ABOUT THE ROLE OF THE MATHEMATICS IN THE ENGINEERING EDUCATION

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ABSTRACT: It is evident that the development of future generations with the right skills and knowledge, for a career in engineering at all levels, is essential for the future economic prosperity of any country. Moreover, in the future we will need professional engineers with greater interdisciplinary understanding, and with more specialist skills. So, we will need a deeper understanding of the sciences that underpin the art of engineering, and we will therefore need to know which are the mathematical skills needed to apply these sciences. Because advances in the use of information technology and computers have transformed engineering analytical techniques, production and management processes, it raises some questions: What is and will be the role of mathematics in the education of engineering? What mathematical skills are needed for the engineers of tomorrow, and how and when these might best be acquired? This paper is dedicated to an objective analysis of the positioning of mathematics courses to those of specialized training mechanical engineers. Both authors share their extensive experience in teaching mathematics and science of mechanical engineering at the Faculty of Mechanical Engineering.

Key words: engineering education, mathematics, mechanical engineering

1. INTRODUCTION

It is a well-known fact that engineering has created and continues to create wealth and development for every nation. In the actual development phase of mankind we cannot indicate any domain of human activity that did not benefit from at least one of the engineering science accomplishments.

The engineering science’s can no longer be considered in the restrained context of the ‘construction of a purely industrial society’, as it was in the past century. These go beyond the boundaries of other sciences, such as mathematics, physics, biology, medicine, ecology, economics etc. The interactions and the inter-influences between engineering and the other sciences have, as a result, developed a deeper knowledge and understanding of our Universe. Furthermore, the major climate changing, the development of new technologies to produce unconventional energy, the production of new materials that satisfy the modern technologies, the food supply problem for the human race in the globalisation process etc., has become huge challenges for the engineering science’s. That is where the need for the training of capable engineers who can overcome all of these challenges has come from.

In each and every country the problem of the educational system reform for engineers is made more acute from the perspective of changes and objectives of the future human race development, as well as from the perspective of the educational technology, especially in order to design the optimum curriculum, adequate and flexible that can be adopted for training an engineer with necessary competences in a certain direction of activity.

These problems are very seriously, professionally and responsibly taken into account by the universities, as well as by the economic and business environment, in order to be in line with the governmental policies of each state. Furthermore, they consider the coherency, the harmonisation and the resonance of the curriculum for the different fundamental disciplines (mathematics, physics, chemistry, biology etc) and the technical disciplines. The main problem is the one of the knowledge level, of the abilities and skills that a high school graduate must have in order to go to an engineering university and get an appropriate level of training in order to become a competent engineer who can integrate professionally and prove his worth to society.

The problem regarding the technology of education for engineers is viewed differently in each country in order to comply with the educational traditions, with the existing economic and industrial development level. To support this statement, we mention a few of the research studies done in various countries more or less developed, G. Rogers (2005), T. Kelley & all (2008), P. J. Williams (2001), R. Banerjee & all (2007). These researches study the problem of training for the engineers in the existing context of knowledge and the future needs for development and economic stability.

We should also note that everywhere in the world research centres exist for engineers’ education, national and/or international engineer’s organisations that are dealing with the optimisation of the engineering education. For example, at the EU level there is the European Society of Engineering Education that, in 2011, proposed the foundation of the European Engineering Deans Council (EEDC) composed by the leaders of the engineering education university institutions.

Unfortunately, we have to observe that in our country, for all we know, there are no such research studies and no governmental policies for that. This is also proven by the inexistence of a national research and development centre for the engineers’ education [14]. The polytechnic universities or those that have studies for engineers are the only ones that assume and have this responsibility, and the result of
engineers’ education is manifested only implicitly through the competences that their graduates acquire, judged only through the level of professional integration for the engineers into our labour market [15]. Is this good or bad, could it be better, what is to be done? These are questions that should be answered not only by the nation education system and the universities, but also by our entire society.

The authors propose in this paper to only present a problem. An extremely important one linked to the engineers’ education. In other words, in the imposed (agreed) context by the ARACIS for a plan for the mechanic engineers training, in particular, for the engineers with the AR speciality from the Pitesti University, what is the ratio for mathematics?, what should be the content for the mathematical disciplines in order to sustain and help the specific competencies of the engineers who take these courses? This problem is looked at from the point of view of the engineer teacher, who teaches the specialty disciplines, such as the dynamic of the automobile, as well as the maths teacher, who teaches for example mathematical analysis and/or special mathematics.

2. ENGINEERING DEGREES AND THE PLACE OF MATHEMATICS

From the engineer teacher’s point of view and the educational governing body who decides the training curriculum within the polytechnic universities, the mathematic training courses for future engineers are believed to be part of their fundamental preparation. In this sense the mathematical training is covered during the first two years of initial studies. During this two year period the student studies the disciplines of linear algebra, analytical and differential geometry, mathematical analysis, special mathematics and numerical methods. In the first year of study 20% of the course is dedicated to mathematical studies and in the second year this is 10% of the course. The other disciplines studied use to a lesser or greater extent the mathematical principles learnt.

