that time gave rise to demands on engineering, particularly for roads, water supply systems, sewerage systems and transportation. The extensive international trade, which Britain had with its colonies and the way in which the Industrial Revolution manifested itself, gave rise to an industrially focused society under a Parliament firmly under the control of the merchant and capitalist classes[3].

It can be argued that these factors created a situation where the control of the engineering profession and its development lay with its practitioners rather than with the universities which were teaching engineering. A manifestation of this can be seen in the development of engineering professional bodies in Britain and the control these bodies have over the formation of engineers and membership of the engineering profession. This led to an approach to engineering formation based on the completion of a satisfactory education program, followed by a period of experience / training in industry.

To a large extent, Ireland, which was then part of the UK, was not as seriously affected by the Industrial Revolution. However, the professional body concept was part of the development of Irish engineering, in that the Institution of Civil Engineers of Ireland (later the Institution of Engineers of Ireland), was established in 1835.

However, the engineering profession in Ireland consisted largely of civil engineers, who were university educated, giving them a higher “status” than that of their British counterparts, many of whom had become engineers through an apprenticeship system.

Today, the structure of the engineering profession in Ireland and the UK is very similar and its membership can be divided into three separate parts:

i) The Chartered Engineer- has accredited engineering degree, plus four years experience, and a professional review.

ii) The Associate Engineer (Ireland), Incorporated Engineer (UK) - accredited degree/ diploma in Technology, plus 3 to 4 years’ experience and a professional review.

iii) The Engineering Technician- accredited certificate, plus 3 years experience, and a professional review.

2.2 The Continental Europe Model:

This model of engineering education evolved from the French schools and was used in France, Germany and many other European countries. It is a process traditionally influenced by research activity. According to Wilhelm Von Humboldt, research activities should be encouraged and universities should strongly contribute to the discovery of new scientific principles and not be influenced by political or industrial forces. The engineer should be exposed to scientific ideas and have the skills necessary to carry out research[4]. Thus, in this model, the universities were in control of engineering education and technical universities were established where students spent, sometimes 7 or 8 years studying for this professional engineering degree.

Strong links also developed between these technical universities and industry, which used research results emanating from these universities. At the beginning of the 70's in Germany, the Netherlands and some other countries "Short- Cycle" engineering diploma programs were developed in institutions such as Fachhochschulen, in order to respond to the needs of industry.

Therefore, the typical continental European model of engineering education can be described as consisting of two parts:

i) Short cycle engineering programmes of 3 or 4 years duration to produce technological or production engineers.

ii) Long cycle engineering programmes of a minimum of 5 years duration and producing "theoretical" or research/ design engineers.

In the case of engineering technicians, these are mostly trained in technical schools such as technikerschule in Germany, following completion of an apprenticeship.

While the above descriptions are not precise, they do serve to demonstrate two different traditions in Europe. It is important to understand these when analysing the implications of the Bologna Declaration for engineering education.

3. Current Challenges to Engineering Education

The following challenges must be borne in mind when considering any review of engineering education at this time.

3.1 Engineering, School- leavers and Students

In most European countries a number of factors have combined with the result that the enrolment of students on engineering programs has significantly reduced in recent years and looks set to continue reducing.

These are:

a) The low level of interest of young people in science and mathematics in school, without which a proper study of engineering is very difficult,
b) The perception among young people that engineering is difficult to study, when compared to the wide range of equally lucrative careers (such as in business, accountancy etc.) which are available nowadays, and which require less effort.
c) The negative opinion young people have of engineering based on old- fashioned stereotypical images of engineers working in uncomfortable and unattractive industrial settings.
d) The reducing population of 18 year old school-leavers which arises mostly from the drop in the birth rate in most European countries from the mid 1970's to the present day.

The consequences of the above are very serious, not only for the engineering schools which must have students to survive, but also for the growing economies of European countries which rely heavily on engineers for the skills needed in modern manufacturing industry.

3.2 International Agreements

A number of International Agreements have been signed by engineering professional bodies in recent years. Among these, the most important are the following:

(a) The Washington Accord requires the eight signatories (Ireland, Australia, Canada, New Zealand, UK, USA, South Africa and Hong Kong) to give the same recognition to other signatories' professional engineering degrees, as they do to their own.

