

Which Model of Engineering Education to Adopt

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Abstract. *In this paper are considered advantages and disadvantages of various models of engineering education: 3+2+3 or 4+1+3 or 5+3. Some examples of application of each model are presented from the point of view of teachers, students and stakeholders. In some countries the traditional engineering studies were 5 years, prior to Bologna process, while in England for example basic engineering studies were only 3 years. In the Western Balkans countries “juggling” between 4 and 5 years of basic studies was permanent. After joining the Bologna process, many countries accepted the 3+2 model for Bachelor and Master Studies, respectively. After a few years of application, it turned out that employers were reluctant to hire “the 3 year engineers”. Now many universities are considering changing back to 4 + 1 model, while some still kept the integrated 5 years long studies leading to degree known as “Diploma engineer”. Thus, the question remains, which model is the best?*

Index terms. *Bologna process, Credit system, Education models, Engineering studies, Studying efficiency.*

INTRODUCTION

Traditional university studies were four years for almost all the areas, the only exception were medical studies (human medicine, pharmacy and veterinary medicine and alike). Here term “traditional” refers generally to the twentieth century, more precisely its second half. Older studies were quite different in types and duration, so they are not the subject of this study.

The usual duration of four years for engineering studies, at the beginning, in some countries also meant the “mandatory” two-degree studies, i.e., it was mandatory to finish the first two years, the so-called “first degree”, have some kind of final exam and then continue to the “second degree”, which then required the “Diploma thesis” to be written and publicly defended. In engineering education that meant that there were “engineers” (those who finished only the first two years) and “Diploma engineers” (those who finished the full four year studies). In Yugoslavia the first ones were also called “the factory engineers”. The “first degree” in some areas (engineering included) also required that for the final exam a voluminous paper - “the final work” had to be written and also publicly defended. So the “Diploma engineer” had the “privilege” of having two theses to write and defend.

YUGOSLAVIA VERSUS THE REST OF EUROPE

In the seventies, the system in Yugoslavia was changed, the two degrees were separated and the freshmen could decide whether they would study directly for the first degree or for the second degree only. That also meant writing only one thesis and having only one defense. What also changed was the duration of studies. The first degree lasted five semesters plus one semester for the “final work thesis”, i.e., total of three years. The studies leading to Diploma were five years long, nine semesters for lecturing and exams and the tenth semester for the “Diploma thesis” writing and defending. Switching from the first degree to the diploma studies was not allowed. The students who enrolled for the first degree and then wanted to obtain the second degree too, had first to graduate from the first degree and then to enroll only into the third year of the Diploma studies – thus they were practically obliged to studying for 6 years. Another interesting point was that the part time students could enroll only for the first degree program, for the Diploma studies the condition was the full time studying enrollment.

The courses burden was between 35 to 45 courses; majority had mandatory both written test (usually 4 hours test of solving numerical problems in the subject area) and the oral exam (mainly consisting of theoretical questions). The written test was eliminatory and the prerequisite for the oral exam. If the student, who qualified for the oral exam by previously passing the written test, failed to pass the oral exam, he/she was obliged to retake the written test again. The exemptions from this severe rule were non-engineering courses, like sociology, economic system, etc. which had only the written or the oral exam. So practically, the student all together had to pass between 60 and 70 tests, written or oral, to qualify for obtaining the topic for the Diploma thesis.

In the eighties the mainstream tendency in Europe turned to "reducing" the engineering studies to four years. Western Balkan countries accepted this "unwritten rule" in their own specific way. All the students' burden was compressed into four years; almost nothing of the program was omitted. Thus, the number of courses and exams remained the same.

The specifics of Yugoslavia was that there were faculties who offered four year studies and those who offered five year studies, so transferring from one engineering faculty to another (in the same subject area) was practically impossible, sometimes even officially forbidden.

The graduate courses assumed two degrees: Master of Technical Sciences and Doctor of Technical Sciences. Master studies required two years of lecturing and exams. Number varied from branch to branch of engineering, but generally it was between 8 to 14 courses. After passing all the exams (again both written and oral tests) the candidate qualified to obtain the topic for the Master's thesis. The thesis had to contain "original scientific contribution" of the candidate to the subject area. Research and writing of the thesis required minimum of two to three years. The defense was public; the defense committee had 3 or 5 members, the thesis advisor included.

