THE NEED AND ROLE OF HIGH-LEVEL MATH SKILLS IN ENGINEERING STUDIES

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Abstract
This article examines the importance and necessity of high-level mathematical skills in engineering studies. It analyzes the specific mathematical skills required for successful engineering education and their role in engineering studies. The results provide insight into how high-level mathematical skills contribute to the development of engineering competencies and enable engineers to solve complex problem scenarios. Key findings reveal that high-level mathematical skills are indispensable in engineering education, providing the tools needed to solve real-world problems and drive innovation in engineering. Mathematics is the language of engineering. It provides the analytical and problem-solving tools necessary for engineers to design, analyse, and optimize systems, ensuring that they meet safety, efficiency, and performance requirements. Engineers use math as a fundamental tool to make informed decisions and drive technological advancements across various engineering disciplines. Without math, engineering would be severely limited in its ability to design safe, efficient, and innovative solutions to the complex problems that engineers encounter in various industries. The questions contained in the article are investigated using survey data of university students. The purpose of this study is to research the relative applicability and level of knowledge of the learning material learned in secondary educational institutions in mathematics, based on the experience of school graduates and engineering students.
Key words: mathematical skills, role of mathematics, engineering studies.

Introduction

The world is constantly undergoing various changes in economy, politics, and education. There are many different educational systems, which are evaluated ambiguously by experts.

There are also continuous reforms and changes in Latvian education, about the structure of which, implementation rates and role in the growth of young people, there are continuous discussions, up to protests. One of the most widely discussed blocks of learning subjects is exact sciences, their necessity, quality and intensity of teaching (from various aspects) (Kopeika & Zvirgzdina, 2020).

In order to understand the situation more fully and at least to try to find solutions to the problems that have arisen or are already lasting, it is not enough to evaluate it only from the position of experts (both local and international).

It is also worth listening to the judgments of educators and, even more, to the opinions of young people themselves.

Regarding the new policy of the education system in the field of exact subjects (especially mathematics), experts and teaching forces have grouped themselves into two groups with radically opposite attitudes towards what is happening.

The authors of the article do not join any of these groups, because each of the systems, both old and new, have both positive and negative trends.

Mathematics studies have an impact on the development of the necessary outcomes for engineers' both directly and indirectly (Harris *et al.*, 2015; Zeidmane & Rubina, 2017).

Mathematics plays a crucial role in engineering, serving as the foundation upon which engineers build and apply their knowledge to solve real-world problems, see 'Figure 1'.

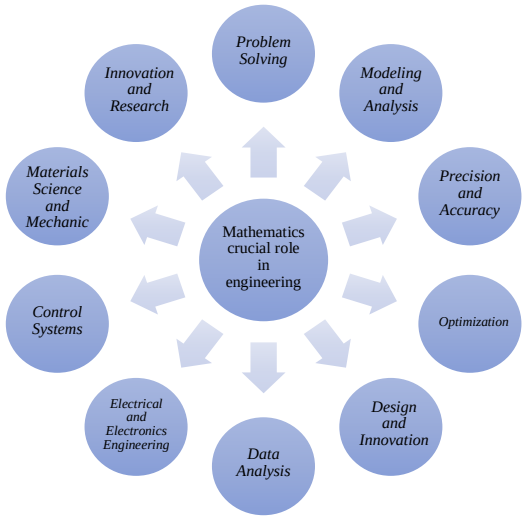

Figure 1. Mathematics a crucial role in engineering studies.

Here are some key ways in which mathematics is indispensable in engineering (Tunesk, 2022; Saranya, 2023):

- *Problem Solving:* Engineers often face professional problems that require logical thinking and problem-solving skills. Mathematics provides the foundation for developing these skills and enables engineers to break down complex problems into smaller, manageable components.
- *Modeling and Analysis:* Engineers must use mathematical models to represent a real-world system. Mathematics helps engineers analyze these models, predict outcomes, and make informed decisions.
- *Precision and Accuracy:* Undoubtedly, engineering requires a very high level of precision. Mathematical tools such as calculus, algebra, and statistics allow engineers to make accurate calculations and

measurements, reducing the risk of errors in design and analysis.

