INDIRECT IMPACT OF MATHEMATICS IN ENGINEERING EDUCATION

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Abstract. The quality of the engineering education depends on the quality of individual study subjects. Mathematics studies have an impact on the development of the necessary outcomes for engineers' both directly (mathematics serves as a tool for solving and calculating various problems) and indirectly (mathematics develops skills to formulate, solve engineering problems etc.). In order to state the indirect impact of mathematics three factors have to be observed in the research process: 1) the role of mathematics in the development of the ability to solve problems; 2) the specific character of mathematics; 3) implementing the achievements of IT in the study process. The aims of the research are to identify the indirect impact factors of mathematics in engineering education as well as to identify the importance of mathematics studies in assessment of students. The survey was carried out among the students of engineering specialties in the faculties of Engineering, Rural Engineering, and Information Technologies at the LUA. The analysis of the results shows that the students positively evaluate the role of mathematics in the development of cognitive skills, willingly use the offered interactive study materials, but not everyone is ready to invest serious effort in the development of this ability.

Keywords: engineering education, impact of mathematics.

Introduction

Alongside with the development of technologies worldwide, there is an increase of qualified engineering employees capable of adjusting quickly to the latest innovations, modern technologies and materials as well as setting up high quality global businesses. Engineering educators in technical universities have to comply with the features of the information era and labour market demands as well as regular changes in the production process due to the transformations of product specifications, management system, technological processes, quality control system, forms of ownership, legal requirements etc. As it is widely known, the volume growth of scientific information has an exponential trend, therefore the university is not able to provide a student with the whole amount of the scientific knowledge and skills necessary for the whole working life. Universal and sustainable knowledge and skills are significant both for university and for production that will be useful in diverse forms of professional activities in the long-term period [1].

The quality of the university education including engineering education depends on the quality of individual programs. The usefulness and the amount of the study courses included in the study programs are evaluated according to the contribution of the study courses in the achievement of the overall aim of the whole study program. Mathematics is involved in this process, therefore it is important to examine the role of mathematics in the present education, especially engineering education. The development of competences driven by teaching of mathematics cannot be ignored, which, firstly, fosters general cognitive development supporting long-life learning.

The aims of the research are to identify the indirect impact factors of mathematics in engineering education as well as to identify the importance of mathematics studies in assessment of students.

Materials and methods

Mathematics studies have an impact on the development of engineers' necessary outcomes both directly and indirectly [2]. First, mathematics serves as a tool for solving and calculating various problems. But much greater is the indirect impact of mathematics which provides the other outcomes (Fig. 1).

Niss M. [3] designs the eight mathematics competences. The competences concerning the ability to ask and answer questions about and by means of mathematics are mathematical thinking, problem handling, modelling and reasoning. The competences concerning the ability to deal with mathematical language and tools are representation, symbols and formalism, communication and aids, and tools.

Mathematics is also a domain for a particular kind of aesthetic experience, it provides moments of clarity and beautiful patterns that can create highly euphoric feelings of unexpected insight and overall understanding [4].

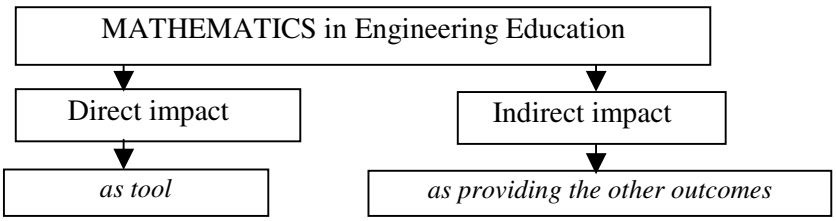

Fig. 1. **Mathematics impact in Engineering Education**

In order to explore an indirect impact of mathematics three factors have to be observed in the research process: 1) mathematics role in the development of the ability to solve problems; 2) the specific character of mathematics; 3) implementing the achievements of IT in the study process.

Mathematics role in the development of the ability to solve problems is very important. For developing the ability to solve engineering problems four parameters are necessary: 1) body of knowledge and three problem solving abilities: 2) ability to formulate a problem in the cognitive sphere; 3) ability to construct the solution of a problem; 4) ability to apply a constructive solution of a problem to the real situation. In mathematics study process the skills are trained to directly apply the formal rules, which are sometimes quite abstract and complex, demanding to choose exactly that one which is necessary from the long list of known rules to complete the task, to build a sequence of applicable regulations. The latter means the ability to design solution plans which develop the management skills. Demonstrations of different theorems are significant in the mathematics study process. Acquiring demonstrations, students develop skills of logical conclusions.

