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The Contribution of Mathematics to the Engineering Education in the Students' Assessment

Anda Zeidmane[1] Dr. paed.; **Tatjana Rubina**[2] Dr. sc. ing.
Latvia University of Life Sciences and Technologies, Latvia
anda.zeidmane@llu.lv[1]; tatjana.rubina@llu.lv[2]

Abstract: Mathematics studies have an impact on achieving the necessary outcomes in engineering education both directly and indirectly. First, mathematics serves as a tool for solving and calculating various problems. Second, mathematics studies develop mathematical competences such as the ability to ask and answer questions in and with mathematics, and the ability to deal with mathematical language and tools. More than 100 first-year students from the Faculty of Information Technology and Faculty of Engineering of the Latvia University of Life Sciences and Technologies who studied mathematics in 2016/2017 study year and more than 70 second-year students from the same faculties who are studying in 2017/2018 were surveyed. The aim of the study is to identify the contribution of mathematics studies in engineering education in assessment of students. Comparing their own competences before studying mathematics in university and after completion of the higher mathematics course students recognized improvement of the mathematical competences and identified importance of maths studies in engineering education.

Keywords: university education, mathematics, competences, students' assessment.

Introduction

Many researches in engineering education emphasize the need for engineer educators to adapt to the changes of the 21st century both in the engineering profession and in student populations. Exponential growth for scientific information cause difficulties for universities to provide students with all the knowledge and skills that will be needed for the whole working life. Therefore, in engineering programs, the contribution and scope of each study course is being evaluated. Therefore, the question arises: is mathematics an important part of engineer education in the 21st century? Mathematics is often regarded as an object that is hard to understand for students (Prakash, Jerlin, Fernandes, 2014).

We can ask: "What is mathematics in the context of engineering education?"– a language? a mental discipline? a set of techniques? One may say of engineering that it is concerned with physical systems whose behaviour must be (Scanlan, 2006):

- understood qualitatively,
- analysed quantitatively,
- designed to behave in a desired manner.

The first task requires understanding physics, biology, chemistry and mathematics education plays a secondary role, but to be able to analyse quantitatively (second task), mathematical education is required.

In the last twenty years, both new demands of the engineering profession and inadequate **mathematics** ability of the engineering students have led to a big change in the scope of the mathematics education (Uysal, 2014). The advancements in modern technology have introduced changes in engineering mathematics studies and have provided students with an opportunity to use modern technologies and methods. Therefore, there is much debate as to how these changes should be addressed (Broadbridge, Henderson, 2008).

Engineering institutions are faced with a problem like:

- the reduction of mathematical skills of entering engineering students,
- the reduction of mathematical content and course hours,
- the difficulty of teaching large classes,
- the lack of mathematics staff,
- increasing the diversity of students' mathematical backgrounds as the number of international students increases,
- to cater for mathematical needs for all engineering disciplines in one subject and the difficulty of reaching a shared understanding between the mathematics and engineering departments about what is to be included in the curriculum.

Insufficient skills in basic mathematics cause problems for those majoring in engineering at university level. The one of the most important skills required of engineering students are problem solving and creative thinking, but they have some difficulties in these issues (Adams et al., 2007).

The aim of the study is to identify the contribution of mathematics in engineering education as well as to identify importance of mathematics studies in assessment of students.

Methodology

More than 100 first-year students from the Faculty of Information Technology and Faculty of Engineering of the Latvia University of Life Sciences and Technologies who studied mathematics in 2016/2017 study year and more than 70 second-year students from the same faculties who are studying in 2017/2018 were surveyed.

Theoretical background of mathematical competences

Mathematics studies have an impact on achieving the necessary outcomes in engineering education both directly and indirectly (Zeidmane, 2012). First, mathematics serves as a tool for solving and calculating various problems. However, much greater is an indirect impact of mathematics, which provides other outcomes (Figure 1).

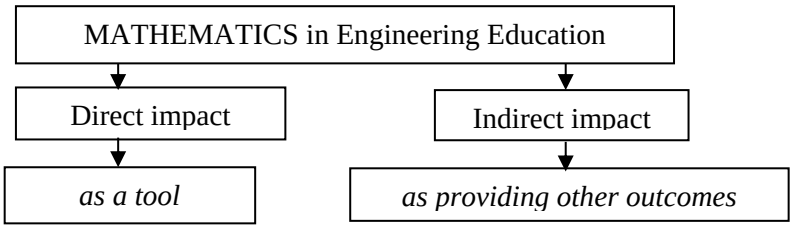

Figure 1. Mathematics impact on Engineering Education.