- *Optimization:* Engineers often need to optimize systems and processes to achieve specific goals, such as reducing costs, increasing efficiency, or optimizing performance.
- *Design and Innovation:* Mathematical principles underlie the design of various engineering systems and technologies. Whether it's a bridge, an airplane, or a computer chip, engineers rely on mathematical principles to ensure that their design is functional, safe, and efficient.
- *Data Analysis:* In the age of data-driven decision-making, engineers must analyze large sets of data to improve processes and products. Statistics and data analysis techniques are essential for drawing meaningful conclusions from data and making informed decisions.
- *Electrical and Electronics Engineering:* Engineers working in fields like electrical and electronics engineering rely heavily on mathematical concepts, such as complex numbers and differential equations, to design circuits, analyze signals, and develop electronic systems.
- *Control Systems:* Control systems engineering involves designing systems that regulate and control processes. Mathematics, particularly differential equations, and linear algebra, is essential for modeling, analyzing, and designing control systems.
- *Materials Science and Mechanics:* Engineers in fields like materials science and mechanics use mathematical concepts to understand the behavior of materials under different conditions, predict mechanical properties, and design structures that can withstand various loads.
- *Innovation and Research:* Engineers involved in research and development often need advanced mathematical tools and techniques to push the boundaries of technology and innovation.

More than half of practising engineers use a high level of curriculum mathematics in their work. There is also evidence that engineers' mathematical thinking usage is significantly greater than their curriculum mathematics usage (Goold & Devitt, 2012).

Without mathematics, engineering is impossible, and the consequences in this field would be significant (Saranya, 2023), see 'Figure 2':

1) *Lack of precision:* Without mathematics, engineers would have to rely on trial and error, intuition, or imprecise methods that could lead to less accurate designs and potentially dangerous results.
2) *Inefficient designs:* Without mathematics, engineers would struggle to find the best solutions among many possible alternatives, resulting in less efficient designs.
3) *Safety Concerns:* Math plays a crucial role in ensuring the safety of engineering projects. Without math, engineers would have a much harder time assessing safety risks and ensuring that projects meet safety standards.

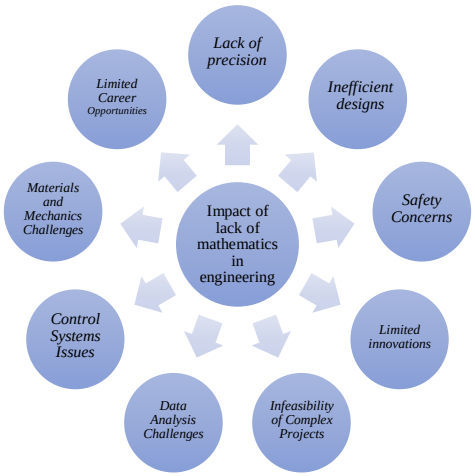

Figure 2. Impact of lack of mathematics in engineering.

4) *Limited innovations:* Many innovative developments in engineering are driven by mathematical concepts and techniques. Without mathematics, the pace of innovation in engineering is likely to slow significantly.
5) *Infeasibility of Complex Projects:* Many engineering projects, such as designing modern aircraft, bridges, or computer chips, rely heavily on advanced mathematical principles. Without math, these complex projects would be practically impossible to undertake.
6) *Data Analysis Challenges:* In today's data-driven world, engineers need mathematical tools to analyze large sets of data and make informed decisions. Without math, engineers would struggle to draw meaningful conclusions from data, hindering their ability to improve processes and products.
7) *Control Systems Issues:* Without math, engineers would struggle to design effective control systems, leading to inefficiencies and instability in processes.
8) *Materials and Mechanics Challenges:* Without math, engineers would struggle to predict how materials will perform and design safe and reliable structures.
9) *Limited Career Opportunities:* Engineering is a highly technical field that requires strong mathematical skills. Without math, individuals would find it challenging to pursue careers in engineering, limiting the pool of talent available to solve complex engineering challenges.

Materials and Methods

This article analyzes the assessment of the learning process and content of engineering students (1st to 4th year) in mathematics. 260 students from Riga Technical University (RTU) and Latvia University of Life Sciences and Technologies (LBTU) participated as respondents. Students are currently pursuing programs in smart electronics, telecommunications engineering, automotive electronics, agricultural engineering, and machine design and manufacturing. The results of the survey were analyzed with descriptive statistics, the general scientific logically constructive and graphic method was applied.

