ENGINEERING EDUCATION AND THE BOLOGNA PROCESS

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Abstract: A retrospective view on the introduction and implementation of the Bologna process in engineering education in Europe is given. The advantages and disadvantages of the Bologna process are discussed, with a particular referral to the Montenegrin experience. Several recommendations for possible improvements of engineering education within the Bologna process are suggested.

Keywords: accreditation, Bologna process, cycles of education, curricula, degrees, diversity, engineering, E-education, inflation of knowledge, life-long learning, quality assurance, outcomes, student mobility.

1. Introduction

Engineering education has a long tradition in Europe. A few rather different types of university engineering education could be recognized. The "German type" education was implemented in most European countries. The traditional German education system provided two distinct engineering programs having several features in common. One was offered by the technical universities and had a more theoretical orientation, while the other, taught at the *Fachhochschulen*, had a more applied profile. The former required typically five years of studying, enabling for research and in-depth development activities; the latter was a shorter cycle of typically four years and was meant to train production-type engineers. They were both implemented as one cycle programs. Students were supposed to get some insight into basic industrial manufacturing and develop engineering skills, as well as the appreciation for the work of others upon which they would rely on. Following the thesis work, which typically took one semester, the students would receive the *Diplom-Ingenieur* (*Dipl.-Ing.*) degree.

The engineering education in France was not much different but was more theoretical. In UK engineering education was organized mostly on the basis of three-year courses leading to the degree of *bachelor of science* or *bachelor of engineering*. Some four-year course programs have also been organized leading to M. Eng. which is equivalent to master degree. On the other hand, in some European countries, and at some point of time, the engineering education was organized in concentric cycles: two years of course work for the degree of *engineer*, with the continuation of another two or three years for the *Dipl. Ing.* degree (*diploma of engineering*). This practice was later abandoned.

The length of the actual study for the university degree in engineering departments was in practice much longer then the prescribed 4 or 5 years. Students were allowed to retake the exam many times, after failing the course first time, until they pass. Often, students would finish all required course work, but would remain students for much longer, even several years, to pass all exams for audited courses and complete their degree. Consequently, many argued that such a system was inefficient and expensive to run.

The master program lasted most commonly two years and was a prerequisite for the doctoral program. In Germany the *Dipl.-Ing.* was the prerequisite for the doctoral degree (*Doktor-Ingenieur, Dr.-Ing.*). The scientific work for the doctoral thesis was usually performed at the university within three to five years, and was conducted as part of research projects. In engineering sciences, the higher-degree candidates often worked on their theses as the paid departmental teaching or research assistants. In the former USSR, the graduate study was organized for the *candidate of science* (kandidat nauk) degree. This was recognized by other countries as an equivalent to master degree, but nowadays it is more commonly recognized as an equivalent to Ph.D. degree.

2. Introduction of the Bologna Process in Engineering Education

The engineering education in Europe has been greatly affected by the implementation of the Bologna Process, a major reform in the European higher education [1-6]. This process is based on agreements between European countries aimed to achieve comparable standards and quality of higher education within Europe as it integrates, and to meet the growing needs for creative global competitiveness and quality assurance of engineering and other professions. The Bologna declaration was signed by the education ministers from 29 European countries in 1999. In an increasingly globalized world, the Bologna Process currently involves 47 (EU and non-EU) countries. As such, it is a global process of higher education in Europe, introduced with the expectation to facilitate higher exchange and mobility of students and academics among institutions from different countries, promote internationalization, enable less constrained employment after graduation within a broader region, continent, or the entire world, and thus contribute to overall economic growth. The Bologna Process is based on two main cycles, undergraduate and graduate. The prerequisite for the second cycle is successful completion of the first three-year cycle. The first cycle degree represents a preparation for the labor market, while the second is a graduate cycle leading to master and/or doctorate degree.

The implementation of the Bologna Process is to a large extent reflection of the modern globalization [7-11]. University campuses are populated by students of diverse ethnical and cultural background, particularly in graduate schools. The faculty is increasingly diversified, as well. New international universities are being created, with large funding invested to attract the best faculty and students and compete in academic excellence with leading universities and technology institutes worldwide. Engineering education is greatly affected by the development of electronic data bases, open-access journals, and online citation indexes, such as the Web of Science, Scopus, and Google Scholar. Their availability within the countries participating in the Bologna Process significantly improves the effectiveness and quality of both education and research in these countries.

3.1. Accreditation Process

To ensure that engineering education programs produce graduates with a good engineering foundation and professional competences, they are subject to an accreditation process. The European Standards and Guidelines represent a set of standards, procedures and guidelines on quality assurance (QA), adopted by the ministers for higher education in the European Higher Education Area. This includes internal and external quality assurance. The internal quality assurance involves monitoring and periodic review of programs, critical self-assessment report with the assessment of curricula, students and teachers. This serves as an input for the external quality assurance evaluation by the independent peer group or the external QA agency. The accreditation agency makes a decision whether the program is accredited, conditionally accredited, or rejected. The EUR-ACE is the accreditation system that provides a set of standards for high quality engineering degree programs. The European Network for Accreditation of Engineering Education (ENAEE) is the network which authorizes accreditation and quality assurance agencies to award the EUR-ACE label to accredited engineering degree program [12, 13]. Students who graduate from accredited programs have better opportunities for employment, licensure and certification, graduate education and global mobility.