Extensive study has focused on mathematical competences. What is the mathematical competence? One could also say that a mathematical competence is a well-informed readiness to act appropriately in situations involving a certain type of mathematical challenge (Niss, Hojgaard, 2011). Each competence, based on actual knowledge and specific skills, allows to take certain mathematical activities. Eight mathematical competences are recognized, divided into two groups: *ability to ask and answer questions in and with mathematics* and the *ability to deal with mathematical language and tools* (Figure 2.)

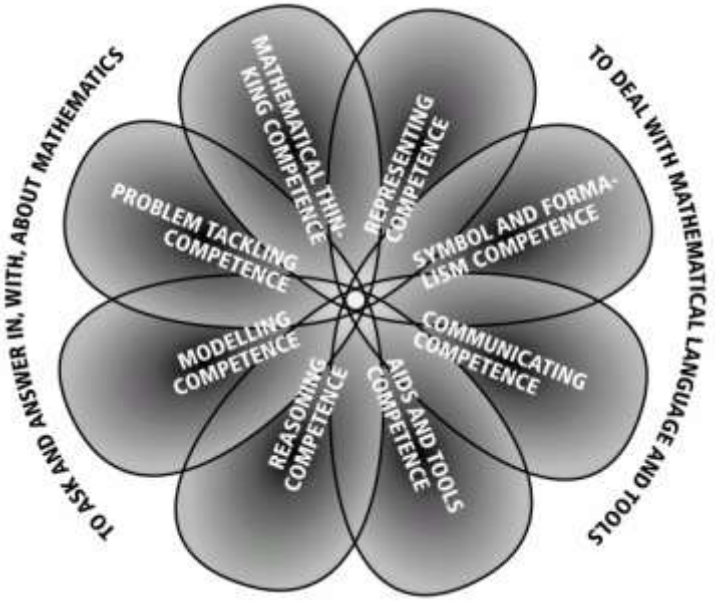

Figure 2. A visual representation of the "KOM (Competences and the Learning of Mathematics) flower" of the eight mathematical competences presented and exemplified in the KOM report (Niss, Hojgaard, 2002).

The first competence group "Being able to ask and answer questions in and with mathematics" combines the following competences:

- mathematical thinking competence – mastering mathematical modes of thought; this competence includes understanding the types of math questions, the ability to ask such questions and an overview of what answers can be expected;
- problem tackling competence – formulating and solving mathematical problems; this competence means the ability to formulate, separate, and clarify various mathematical problems and the ability to solve them in different ways;
- modelling competence – being able to analyse and build mathematical models concerning other areas. Modelling contains a range of different elements: the ability to structure the real area or situation, the ability to implement a mathematization of this situation, the ability to work with the resulting model (solving the mathematical problems, assessing), the ability to monitor and control the entire modelling process;
- reasoning competence – being able to reason mathematically. This competence means the ability to follow and assess mathematic reasoning, knowing and understanding what a mathematical proof.

The second competence group “Being able to handle mathematical language and tools” combines the below described competences:

- representing competence – being able to handle different representations of mathematical entities; this competence means the ability to understand and utilise different representations of mathematical objects and problems as well as to understand the reciprocal relations between different representational forms of the same entity;
- symbol and formalism competence – being able to handle symbol and formal mathematical language. This competence means the ability to decode, translate and handle symbolic statements;
- communicating competence – being able to communicate in, with, and about mathematics. This competence means the ability to understand and interpret expressions and texts;
- Aids and tools competence – being able to make use of and relate to the aids and tools of mathematics (incl. ICT); this competence means having knowledge of the existence and properties of the diverse forms of relevant tools used in mathematics and the ability to use such aids.

Mathematics teachers need to think about how to develop these competences by introducing new teaching methods and knowing how much these competences can be developed by teaching specific mathematical content, for example, by completing table in Appendix. For example, on the one hand, by learning arithmetic, students develop mathematical thinking, symbol and formalism competences, little reasoning, but by learning geometry, students without the aforementioned competences should also develop modelling, reasoning and problem tackling competences. The teacher may choose which aids and tools to use and how much. On the other hand, teacher can choose easier tasks, solution of which requires only some competences, or more difficult tasks, the solution of which develops all mathematical competences in each topic.