No less important is to be aware of the **specific character** of **mathematics.** The point is that:

1) ***Mathematics is a language of symbols***; it combines a continuous unity of the verbal expression and the sub-language of special symbols with exact rules. The following example will be analysed in Fig. 2.

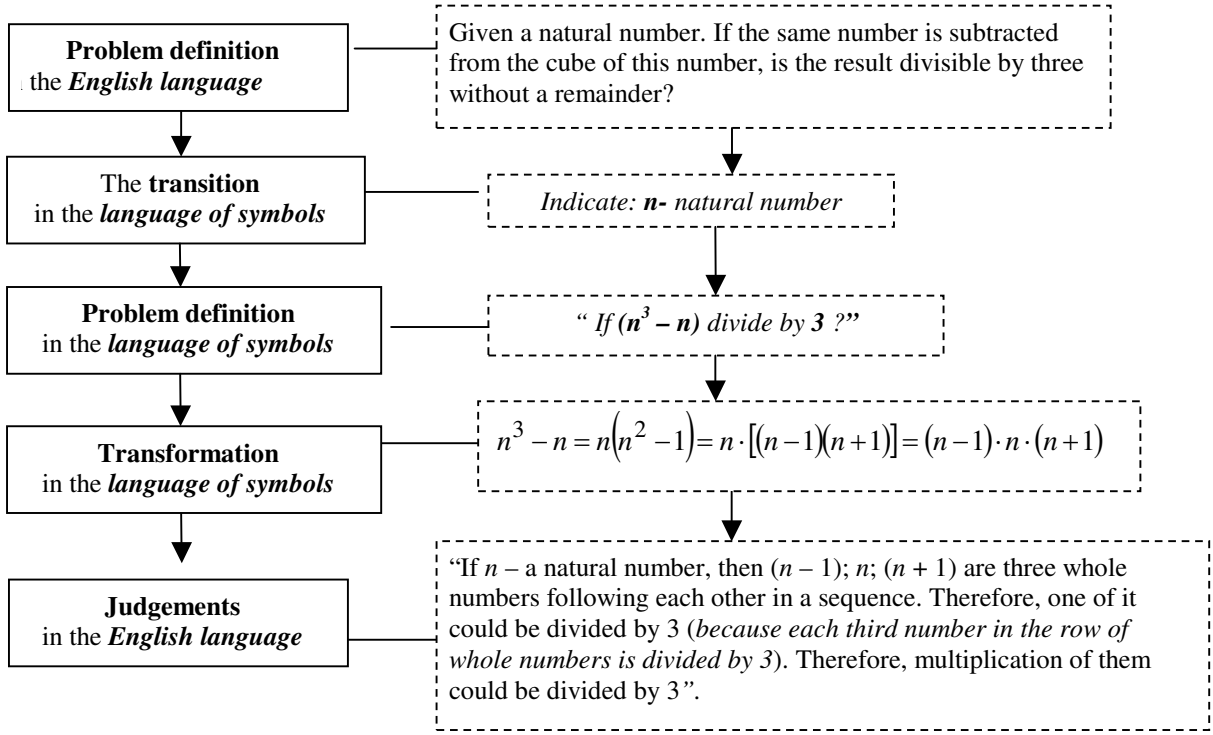

Fig. 2. **Example of mathematics: problem solution using transition from English into language of symbols**

The problem definition is in the English language, which does not use mathematics concepts, symbols, axioms, theorems, formulae etc. Analysing solutions, the understanding should be focused on the symbols, letters, and signs in algebra. As a result the problem could be written in a shorter way than in the first version. Then we can perform algebraic modifications (make transformation). Further

we return from the language of symbols back to the English language and create judgments. It should be noted that an example is a special case of Ferma small theorem *(if p – a prime number and n – a natural number, then* $n^p - n$ *is divided by p).*

The given example shows that alongside with mathematics students acquire the language of symbols. Sometimes professors of mathematics are criticized for using too much energy and time for developing technical skills that are related to the skill of playing scales on a musical instrument. Certainly, scales do not point to the essence of artistry, but there are no musicians who have not spent much time and energy on acquiring them. The same refers to formal mathematics formulations and their identical modifications.