Results and Discussion

Although 80% are RTU students, taking into account the number of students in both universities, such a difference is acceptable.

Before starting their studies, the respondents have obtained secondary education in schools of different profiles (see Table 1).

Table 1

Obtained secondary education of respondents

RTU Engineering Secondary School	Private school	Professional technical school	State Gymnasium	Secondary School
2%	1%	18%	23%	55%

It must be recognized that only 48% of these young people have also passed the higher level centralized exam in mathematics after graduating from university in 2023. When evaluating what level of exam the young people took and comparing the results, only the results from the 1st year students are taken into account, which is almost 40% of all the respondents, so the results can be considered significant. Comparing the results obtained by students in two exams, a pronounced regularity can be seen. If you compare the results, group the 10% interval in this Highest rating, both ratings are equivalent, except for the group 1% to 100%, clearly better results in the group have been achieved in the highest level exam. It is better if you evaluate the exact results, as there is only a small part of all respondents, or 7%, for whom the results of the Optimal exam are rated higher.

There are several explanations for this situation. It would seem that the most important factor is that a large number of students, at least until now, have taken both these exams by the end of the 12th grade, which is exactly one year after the optimal level of study of the exam topics at school.

However, several other factors are even more important - the number of mathematics lessons at school, the amount of topics to be learned, the pace of teaching, the interest of students and others.

We all know that the number of mathematics lessons per week at school depends on the chosen program, sometimes also depending on the attitude of the school or the municipality. So from 2 hours per week, for example, in the Riga Trade vocational secondary school, moreover, probably due to the lack of teachers, they take place in modules way, to 8 hours per week, for example, RTU Engineering Secondary School, where there are 4 math lessons and 4 math groups per week. There are schools in Latvia that provide even 12 hours a week, but no permission was received to publish information about them. It seems logical, the student is not good at the exact subjects, so he chooses the program with the least number of hours. But a dilemma arises, the optimal level exam must be taken by all young people at the same level, the program must be equivalent.

There are more and more young people for whom it is very difficult to understand and remember mathematical relationships, and sometimes it seems impossible (this is a global problem). The authors of the article will not investigate the reasons for this situation. In order to understand and be able to see mathematical relationships, to be able, at least at an intermediate level, to solve problems of a mathematical nature, it is necessary to devote much more time to intensive studies, in cooperation with a teacher. Homework must also be done regularly, without which successful learning of topics is unthinkable.

Table 2

Students' answers to the question 'Was the number of lessons in mathematics sufficient at school'

Obtained secondary education	Yes	No
RTU Engineering Secondary School	100%	0%
Private school	100%	0%
Professional technical school	18%	82%
State Gymnasium	91%	9%
Secondary School	17%	83%

The previous information is confirmed by the data presented in Table 2. In addition, many young people, indicating that the number of lessons in this subject was sufficient for them, indicate several comments and remarks:

- it was enough for me, because mathematics is my favourite subject, but it was too little for a large part of my classmates;
- it was enough because I also studied with a private teacher;

- I personally would like more because I like mathematics.

It should not be forgotten that engineering students participate in the survey, young people, a large part of whom understand the necessary basic relationships in mathematics, diligently and actively listen and solve in classes and at home, go to consultations in case of confusion and do not comment on each new topic 'Where will this be useful for me in real life'.

Changes in the topics to be learned at school course are also not insignificant.

Widely available resources do not provide sufficient information on the extent to which mathematical skills learned during school are used in later studies. It is clear that for this amount of information, the number of contact hours in schools is catastrophically small, especially when learning the optimal block of mathematical knowledge.

In the research, an assessment of young and future engineers has been carried out - how intensively they use what they learned at school during their studies, both in study subjects and also when developing coursework, projects and research papers.

The research included questions about topics to be learned in the optimal mathematics program, see 'Figure 3'.