In order to improve the mathematical learning process, students’ motivation needs to be increased. Students should be aware of both the application of mathematics and what competences are acquired through learning mathematics.

Results and discussion

More than 100 first-year students (the principle of occasional selection) from the Faculty of Information Technology and Faculty of Engineering of the Latvia University of Life Sciences and Technologies were surveyed in order to identify the student's opinions regarding mathematical competences acquired in secondary schools. In the survey, students mentioned mathematical competences such as the use of symbol language, mathematical representation, problem solving, opinion formation and others as well as assessed how the corresponding competence has been acquired (Figure 3), except for communication competence this because this competence can be developed only indirectly studying mathematics one year.

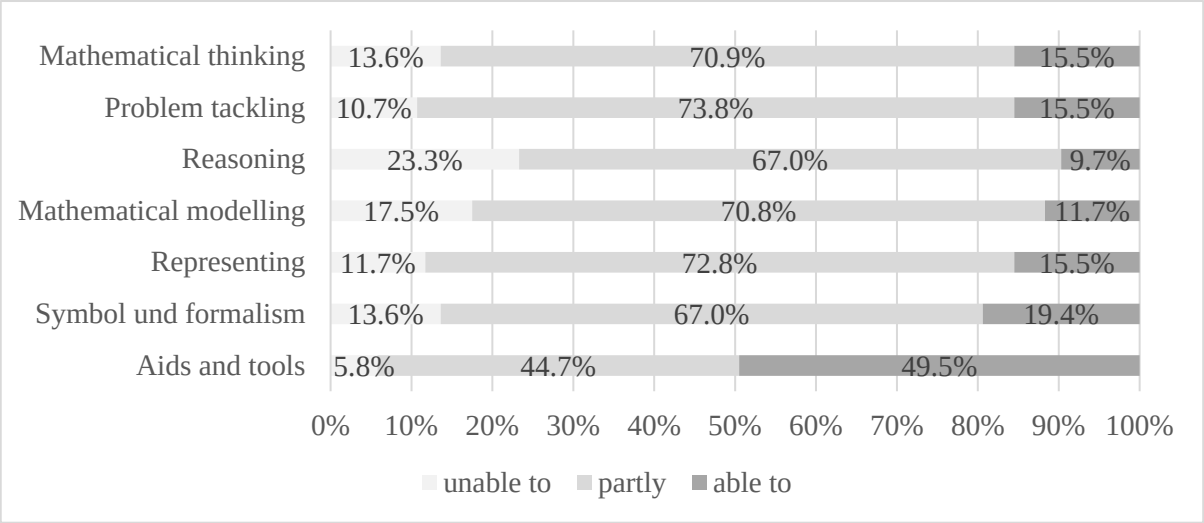

Figure 3. The results of the first-year engineering students' competences assessment at the beginning of the Higher Mathematics course.

The results show that the largest part of respondents consider that their competences have been developed partly. Almost 50 % of engineering students evaluate using ability of mathematical packages as the most well-developed competence (median = "partly", mode = "able to"). As the second better-developed competence the using of symbol language, which was acquired by 19.4 % of students. It is sad to note that 23.3 % of engineering students consider that they cannot form their opinion (mode=median = "partly"), 17.5 % are unable to perform mathematical modelling (mode = median = "partly"), 13.6 % of students are unable to use symbol language (mode = median = "partly"). More than 10 % of students consider that they are unable to solve problems and have not developed mathematical thinking (mode = median = "partly").

Correlation analysis exploring bivariate correlation with the calculation of Spearman's correlation coefficient was performed in the study. As the results of the analysis indicate there exists a weak positive correlation between CE score and mathematical thinking competence (r_S=0.345, p=0.01). In other cases, a significant correlation between CE score and other competences was not detected. Examining the correlation between competences revealed positive moderate correlation between mathematical thinking and the opinion formation (r_S=0.489, p=0.01), between the opinion formation and mathematical symbol language understanding (r_S=0.447, p=0.01), between the opinion formation and mathematical modelling (r_S=0.402, p=0.01), between opinion formation and mathematical presentment (r_S=0.418, p=0.01), as well as between mathematical symbol language understanding and mathematical presentment (r_S=0.482, p=0.01). It can be concluded on the basis of these results that knowledge of one competence contributes to the development of the other competence and vice versa.