Formal mathematical formulation and modification of the identical do not make a mathematical nature. However, learning mathematics is not possible without knowing a large amount of formulae and without freedom of the identical transformation, even more of the creativity in the field of mathematics.

2) ***Long chains of logic conclusions*** are characteristic of mathematics. If students have not practiced long chains of logical conclusions before the university, they are not ready either physically, or mentally for the hard work to acquire long information units, therefore the studies at the university will be complicated, if not impossible. Dealing with reduced attrition (mental and physical) is one of the students' mathematical ability components. Cognitive load may be reduced using a kind of 'information quanta‘- it is a designation for a portion of information with a new symbol. It is called a method of substitution in mathematics. The analysis of an example is given below (see Fig. 3):

$$\int \frac{(x+1)dx}{(x+1)^2 - \sqrt{x+1}} = \left[\begin{array}{l} \sqrt{x+1} = t \rightarrow x+1 = t^2 \\ x = t^2 - 1 \rightarrow dx = 2tdt \end{array}\right] = 2\int \frac{t^2 dt}{t^3 - 1} = \ldots$$

(1) (2)

Fig. 3. **Using integral substitutions**

It is used for substitution $\left[\sqrt{x+1} = t\right]$ and the integral (1) is transformed into the integral (2), which is much easier to integrate.

3) Mathematics contains ***huge didactic units of learning material***. Teaching mathematics, the teacher cannot avoid the review of complex definitions and long evidences. A standard course in mathematics can include demonstrations of theorems that take one lecture or even more than one lecture. For example, the demonstration in the theme "*The general solution of the second round linearly homogeneous differential equations with constant coefficients"* takes up the whole lecture. In addition, it regards only the demonstration, since "all preparatory work" – mathematical substation, symbols, formulations of a theorem have been presented before. At the same time, in the university an effective researcher training cannot be performed without the development of these competences.

Concerning **implementing the achievements of IT in the study process,** the Department of Mathematics in the LUA has good experience in integrating IT program MathCad in the mathematics study process for Bachelor and MathLab for Master programmes, accounting for 0.5 of contact lessons per week as laboratory work.

The teacher of MathCad in cooperation with the teacher of the practical work hand out homework to the students about the corresponding topic which they must solve on the paper, showing the process of solving step by step, afterwards the students check the solutions themselves using MathCad programme in the practical classes. The analysis of the students' success and the students' survey at the LUA shows that the students prefer the introduction of MathCad in the study subject of mathematics instead of learning MathCad as a separate subject supplied by mathematical examples. The students enjoy comparing the results of their individual tasks with the results obtained via MathCad that, in turn, increases the motivation to solve more mathematic problems, since the students are interested in solving several variants. The final tests complete the study period of individual tasks and MathCad problems, thus the final tests show the improved scores.

Results and discussion

The survey was carried out in order to determine the skills that the teaching of mathematics indirectly develops and to identify the importance of mathematics studies in assessment of students.

The survey involved the first and second year students of engineering specialties at the faculties of Engineering, Rural Engineering and Information Technologies at the LUA. 110 respondents were questioned. The questionnaire included eight skills which could be developed indirectly teaching mathematics. The respondents had to determine the importance of these skills and their readiness acquiring these skills.

The analysis of the results shows that the students positively evaluate the role of mathematics in the development of cognitive skills, but not everyone is ready to invest serious effort in the development of this ability, see Table 1.

Table 1

The results of the survey about mathematic indirect impact

Skills		Readiness			
		I would like to get these skills, doing nothing	I have partially mastered these skills at school and believe that there is no need to further develop the skills	I am ready to invest minimum effort to just get the minimum positive evaluation	I am ready to invest the necessary effort to obtain these skills at the highest possible level
1	to move to the formal language, using mathematical symbols	9.1 %	18.2 %	19.1 %	53.6 %
2	to create a series of logical conclusions, using the formal language	1.8 %	32.7 %	17.3 %	48.2 %
3	to split large amounts of information in separate parts	7.3 %	40.9 %	23.6 %	28.2 %
4	to find the necessary solution method by selecting from a large number of methods	13.6 %	23.6 %	32.7 %	30.0 %
5	to use formal rules of mathematics in real situations	10.0 %	23.6 %	19.1 %	47.3 %
6	to use IT programs for mathematical calculations	9.1 %	20.0 %	19.1 %	51.8 %

The mathematics role in the development of the ability to solve problems is very important. Most of the students (53.6 %) consider the skill to “translate” real-life tasks to symbol language is necessary to develop the highest possible level and they are ready to work to develop this skill. At the same time 19.1 % are ready to work just enough to get the minimum positive evaluation, but 9.1 % would like to get it doing nothing.