(b) The Sydney Accord (to be signed in June 2001) will apply in the same way to technology diplomas in the eight signatory countries.

(c) In December 2000, the Engineering Council (UK), the CNI (Italy) and the CNISF (France), all engineering professional bodies, will sign a trilateral agreement at both the "long cycle" (theoretical) engineering and "short cycle" (applied) engineering level. This agreement will apply to registered engineers with four years post- academic professional experience with the ability to operate as a professional engineer in the language of the receiving country.

(d) The Engineers Mobility Forum Agreement to establish an International Register of Professional Engineers is to be signed in South Africa in June 2001. The signatories are the eight Washington Accord signatories together with Japan, Korea and Malaysia. All licensed professional engineers in these countries who hold an accredited engineering degree and have seven years' post-qualification experience will be eligible for listing on the Register.

3.3 FEANI

The FEANI Index can be regarded as a useful mechanism, whereby members can accept each other's engineering qualifications. However, the FEANI Index contains both short and long cycle engineering degree/ diploma programs side by side. Both types are considered acceptable for the EUR Ing Register though not all FEANI members accept that “ short cycle” degrees are “professional” engineering degrees. In future, the Index will classify degrees and diplomas in terms of type and profile, as follows:

Type	Profile
First cycle	Theoretical
Second cycle	Practical
(As in Bologna Declaration)	

3.4 Student Placement in Industry during a Degree Programme

Industrialists, who make contributions to discussions on engineering education, almost always place a high value on providing engineering students with the opportunities to work in industry as part of their education programme. The objective of such a placement is to enable students to learn about the application of engineering principles to the manufacturing or design process. This practice forms a part of a number of accredited engineering degree programmes in many Irish, British and American universities.

The following matters are important to bear in mind about such student placements:

(a) The objectives must be clearly articulated and understood by the employer, the student and the university, and should be such that the student must learn about engineering applications in that industry during the placement. This objective is best achieved by establishing a contract between all three parties, laying down the specific learning outcomes to be achieved. Without this process, the student will not benefit significantly from the placement and could spend his/ her time carrying out routine and irrelevant work.

(b) The performance of the student in achieving the learning outcomes specified, should be assessed and graded as part of the placement.

(c) The minimum duration of placement should be one semester or six months. A shorter period does not allow either for adequate training of the student, or for the student to be of value to the employer. The summer vacation period(s) during the engineering education programme may form part of the placement.

(d) Students should receive satisfactory payment for their work from their employers.

4. Current Engineering Education Structures

4.1 The Professional/ Theoretical Degree:

The characteristics of this degree programme can be summarised as follows:

- Competitive entry by examination to engineering schools.
- An engineering degree/ diploma program, which builds a strong foundation in science and mathematics, followed by mastery of engineering sciences, the art and practice of current technologies, and finally their application to engineering design and decision making[2].

It is widely accepted that the above process requires 4 or 5 years of full-time studying in a university or other college of higher education.

This degree is to be described in the FEANI index as having a “theoretical” profile.

4.2 The Professional (Applied) Engineering Degree

In many European countries in the early 1970’s, institutions known as Fachhochschule in Germany and Hogeschole in the Netherlands established engineering diploma programmes of 3 or 4 years duration, which had an “applied” profile, focusing more on the immediate requirements of industry by placing a heavy emphasis on the study of technology. In the intervening years, other countries followed suit and now similar programmes are offered in other European countries.

These are highly valued by industry as the graduates do not require extensive training and are ***au fait*** with current technology. However, some people will argue that such engineers are really ”technicians” or “technologists” and as they do not have the foundation in mathematics and science of the “theoretical” engineer they will have difficulty in learning about new technologies.

This degree is to be described in the FEANI index as having an “applied” profile.

4.3 The Engineering Technician

While in most continental European countries, engineering technicians are educated in technician schools, in Ireland these students follow a two-year programme in an Institute of Technology and can progress to complete a further year of study to become “technologists”. These students then receive a National Diploma in Engineering, the standard of which is accepted internationally as being equivalent to a technology diploma/ degree.