Only after obtaining the Master of Technical Sciences degree, the candidate was eligible for obtaining the topic for the doctoral dissertation. There were no courses requirements; only the voluminous research was required. After completing the dissertation, the candidate was asked for the public defense; again the defending committee included 3 to 5 members, experts in the field (dissertation advisor included). The time period for completing the dissertation was 5 years with possibility for an extension for another two years. So, all together, from enrolling as a freshman until obtaining the doctoral degree, with "usual progress rate" of the candidate it took between 12 to 15 years, which meant that the "youngest" Doctors were well above 30 years old.

But, let us go back to undergraduate studies. In the nineties the system was turned back to five years long undergraduate studies. At the same time, in the Western Europe the system was different, as well as in the "eastern" block countries. For instance, in Poland the undergraduate studies were four years, master studies one year and then two to three years for Ph.D. This led to a ridiculous situation that the Ph.D. degrees obtained in Poland in Yugoslavia were recognized only as Master of Technical Sciences degrees and candidates had to obtain another Doctoral degree. On the other hand, in United Kingdom, the undergraduate studies in engineering fields were only three years long. Industry was satisfied with "three years engineers", the possibilities for "reeducation" for an additional year was a good chance for carrier moves from one to another sub-area of engineering. Thus, the various models of engineering education were present and somehow everybody was reluctant to change to somebody else's system. Finally, then came Bologna process.

WHAT BOLOGNA PROCESS BROUGHT TO ENGINEERING EDUCATION

The Bologna process opened chances for standardization or unification of studies in all the educational fields, the engineering was not an exception. Or was it? Well, first of all, joining to Bologna process was not unanimous and everywhere accepted immediately. It started with 29 countries and every two years, on the "progress control" conferences, several countries were invited to join. However, joining the Bologna process did not mean accepting its principles and rules right away. The common practice was to try to find "our own ways" of applying those principles or rules. That usually meant twisting and changing them, sometimes to the extent of non-recognizability, or even to completely opposite applications.

In engineering education, the commonly accepted was 3+2+3 model; rarely was it 4+1+3. The mobility was somewhat enhanced, especially from the East to the West; i.e., from the non-EU to EU countries and universities. The major problem was that the mobility generally was only the one-way street; in the mentioned direction. The other direction mobility is still pretty rare; the main reason (obstacle) being the language of lecturing. With the growing introducing of courses offered in English, this problem is gradually being overcome.

What different models brought to different engineering fields? First of all, in England, engineering education at the undergraduate level is still preferred to be the three-year long. English industry is still happy with "three-year engineers". The 3+2+3 model, which assumes three years of undergraduate studies, was applied in the majority of the Western Balkan countries. The experience is almost the same everywhere. The "three-year engineers" are not welcome in the industry. They are considered as "unfinished", without complete education. The first generation of Masters, those who finished 3+2 years of study, are well accepted and can get employment easily, though still not in all the branches of engineering. Generally speaking the electrical, traffic and civil engineering graduates (Masters) can easily find jobs, or to be more precise, easier than mechanical engineers. The cause of this is not in the wrong model of studies. In the Western Balkan countries the problem is that the machine and metal working industry in general, are still suffering the consequences of the turmoil and wars of the nineties. The worst example is Serbia, where hundreds of mechanical engineers are on the unemployment lists for years. With revitalization of industry, the problem is somewhat alleviated, but then the model of study comes as problem. For example when the "FIAT-Serbia" company was formed in Kragujevac, Serbia, the graduates from the first degree of studies, Bachelors of mechanical engineering were not even invited for job interviews. The Italian factory executives preferred the "old" engineers, who were jobless for almost a decade or were on the so called "forced holidays".

However, the model of studies is also an influential factor in other branches of engineering. Thus, the faculties (or universities) realized that something has to be changed. The majority of engineering schools decided to go to the 4+1+3 model, which would be more acceptable to potential employers of the schools' graduates. The problem arose because 3+2+3 models were already accredited, so switching to another model is difficult and requires accreditation again. The transition from the first to the second model is thus slow and also causes quite a medley of programs within one engineering branch and often even within one particular faculty. So, now one can find faculties which offer four or five different programs. The 3+2+3 freshmen have rights to finish the program they enrolled into; the 4+1+3 students did not yet graduate; some "old" models of integrated 5 year program (Diploma engineer) still exist at some faculties, while some are now introducing that model again.

SOME EXAMPLES OF CURRENT PROGRAMS

How different are existing programs in engineering will be presented on a few characteristic examples. This is the best illustration why the question in the title is posed.