The engineering profession, indifferent of its field, is generally practical in regards to the concrete activity of engineering. This results in a multitude of specialisation and diversification in theory and application of engineering science. Mathematics is the basis and supporting pillar for the engineering science used.

At the same time the technical disciplines are important considerations which assure the initial foundation for various fields of engineering. Technical disciplines through their content and specific application require a mathematical base in order to know, understand and use them according to the functional limitations of different devices and components, to determine a stable or a changing regime within the limits of admissible functions in order to measure a system’s complexity to a greater or lesser extent.

The necessary mathematical calculations encompass many different aspects in function of the discipline specificity, degree of application and not least, the teachers training.

An important and difficult problem to solve is linked to the development degree of mathematical notions taught within the polytechnic universities, their degree of applicability in solving real technical situations, but their use in the modelling of real phenomenon, sometimes extremely complex, that are the base of the numerical simulation for these phenomenon.

Starting with the natural teacher’s desire to do his job at the best level in order to give the students the most competences for their future profession, to fulfil the labour market requirements, a continuous collaboration and communication is required between the engineering and mathematical departments within a university, in order to establish not only the ratio between mathematics and technical disciplines, but also the content of them. Without such an approach there is a risk for both sides:

- either the content of mathematical disciplines has no use for the engineering profession,
- or the technical disciplines use mathematical apparel that has not been taught within the mathematical disciplines.
- In both situations, the student looses being a victim of this false conflict.

What can we do?

The answer is not easy to give, but at least some directions can be established, assuming that the existing ratio for the hours dedicated to mathematical disciplines cannot be changed.

The experience shows that until now, that in general the technical universities graduates found jobs and the employers rarely criticised the mathematical knowledge. It is more common for the employers to criticise the insufficient training in other domains, such as technical drawing, communication, lack of practical skills, lack of modern programming knowledge or simulation etc.

The second direction is the permanent, constructive and efficient dialogue between the teachers for mathematical and technical disciplines, so that each one of them to adapt their course to real technical situations. It is possible that over the years the content of a technical course must change a lot (for example in the computer programming field). This implies important changes in the content of mathematical disciplines as well.

This problem is almost a general problem and its resolution involves agreement and collaboration between the technical and mathematical teachers. The dialogue is not an easy part, because they must overcome the discussions concerning the number of hours, the routine and sometimes the egos. But taking into account the final objective, the effort of this dialogue is worth while.

The third direction is communication and exchange of experience between the polytechnic universities in the form of transferring best practices. It is a known fact that marked differences exist between curriculums of the universities. The exchange of best practices is welcomed.

The fourth directions elevate the level of the knowledge and mathematical skills of the students in the pre-university level. Even if the exigency of the national baccalaureate has risen in the past two years, but it is insufficient. We observe that students in their first year of study remain with a lower level of knowledge and skill necessary in mathematics. This fact has a direct relevance in a large number of students who do not graduate mathematical disciplines in the first two years of engineering.

3. MATHEMATICS IS AN ESSENTIAL TOOL FOR KNOWLEDGE AND RESEARCH IN ENGINEERING SCIENCES?

In many instances during our mathematical lessons students query why they need to learn mathematics to be an engineer. Their question is natural taking into account their lack of knowledge and skills in mathematics after graduating from...
high school and become students at the polytechnic universities. Otherwise such kinds of questions are also asked by the students within the faculty of engineering across the world. Therefore the academic community reacts trying to give more and more satisfactory answers [4], [6], [7], [8].

A few times, during the maths courses, whether they were for the first year of study – for example mathematical analysis or differential geometry- or for the second year – special maths or numerical methods- students have asked us what is the use of all these notions, concepts in the engineering profession? Their question is natural, especially for the students who had a technological profile during high school.

But what can a maths teacher respond, especially when he must, needs to teach all the different things throughout his course- for example the Gateaux derivate, the Fréchet derivate for vector fields, ordinary differential equations for which they formulate the Cauchy problems, i.e. imposing the initial conditions, equations with partial derivatives to which we attach initial boundary problems, Fourier analysis, asymptotic analysis etc.

The maths teacher must teach following the natural logic of mathematics and often, if not always, does not have the time or, unfortunately, does not even try to link all these to their engineering applications. So, the maths teachers are much attracted by the concept of mathematics being ‘pulled’ rather than ‘pushed’ into the engineering context.