4.4 The Requirements of Industry

It is widely agreed that industry has a very large requirement for engineering technicians, “practical” engineers, and “theoretical” engineers. In many countries industry employs a greater number of “practical” engineers than “theoretical” engineers. All are needed.

5. The Bologna Declaration: Relevance to Engineering Education

The Bologna Declaration is a very important document, which has strong support from the 29 signatory countries. It is based on:

- A clearly defined goal: to create a European Area for Higher Education, which will enhance the employability and mobility of citizens and increase the international competitiveness of European higher education.
- A deadline: to be implemented by 2010.
- A set of specified objectives.

These objectives can be summarised as follows:

a) Adoption of a common framework of readable and comparable degrees, “also through the implementation of the Diploma Supplement”.

b) Adoption of a system of higher education based on two cycles, undergraduate or first cycle studies, lasting a minimum of three years, and postgraduate or second cycle studies following successful completion of first cycle studies and leading to a master or doctorate degree.

c) ECTS credits system.

d) Elimination of obstacles to free movement of students and teachers.

e) A European dimension to quality assurance in higher education.

The implementation of objectives (a), (c) and (e) should not give rise to any major difficulties in engineering education in Europe. In many countries a “diploma supplement” or transcript is now available to students. Furthermore, many European countries have adopted the ECTS Credits System, or at least systems that are ECTS compatible. Also, much work has been done, and continues to be done in quality assurance in European universities.

However, objectives (b) and (d) together have implications for engineering education as it is currently structured in many European countries.

5.1 Objective (b)- Degree Structure

The wording in the Bologna Declaration is as follows:

“Adoption of a system essentially based on two cycles, undergraduate and graduate. Access to the second cycle shall require successful completion of three years. The degree awarded after the first cycle shall also be relevant to the European labour market as an appropriate level of qualification. The second cycle should lead to the master or doctorate degree as in many European countries”.

This objective can be broken down as follows:

- First cycle degree must be 3 years or more.
- First cycle degree must be relevant to the labour market.

- Admission to second cycle degree requires successful completion of first cycle degree.
- Second cycle to lead to Master or Doctorate Degree.

A reasonable interpretation of this objective would be that Bachelor Degrees in Engineering should be three or four years in duration. Successful completion of this degree should be a requirement for admission to a one or two-year **taught** (for those who completed a 3 year Bachelor degree) or **research** (for those who completed 4 year Bachelor degree) Master Degree as appropriate. Furthermore the three or four year Bachelor Degree should be "relevant to European labour market" as an appropriate level of qualification. This means that it must contain as much current appropriate technology as is necessary for the graduate to be a productive employee in an engineering company. It is true to state that this can be achieved in different ways and at different levels in both three and four year programmes. However, the three year Bachelor degree cannot be simply an "intermediate" degree consisting of basic mathematics and scientific studies if it is to be "relevant" to the European labour market.

A three year engineering degree programme which produced graduates "relevant to the European labour market", probably could not contain enough mathematics and engineering science to enable graduates to carry out research at either Master or Doctorate level. However, a four engineering degree programme could contain enough mathematics, engineering science and technology to render graduates both "relevant to the European labour market" and adequately prepared to carry out research at Master or Doctorate level. This model applies in Ireland and those who achieve high grades in their final honours degree examinations can either proceed to Master or Doctorate research or seek employment. However, those who do not achieve honours grades but achieve an overall pass in their degree examinations may not proceed to Master of Doctorate research, but do receive a pass Bachelor Degree and normally go directly into industry.

If the above models are acceptable, then a number of models for the Master/ Doctorate degrees could emerge.

(a) Three- year Bachelor Degree holders who achieve high honours grades in their degree examinations could be admitted to a special **taught** Master Degree programme of two years, to bring them to the level of “theoretical” engineer. Graduates from this master degree could then be deemed qualified to carry out Master or Doctorate level research.

(b) Four- year Bachelor Degree holders who achieve honours grades in their degree examinations could proceed to a **research** Master or Doctorate Degree.

(c) Four- year Bachelor Degree holders who achieve honours grades in their degree examinations could proceed to Master or Doctorate **research** degrees or go directly into industry with their “pass” level colleagues.

5.2 Objective (d) Student mobility

The Bologna Declaration requires:

“Promotion of mobility by overcoming obstacles through the effective exercise of free movement… for students, (by providing) access to study and training opportunities and to related services”.