Silesian University of Technology, Gliwice, Poland

The Silesian University of technology offers courses in 21 engineering disciplines, with more than 100 honors, including full-time MSc courses, full-time and part-time BSc courses, as well as supplementary MSc courses. Optional PhD courses and post-MSc courses are offered in the most attractive engineering disciplines, enjoying increasing popularity. Several post MSc studies are run in English or French.

Undergraduate courses (BSc equivalent) last 4 years; graduate courses (MSc equivalent last 5 years); postgraduate courses are for the research leading to the PhD (Eng) or for advanced instructional courses leading to the degree of MSc (Eng). Research students normally require about three years full-time study for PhD and up to two years for MSc.

Technical University of Denmark, Lyngby, Denmark

Bachelor-Diploma Engineer (BEng) training lasts 3.5 years including a half-year internship in a Danish or a foreign company. The exception is Arctic technology – training here is four years. BSc program at DTU is a business-oriented, application-oriented and interdisciplinary education, where students are enrolled in the professional direction of their choice. MSc programs are four semesters long, equivalent to 120 ECTS credit points. There are also special MSc programs with cross-disciplinary content.

The so-called Elite and Honor programs consists of individual study plan for each student, with an internationally recognized faculty member as personal tutor. The PhD program consists of:

- An independent scientific project
- A study program corresponding to 30 ECTS teaching and dissemination activities to approximately 3 months
- An external research study
- A PhD thesis
- A public defense.

Technical University of Berlin, Germany

The TU Berlin have transformed its entire syllabus into a Bachelors/Masters program in the winter semester 2007/08. The Bachelor of Science (B.Sc.) degree lasts three years (minimum of 180 ECTS credits); the Master's degree lasts two years. The Master's degree is equivalent to the former Diplom Engineer with State exam.

For the doctoral studies the candidate draws up an extensive scientific work – the doctoral dissertation or thesis, which can principally be written in German or English (with an abstract in German **and** English). In case this work gets accepted by the school, the candidate will have to pass an oral component of the exam for the doctorate - the scientific defence - which can be held in English. As opposed to first or second degree study programs there is **no fixed plan of studies for doctoral candidates**. In this respect the German model still mostly differs from, for example, the Anglo-Saxon model of postgraduate studies.

University of Žilina, Slovakia

Bachelor studies in the Civil Engineering field last three years, as an integrated part of academic study. Students can specialize in their third year in the following areas: Roads and Highways, Railways, Bridges and Tunnels, Building Constructions. The study is finished by a final work, which students defend before the examining body. The graduates obtain the degree "Bachelor" and have possibility to continue towards the Master's degree. Master studies last two years and are finished by the diploma work, which students defend before the examining body. The graduates obtain the degree "Master".

The PhD degree is obtained after the extensive research, writing and publicly defending the doctoral dissertation.

University of Manchester, UK

The core programs on offer are the three year BEng (Bachelor in Engineering) and four or five year MEng (Master in Engineering). All programs are accredited by the Royal Aeronautical Society. However, BEng graduates are required to undertake further learning or postgraduate study to meet the educational requirements for Chartered Engineer.

Postgraduate research qualifications include: Doctor of: Philosophy (PhD), Engineering (EngD), Enterprise (EntD), Business Administration (DBA); Master of: Philosophy (MPhil), Research (MRes), Science (MSc, directed research), Enterprise (MEnt), Dental Science (MDSC).

There is an interesting feature at some UK universities (UM included) and that is the so-called foundation year. That is offered to high school graduates who do not have adequate knowledge to start the first year of (engineering) studies or do not have the proper prior twelve-year education. This is a bridging designed to provide future freshmen with the appropriate academic background for study at Bachelor degree level and includes additional English language teaching. Candidates enroll for the "foundation year", which contains courses in Life Sciences, Engineering and Science. The successful finishing of foundation year guarantees acceptance to bachelor degree studies, i.e., those candidates do not have to take the usual mandatory entrance exam.

Stanford University, San Jose, Ca, USA

The undergraduate curriculum at Stanford allows considerable flexibility. It permits each student to plan an individual program of study that takes into account personal educational goals consistent with particular interests, prior experience, and future aims. Courses are assigned credit units. To earn a bachelor's degree, the student must complete at least 180 allowable units and, in so doing, also complete the Writing Requirement, the General Education Requirements, the Language Requirement, and the requirements of a major.