In the USA, the accreditation of post-secondary education programs (excluding doctoral programs) in applied science, computing, engineering, and engineering technology is done by a non-governmental organization ABET (Accreditation Board for Engineering and Technology), recognized by the Council for Higher Education Accreditation (CHEA) . The latter is also a non-governmental organization which maintains an international directory of quality assurance and accreditation bodies in 175 countries, which have been authorized to operate by their governments as either governmental or private agencies. ABET accreditation is voluntary - the request for accreditation of a program is made by the institution seeking accreditation for that program. ABET specifies minimum curricula for various engineering programs. Accredited programs must request reevaluation every six years to retain accreditation. Further description of the process of ABET accreditation can be found on the organization's website (www.abet.org).

3. Advantages and Disadvantages of the Bologna Process

The first cycle, or the undergraduate engineering cycle of the Bologna Process lasts three years. It is characterized by more focused and shortened curricula, with more intensive faculty engagement in the education process. This new significantly shorter program resulted in larger number of graduates and faster graduation rates. The so-designed European higher education system became more attractive to non-European students, who are coming in increasing numbers to study at European universities (European Higher Education Area – EHEA). Furthermore, the system helps European integration, contributes to its economic and cultural growth, and thus overall prosperity. The Bologna process continues to be merged with political processes in Europe, although some education reforms, presented as part of the contemporary Bologna Process, were underway even before the Bologna declaration.

The implementation of the Bologna Process has revealed numerous weaknesses. Notable among them is a diminished quality and quantity of engineering knowledge gained by students

during their BS program (inflation of knowledge). This was recognized by industry and resulted in increasingly more difficult employment, as the graduates were not sufficiently prepared to successfully join the workforce. Shortening the 4 or 5 years of courses to only three years was not an easy task, and unfortunately in this process the quantity and quality of knowledge required for the work in industry was lost. Additional year of specialization offers some remedy. The M.Sc. program is most often designed as the preparation for the Ph.D. program, rather than being an enrichment of engineering knowledge towards the immediate industry needs. The loss of the old and well-conceived degree of the *Diplom-Ingenieur* has thus been a troubling issue for the industry from the beginning of the process of higher education reform [14]. At some universities in USA, UK, and Australia, the Professional Master of Engineering degree is comparable in its qualities with the Diplom-Ingenieur degree.

One of the major objectives of the Bologna Process was to enhance mobility among students and faculty throughout Europe, but this did not happen as expected. Within the ERASMUS program, which started in 1987, over 2.2 million students spent a term in a different country of Europe until mid-2010. More than 4,000 higher education programs from 33 countries now participate in this program. However, a study of the Higher Education Information Center shows that engineering students show the smallest interest for the study abroad, with only 16% of them studying abroad during 2009 [15]. More efficient processes are under consideration to achieve the high-mobility goals set at the beginning of the Bologna Process and to approach in quality the Anglo-Saxon system of education. Hearings in European Parliament have taken place in that direction (personal communication with D.P. responsible for higher education in the European Parliament).

The critics of the Bologna Process assert that the process does not offer the quality of the old Anglo-Saxon system of education, and that, to some extent, the Bologna Process transforms universities into “diploma factories”. This is partly attributed to the fact that the Bologna Process originated from the political decisions and activities, without sufficient initial involvement of the institutions of higher education. The Bologna Process has led to student demonstrations during the Vienna conference of the European higher education ministers in 2010. Students questioned the acceptance of the bachelor in the industry, especially in small and medium-sized companies. They stated that the bachelor degree does not prepare well for the working world, that it demands too much learning matter per time, that it does not foster mobility, and that there are too few offerings for soft skill trainings [15].

4. Bologna Process and Engineering Education in Montenegro

Before introduction of the Bologna Process, the organization of engineering education in Montenegro was similar to German system: nine semesters of required lectures, each semester consisting of 15 weeks, plus one month for exams. The tenth semester was used for writing the engineering diploma thesis. The graduates would receive a Dipl. Ing. degree in the particular field of engineering, such as electrical, mechanical, civil, or metallurgical engineering. The actual duration of studying was on average significantly longer than five years. The Master of Science program consisted of one or two years of lecture work plus an unspecified time for writing and defending the M.Sc. thesis, which usually required one to two years. A doctorate

degree did not involve taking any required lectures, but only the work on the doctorate thesis, which could take two, three, or more years.