In order to determine which of the mathematical competences for the students of the engineering faculties are important, and if students are ready to invest the necessary effort to obtain these skills during studies at the university, the second survey was carried out. This survey contains the practical mathematical skills required for mathematics studies.

The results were compared with the results of previous years (Zeidmane, Sergejeva, 2013). The results show that students' attitude towards the acquisition of mathematical competence has not changed much: not everyone is ready to invest serious effort in the development of these competences (Table 1).

During the survey students were asked to evaluate their abilities regarding to their mathematical skills and their willingness to devote time to develop these skills. As results show more than a half (54.2 %) of students consider that **symbol and formal mathematical language** knowledge and ability to "translate" real-life tasks to symbol language are most necessary skills and they express readiness to invest the necessary effort to develop these skills. However, at the same time other students are not at all ready or willing to invest a minimum effort to develop partly or acquire these skills. Almost the fifth of students (17.7 %) consider that skills level acquired at school is sufficient and believe that there is no need to develop these skills further. A similar opinion is expressed by students of IT software using skill for mathematical calculations. It is not a surprise because the ability to use IT provides several benefits

to students such as the ability to check correctness of the result, make calculations automatically and get results faster, the ability to display results in a smoother graphic, as well as create smart programmes for some method implementation.

Table 1

The results of the survey on students' mathematical skills and the readiness to acquire them (%)

No	Readiness / Mathematical skills	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 the 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	10.2	17.7	18.8	54.2
2	to create a series of logical conclusion, using the formal language	2.8	31.2	19.2	47.3
3	to find the necessary solution method by selecting from a large number of methods	12.5	20.2	30.9	29.0
4	to use formal rules of mathematics in real situations	9.2	21.3	19.1	46.2
5	to use IT programs for mathematical calculations	9.3	19.6	19.1	51.8
6	to mobilize and concentrate relatively long time to solve problems	12.1	26.3	13.9	48.2
7	to manage time and choose priorities	8.5	33.1	14.5	43.6

More than 47 % of engineering students consider that the skill “to create a series of logical conclusion using the formal language” is very important skills and they are ready to invest the necessary effort to obtain this skill at the highest possible level. At the same time, 2.8 % of students would like to obtain this skill doing nothing. Mathematics indirectly develops a very important skill to find the **necessary solution** method by selecting from a large number of methods, which requires time and effort. Unfortunately, only 29 % of engineering students are aware of its necessity and are ready to invest the required effort for its development at the highest level.

Studying mathematics, many students have a problem mobilizing themselves and concentrating their attention for a relatively long-time period to solve problems. It is surprising that only 48.2 % of students understand its importance and are ready to invest the required effort for its development. 13.9 % of students are ready to invest minimum of effort in order just to pass the course. 26.3 % of students are satisfied with the level of this skill acquired at school.

Inability to manage their time and choose priorities is not a less important problem for the first-year students. The proof of this is: home works which are not submitted on time, attending consultation only after a failed test. Incorrect choice of priorities and laziness are some of the reasons for large dropout numbers among the first-year students. Unfortunately, 14.5 % of students are ready to invest the minimum effort to develop this skill.

The third questionnaire was created to determine which mathematical competences students had acquired or developed studying mathematics at the Latvia University of Life Sciences and Technologies. The second and third year students of engineering faculties participated in this survey (Figure 4).

As indicated by the results of the survey, only one student noted that he does not have one competence after completing higher mathematic study course, although the answer “unable to” was included on the answers’ list. According to the obtained results, studying of mathematics’ course allows students to develop the mathematical competences. All students who participated in the questionnaire recognized that

they are able (60 %) or able better (40 %) to use specialized software for solving mathematical problems. The study results confirm that inclusion of the work with Mathcad and Matlab in the course of mathematics is justified and facilitates students' competence to work with specialized maths packages.