In other words, at university level the mathematical training process, such as it is conceived and applies, for the engineering students does not take into account and overlooks the most important step of the educational process, that is to say the mathematical modelling of real life. In this case, ‘the mathematical modelling of real life’ must be understood when teaching mathematics to the engineers starting with the mathematical modelling of real life. In this case, ‘the most important step of the educational process, that is to say the mathematical educational activities must be adapted to the training level for every student who comes to university. Concentrating on the student, as an educational concept, in the educational activity is not valid only for the pre-university level [5], [11]. It must be applied at university level as well. Is it because, at university level, we do not anymore take into account the H. Freudenthal’s mathematical education theory [2], [3] in which “the mathematics for everyone” and “the mathematics as human activity” are concepts that should be as well applied at university level?

Furthermore, if in the past, the engineer had to learn mathematics for the practical goals of his activity (calculus, design etc), nowadays, he is only an user of the computer, which means that he only has to applied some specialised software for resolving objectives of his engineering activities. For example, software like MATHCAD, FLUENT, EUCLID etc. are usually present in the engineering activities. But, the engineer has to learn mathematics as a ‘logical way of thinking’ for his current activities and for the research ones. That is why, it is interesting what is happening with the use of FLUENT software for the aerodynamic optimisation of the automobile body. FLUENT has developed an optimisation section for the shape of the automobile, but it starts with a standard geometrical shape, for which has the algorithm of air movement simulation. That makes the geometrical modifications of the vehicle body to be minor, and so, nowadays, most car building companies are lead to almost the same geometry of the models within the same range.

Unfortunately, the debate about the kind of mathematics needed by future engineers, with a shift towards the use of software packages and data handling “on the job” is completed in terms of engineers yet to be reflected in mathematics courses that remain based only on algebra and calculus.

The logical way of thinking and researching based on mathematical modelling is the best and the most productive, but also very difficult. Clearly, the role of form through engineering education our students must be assumed by all teachers, whatever subject they teach, but in a coherent
curriculum, well done, appropriate to the current requirements of knowledge and technologies [9], [13].

Unfortunately, the reality today for mathematics content courses for the faculties of engineering, especially in the "philosophy" Bologna, consists in simplification, in dilution of the scientific content, and therefore the mathematics outcomes are unnecessary for the technical disciplines. Moreover, the same phenomenon is true for contents of the technical disciplines, more regarding theoretical aspect of engineering sciences.

Ensure harmonization, continuity and consonance of technical disciplines with the contents of the disciplines of mathematics is indeed a matter of collaboration, communication and teamwork of teachers of mathematics and engineering professors. However, collaboration between mathematics teachers and engineers assumed, on the one hand, the ability and competence of the teachers of mathematics in applied mathematics for engineering sciences, and by the other hand, must exist ability and competence of the teachers for the technical disciplines in use of the mathematical models for own engineering fields and these mathematical models must be also presented in the engineering handbooks.

In the literature [3], there are many reports on a range of subject designs and teaching methods that demonstrate adaptations to the needs of 21st Century engineering students, and these include among others the following recommendations: using computer based methods such as web-based delivery, computer algebra systems and interactive software; using flexible delivery, and support through tutoring and drop-in centres that are provided to address the issue of variability in students’ mathematical preparation; taking a multidisciplinary approach in various ways, such as team teaching of subjects designed by mathematicians and engineering academics working together; using problem based learning strategies.

Instead of the conclusions, we can say:

1. We need to recruit and retain students on engineering courses, which means that it is natural for academics to focus on the mathematics problem at the interface between school and university.

2. We must accept that mathematics plays an important role in professional engineering practice by the „computational mathematics”, which is perceived as a tremendous opportunity, pushing forward the boundaries of engineering design. Within this, mathematics as explicit work by individual engineers has evolved into mathematics as a distributed activity across design teams and the computers that support them.

3. The apparent contradictions of mathematics as problem or opportunity in engineering education, it is necessary to consider the different uses of mathematics in engineering practice and researches: the direct usefulness of mathematical techniques and ideas to practice and their indirect usefulness - the ways in which mathematics contributes to the development of engineering expertise and judgment.

Mathematics is and will remain a crucial aspect, purpose, goal in engineering education, but we must answer to a set of questions facing mathematics education for the engineers:

What types of mathematical knowledge do engineers need at the each level, i.e. bachelor, master, doctoral?

How can the minimum level of mathematical knowledge that remains essential to engineering practice be characterised? On what does this knowledge rely? How does computer technology change this situation? When and how should mathematics be taught for the each level of the studies?

Unfortunately, we have to notice that in our country there are lacks of the research reports on the state of education for engineers, e.g. like the report [1] from a country without the big industrial expectations. Moreover, we have not an institutional national framework for research in science education [9], [11]. By continuity, we must put together all three levels of pre-university education, i.e. primary, secondary, lyceum, with the university education, in general, with the education for engineers, in particular.

4. REFERENCES