It is reasonable to deduce that one or both of the degree structures described in Objective (b) would have to be in place, in most if not all countries, if mobility is to be promoted. This gives an added impetus to the implementation process, particularly in a scenario of a decreasing number of students when the introduction of foreign students into an engineering department could enhance the viability of that department.

However, a mixture of three and four- year engineering Bachelor Degree programmes throughout Europe would inhibit mobility within the Bachelor Degree and transfer to the Master Degrees. This however, might be the only possible result when implementing the Bologna Declaration for engineering.

6. Summary of Issues to be considered

In summary, in considering the implications of the Bologna Declaration, we must consider the following:

(a) Industry requires increasing numbers of engineers, therefore, engineering must be more attractive to young people. (The option of "short cycle" Bachelor of Engineering Degree programmes is attracting greater numbers of young people in Germany).

(b) Industry requires both short- cycle "applied" engineers, and long- cycle "theoretical" engineers, but more of the first than the second at present.

(c) Students should be able to transfer from one programme to another, and from one country to another, while receiving appropriate credit for previous learning using the ECTS credits system.

(d) European engineering education programmes should be more attractive to non-European students, so that they will study in Europe, thereby increasing the viability of engineering programmes.

(e) Academic standards must be set and maintained at a level appropriate to the requirements of industry and research universities.

(f) Engineering degree programmes in Europe must meet the criteria in international agreements and indices such as the Washington Accord, the European Mobility Forum and the FEANI Index.

7. Conclusions

SEFI (European Society for Engineering Education) is currently formulating a position paper on the Bologna Declaration. CESAER (Conference of European Schools for Advanced Engineering Research) has just established a Working Group chaired by Prof. Wakker of TU Delft, the Netherlands with the objective of producing a policy position by end of March 2001. Both of these responses will be of interest.

So, how should engineering education in universities and colleges of higher education be structured to take account of the Bologna Declaration and the above considerations? First, it should be stated that the degree structure proposed offers the possibility of a new beginning and solutions to some of our current problems.

I would suggest the following as being worthy of consideration:

(a) A “first cycle” and “second cycle” degree structure can be accommodated.

(b) Engineering education in European universities might consist of a three/ four year Bachelor of Engineering Degree, followed by one/ two year Master of Engineering Degrees, i.e. a **taught** Master degree and a **research** Master degree.

(c) Admission to the Bachelor Degree should require successful completion of secondary education, with a high level of performance in mathematics and physics/ chemistry.

(d) Each degree should contain mathematics, pure science and engineering science to an appropriate level.

(e) Each degree should contain relevant applied, technological studies to an appropriate level.

(f) Industrial placement, if included, should take place after the fourth semester of the Bachelor Degree programme.

(g) Graduates who receive the bachelor degree should be employable at production/ “middle” level engineering in industry.

(h) Only those graduates (normally about one third) who achieve a high level of success in three- year Bachelor Degree examinations, should be admitted to the **taught** Master Degree programme.

(i) Graduates, who receive a **taught** Master Degree, should have achieved the highest standards of engineering education, as apply in long- cycle engineering degrees at present.

(j) Only those graduates (normally about one third) who achieve a high level of success in a four- year Bachelor Degree programme or a **taught** Master degree programme should proceed to Master/ Doctorate **research** degrees.

If the above can be achieved in Europe by the year 2010, European engineering programmes will be more widely recognised and respected throughout the world.

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1 Bologna Declaration, The European Higher Education Area, Joint Declaration of the European Ministers of Education, Bologna, 19 June 1999.

2 O’Kane, J.P., ***“Matching Engineering Education in Ireland to meet the Requirements of Tomorrow”*** Proceedings of Engineering Education – The Future, Dublin, The Institution of Engineers of Ireland, 1998

3 Hooker, R., ***"The European Enlightenment – the Industrial Revolution"***, Washington State University www.wsu.edu:8080/~dee/ENLIGHT/INDUSTRY.HTM, October 2000.

4 Michel, J., ***"Europe Looks Ahead – New Directions in Engineering Education",*** Proceedings of Engineering Education – The Future, Dublin, The Institution of Engineers of Ireland, 1998.