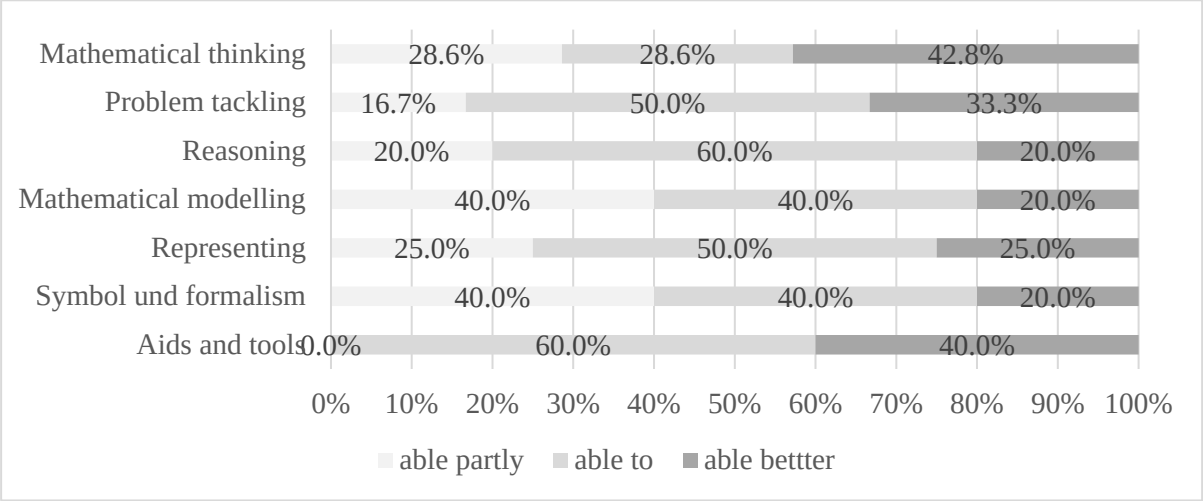

Figure 4. The results of the second and third year engineering students' competences assessment after completion of the Higher Mathematics course.

It is encouraging that 42.8 % of students believe that they have better developed the mathematical thinking competence. Nevertheless, 28.6 % of students have admitted that they mastered this competence still partly (mode = "able better"). The third part (33.3 %) of students consider that their problem-solving competence (mode = median = "able to") has become better after the mathematics course. A quarter (25 %) of students have improved mathematical presentment (mode = median = "able to"). The fifth part (20 %) consider that they are able better form opinions (mode = median = "able to"), use mathematical formal and symbol language (mode=median="able to"), as well as perform mathematical modelling (mode = median = "able to").

The questionnaire also included open questions in order to find out students' opinion and knowledge. One of the questions was: "Does higher mathematics affect the successful study of other courses?" Summarizing students' opinions, the obtained results show that 60 % of students confess that higher mathematics course has contributed to the acquisition of other courses such as physics, programming and courses which require to work regularly and deliver the tasks on time to get an accumulative assessment at the exam. It can be concluded that the higher mathematics course allows students to improve such competences as time management and attention concentration.

Conclusions

- Mathematics studies have an impact on achieving the necessary outcomes in engineering education both directly and indirectly. First, mathematics serves as a tool for solving and calculating various problems. Second, mathematics studies develop mathematical competences such as the ability to ask and answer questions in and with mathematics and the ability to deal with mathematical language and tools.
- The first survey of the first-year students shows that about 10 % have not acquired mathematical competences during studying in secondary school, and only 15 % of students admit that they have mastered these competences.
- It is gratifying that according to the results of the third survey, all students acknowledged that they had acquired mathematical competences, while 42.9 % of the second and third year students acknowledged that they had improved their mathematical thinking competence, 40 % had improved the competence of using mathematical packages, 33.3 % had improved their problem-solving skills. Only some part of the second and third year students that participated in the survey recognized that some competences they have developed partly.
- As results of the second survey show more than a half of students consider that symbol and formal mathematical language knowledge and the skill "to create a series of logical conclusion using the

formal language" is a very necessary skill and are ready to invest the necessary effort to obtain this skill at the highest possible level. At the same time, 2.8 % of students would like to get this skill doing nothing.

- The ability to manage time and choose priorities is not a less important problem for the first-year students. As the proof of it, there are home works that have not been submitted on time, attendance of consultation only after a failed test. This is one of the reasons for a large dropout number among the first-year students. Unfortunately, 14.5 % of students are ready to invest the minimum effort to develop this skill.

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APPENDIX

Rates of the competences development teaching specific mathematical content

Subject area / Competence	Arith-metic	Alge-bra	Geo-metry	Deri-vatives	Inte-grals	Differ. Equat.	Series
Mathematical thinking							
Problem tackling							
Modelling							
Reasoning							
Representing							
Symbol and formalism							
Communication							
Aids and tools							