Admission to a doctoral degree program is preliminary to, and distinct from, admission to candidacy. Admission to candidacy for the doctoral degree is a judgment by the faculty of the student's potential to successfully complete the requirements of the degree program. Students are expected to complete department qualifying procedures and apply for candidacy by the end of their second year in the Ph.D. program. The Application for Candidacy specifies a departmentally approved program of study to fulfill degree requirements, including required course work, language requirements, teaching requirements, dissertation (final project and public lecture-demonstration for D.M.A.), and University oral examination (for Ph.D.). At least 3 units of work must be taken with each of four Stanford faculty members.

University of Washington, Seattle, USA

To qualify for the BSEE (Bachelor of Sciences in Electrical Engineering) degree student must successfully complete 180 credit hours of course work. The EE Advising Office maintains a curriculum chart for each student in the Department. This record shows each curriculum area as well as required courses within each area. Requirements for the BSEE degree are distributed into nine areas of study: Mathematics, Statistics, Natural Science, Computer Programming, EE Core, EE Major Concentration Area, EE Electives, Additional Engineering Electives, Written and Oral Communication, Non-EE Approved Electives, Visual, Literary and Performing Arts/Individuals & Societies and Free Electives. Studies last three to four years, depending on student's ability to acquire required number of credits. There are also possibilities to take courses in summer (the summer semester) and thus shorten the length of studies. This feature is common to many US universities.

The PhD studies requirements are similar to those at Stanford.

University of Kragujevac, Serbia

The example given is from the author's own faculty of Mechanical Engineering. The way of changes from 4 to 5, back to 4 years, now 3+2+3 model is described in the introduction and is a common feature for all the engineering areas in the countries that once were republics in former Yugoslavia. The main problem that those frequent switching from one "system"

to another caused was a total mix-up in students' services office. The usual situation was (and still is) that there are several (3 to 4) programs of study existing simultaneously. The reason is that students have the right to graduate in the system (model) into which they enrolled; the faculty is obliged to maintain all the "old" systems for two years after the new system is enforced. So, if the system is changed, let us say, when students were in their third year and the studies last four years, the system to which they enrolled has to last for at least five more years (they can repeat the third year once and the fourth year once and must have two additional years due to system change).

The consequence of students overburden was also very low study efficiency. Engineering studies in Serbia usually last seven to eight years, for the four-year programs. The EUA evaluation of Serbian state universities, which was performed in 2002, posed this as one of the major problems in higher education in Serbia. The conclusion is that the state is wasting its resources since it is spending exactly twice the funds to get a graduate from the university.

The joining to Bologna process brought some improvement for all the educational areas in Serbia, concerning efficiency and unification of the study systems. However, the 3+2+3 model seems to have failed for engineering studies. The first three years, needed for the bachelor degree, appears not to provide enough knowledge to graduates. Almost all the engineering schools have decided that they will have to switch to 4+1 model. The problem with three-year studies is two folded. Either the students were overburdened with study materials, because teachers simply "compressed" two-semester courses into one semester requiring the same learning outcomes from students, what resulted in lower studying efficiency; or the course materials were trimmed to what students can "process" in one semester what resulted in less knowledge and skills obtained.

The University Act was changed in 2002 and 2006; the new amendments were just accepted in Parliament in Serbia and will apply for the new academic year, starting in October. It allows for this system changes, provides more flexibility in grading and course requirements, so the hope is that the results will also be better.

CONCLUSION

With all the system changes both teachers and students were puzzled. No one can tell which model is the best, which one will guarantee good, complete, or proper engineering education. The old five-year program had problems with studying efficiency due to students being overburdened with courses (lecturing and exam). Bologna on the other hand "requires" efficient and shorter studies, but those graduates can not find adequate employment. The four year model has not produced results yet; its efficiency is unknown, though employability is predicted to be satisfactory.

So, which model to adopt? The question remains. Any suggestions would be more than welcome. The problem is not local, attribute of Serbia or Western Balkans countries, it is practically present in all the countries that are applying the Bologna process. The process itself is OK, the applications are obviously not.

REFERENCES

- [1] www.polsl.pl
- [2] www.dtu.dk
- [3] www.tu.berlin.de
- [4] www.uniza.sk
- [5] www.manchester.ac.uk
- [6] www.stanford.edu
- [7] www.washington.edu
- [8] www.mfkg.kg.ac.rs
- [9] University Act of Republic of Serbia, The Official Gazette of Serbia, 2002, www.slglasnik.com
- [10] University Act of Republic of Serbia, The Official Gazette of Serbia, 2006, www.slglasnik.com
- [11] The Law on Amendments and Changes of University Act of Republic of Serbia, 2010, www.slglasnik.com.