The implementation of the Bologna Process in Montenegro began in 2007. Upon the adoption of the Process, the system of engineering education in Montenegro was radically changed. It is now offered in three cycles: 3+2+3 years. The study for the Bachelor of engineering degree lasts six semesters (each semester consisting of 15 weeks, plus one week for exams). The degree of a specialist is obtained after completion of an additional year (two semesters). The study for the Master of Engineering Science degree lasts two years, after completion of the three-year Bachelor degree. This includes one year of required lectures plus the work on the master thesis. Master degree is in many ways equivalent to former diploma of engineering, but in many cases it provides a more theoretical background needed for the doctoral study. Specialist study attracts fewer students, but it provides lower level of professionalism than the old diploma of engineering. Consequently, the industry is still reluctant to employ students with such specialist degree. The doctorate program includes only the work on the doctorate thesis, which usually lasts three years after completion of the Master degree. It should be pointed out that in Montenegro, as in many other former socialistic countries which are in the process of transition, much of the industry has vanished. As a consequence, there is no much support from the industry to universities and their engineering education. For example, the contacts of students with real engineering through internships in industry have dramatically decreased or have been lost completely. The coordination or balance between the industry demands and the current supply of higher education remains to be a challenge. Further about the higher education in Montenegro can be found in [16] and [17].

4.1. Accreditation of Higher Education in Montenegro

Higher education accreditation in Montenegro is conducted by the Council for higher education, formed by the Montenegrin Government. The Council consists of 13 members, each elected for the period of six years. Six members are chosen from distinguished scientists or artists, nominated by universities, five members are recognized experts from industry or other institutions outside universities, and two are representatives from student organizations. The Council nominates the committees for the evaluation and accreditation of higher education institutions and their programs, which can include foreign experts. If the institution is awarded the certificate of initial accreditation, it must apply and receive the work license from the Ministry of Education. The institutions are subjected to reaccreditation after a period of at most five years, which is based on evaluation and quality assessment of their programs. This is conducted according to the accreditation rules adopted by the Council, which are made in the spirit of the Bologna declaration, respecting specific characteristics of the Montenegrin higher education system. If a private institution of higher education was accredited by a foreign accreditation agency, it must submit the accreditation document to the Council for higher education for its revision and approval. Each institution must continuously conduct its self-assessment and quality control of its programs and submit them to the Council at the time of reaccreditation. Students are included in the process of self-evaluation. In addition, the University of Montenegro has created a Center for studies and control quality. Every engineering department must have a representative in the council or a committee for the quality assurance. The Montenegrin Government has passed the Law and installed the Council for national

qualifications framework, in accordance with the European Qualification Framework (EQF) as an instrument which will enable broader comparative analysis of qualifications, quality assurance, and credit transfer among different countries. Although the Higher Education Act of Montenegro [18] specifies the standards and the process of accreditation of higher education programs and institutions, the obstacle in its realization is the lack of trained and experienced experts for quality assurance. Additional information on the accreditation process within the system of higher education in Montenegro can be found in [19].

5. Recommendations for Improvements of Engineering Education

There are many challenges facing the implementation of basic premises of the Bologna process, such as comparable or equivalent engineering curricula in historically and culturally diverse European countries. Several steps could be undertaken to improve the quality of engineering education. While the official lengths of various engineering programs are standardized, the actual contents of the courses and programs, as well as the criteria for their completion and established learning outcomes, may differ substantially. Similar or equivalent systems of quality assurance and program accreditation should be installed, preserving tradition and autonomy of universities. Specification of learning outcomes and their verification are essential for successful implementation of the Bologna Process. The comparability and equivalency of programs, with created proper interfaces, will result in easier mutual recognition of European programs. Such unification or harmonization of higher education should proceed without sacrificing the diversity, which is challenging by mere definitions of involved concepts. The success here may also prove to be instrumental for the enhancement of student mobility. Equal opportunities and accessibility of higher education must be imperative, regardless of the race, gender, social and economic background.

In addition to the M.Sc. program as a preparation for the Ph.D. study, a Master of Engineering program should be installed, providing a more in-depth engineering knowledge, emphasizing applications and skill-oriented capabilities, and directly linked to modern industry needs. Such programs have already been developed and are expanding in the engineering education in USA. The Bologna Process should incorporate additional measures to adopt other aspects of the American higher education system and establish closer relation to it [20]. For example, it would be desirable for students to give them the opportunity to study for a double-major, e.g., engineering major with a minor in mathematics, physics, biology, economics, or other field. Continuous feedback from students and alumni is a valuable source of information for the improvement of higher education. Finding adequate means to stay in contact with alumni (e.g., via email communications) is challenging but rewarding. Regarding engineering faculty, in addition to their creative research, they should be stimulated to work on the development and incorporation of innovative teaching and learning skills and methodologies.

The quality assurance of engineering programs and institutions must be done with more uniformity throughout European higher education area, promoting the efforts for innovation and developments of new programs within the Bologna Process, but respecting the specific characteristics of education systems in different countries. Minimum curricula for various engineering programs should be specified, paying care to both the education inputs (quality of

curricula) and the education outputs (quality of gained knowledge). Engineering programs must prepare students for rapid technological changes, making them able to continuously improve their skills in multi-disciplinary areas throughout their professional careers. The incorporation of various forms of life-long learning, for example through university extension programs, would provide the means for working professionals to keep track of modern engineering developments and remain competitive in this era of fast changing and developing technologies. This can be achieved through evening or weekend classes, or through on-line interactive courses (E-learning). Engineering education must also ensure that students in their professional work deal knowledgeably and ethically with modern technological challenges and their impact on society and on global issues.

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