One of the skills which the mathematics indirectly develops is the skill to find the necessary solution method by selecting from a large number of methods. The classic example would be the calculations of indefinite integrals. The experience shows that this learning topic for students requires some effort. The results of the survey show that only 30.0 % of the students are ready to invest the necessary effort to obtain this skill at the highest possible level.

In order to maintain the science in future, it is needed to develop and apply new methods and forms of studying. One of them is IT software use in mathematics. The students positively evaluate the IT use in mathematics courses, because it allows them to check the results obtained not only in mathematics but also in other study courses requiring mathematical calculations. The survey shows that 51.8 % of the students are ready to make the necessary effort to get the skills to use IT programs in mathematics at the highest possible level, 20.0 % of them believe that this skill has to be developed at secondary school.

Mathematics helps develop the ability of logical thinking, concentration, accuracy and consistency. Students (especially, the first year students) are often unable to manage their time and choose the priorities, it is hard for them to mobilize and concentrate for relatively long time. The respondents recognize it as an important skill to mobilize and concentrate in order to meet the challenges, but only 48.2 % are ready to develop it. The survey shows that 43.6 % of the students

believe that mathematics indirectly develops the skill to manage time and choose the priorities and are ready to make the necessary effort to develop them (see Fig. 4).

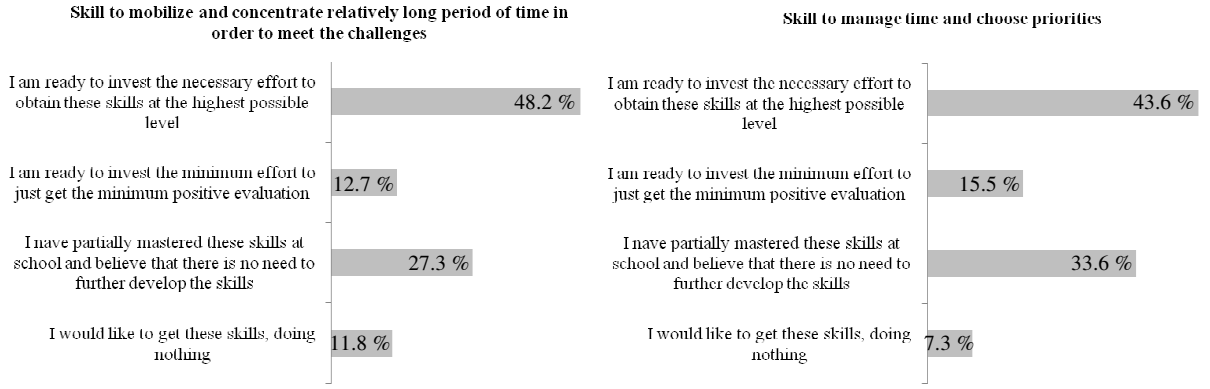

Fig. 4. **Students' readiness to acquire skills to mobilize and concentrate and skill to manage time and choose priorities**

The study of mathematics gives engineers not only certain knowledge, but also develops the ability in them to take, to investigate and to solve a variety of problems. In other words, mathematics develops thinking of the future engineers and lays the basis for the development of many special technical disciplines.

Conclusions

1. Mathematics studies have an impact on the development of engineers' necessary learning outcomes both directly and indirectly. First, mathematics serves as a tool for solving and calculating various problems. But much greater is an indirect impact of mathematics which provides the other learning outcomes.
2. Learning mathematics, students acquire the skills to move to the formal language, using mathematical symbols, to create a series of logical conclusions, using the formal language, to split large amounts of information in separate parts, to find the necessary solution method by selecting from a large number of methods, to use formal rules of mathematics in real situations and the skill to use IT programs for mathematical calculations.
3. The analysis of the results of the survey show that the students positively evaluate the role of mathematics in the development of the above-mentioned cognitive skills and approximately 40 % of the students are ready to invest the necessary effort to obtain these skills at the highest possible level. At the same time about 10 % of the students would like to get these skills, doing nothing.
4. More than 50 % of the students recognize the role of mathematics in developing mobilization and concentration skills as well as time management skills and the skills of choosing priorities.

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