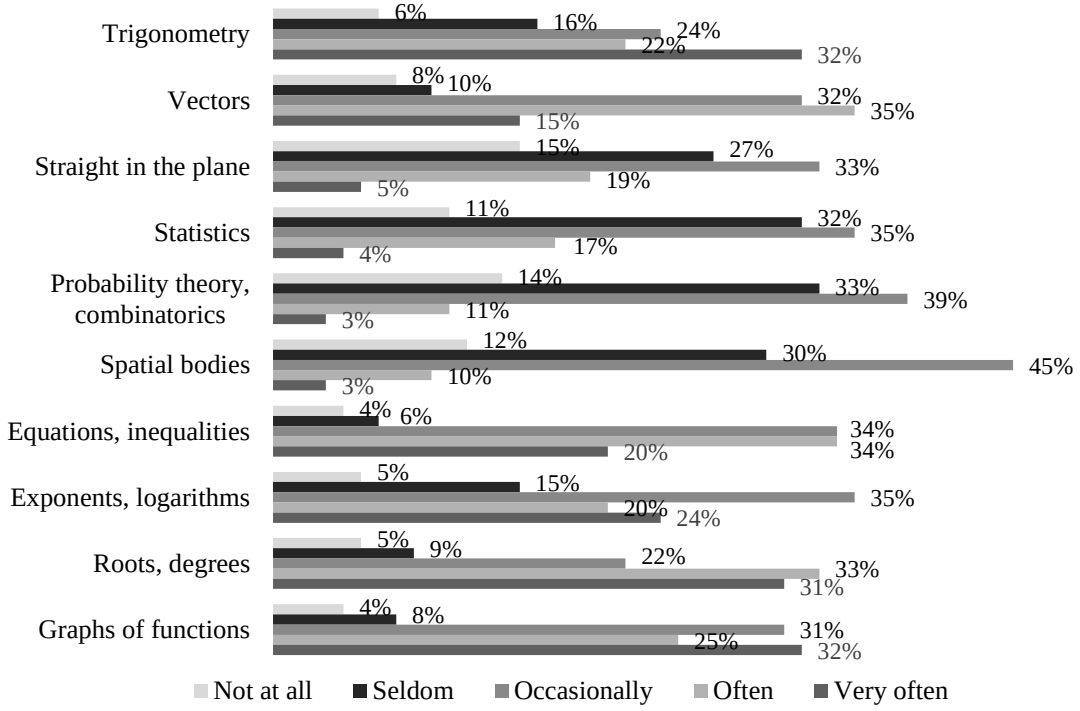

Figure 3. Respondents' answers to the question: 'To what extent do you use the mathematics topics learned in high school in your studies to understand and evaluate different engineering situations?'

From the answers, it is clear that more than 80% of students admit that they use all topics learned at school very often, often or occasionally.

With the exception of spatial bodies, straight in the plane probability theory, combinatorics and statistics, which are considered widely applicable in studies by 53% to 58% of respondents, which is also not a small number.

Taking into account the results obtained both from the survey and from work experience in cooperation with students, it should be emphasized that students in engineering sciences especially need knowledge of exponential functions and power properties, logarithms, graphs of functions and trigonometry.

Respondents, both those who acquired this knowledge sufficiently well at school, and those who diligently studied the optional subject 'Elementary Mathematics' (32 academic hours) in the 1st semester of study and during which they repeated or learned the indicated topics (the majority of such respondents were, i.e. 85% of respondents) indicated that this knowledge not only helps to understand the topics learned in professional study courses much easier, but also creates an understanding of how these relationships are formed and why exactly they are. Of course, this is possible if you also study regularly and intensively at university and add skills in higher mathematics to your high school knowledge.

Unfortunately, we have to admit that the school program for learning these topics has not only reduced the number of contact hours, but also the number of topics included in the program has been reduced to a minimum.

The authors agree that study blocks of math topics such as trigonometry, operations with roots, graphing functions, and more are difficult. But does this make

the need for knowledge less, and just a short overview of these topics is sufficient?

Arriving at the university, it is very difficult for a large number of students to start successful studies precisely because of the lack of this knowledge.

The authors understand that artificial intelligence is increasingly entering our everyday life, research and performance of various tasks.

Solutions to many different problems can be found with the help of computer equipment. We cannot forget that the most advanced and promising is the education of competences. It should not be forgotten that competence education is the next level of development, because without knowledge there will be no competence. In order to base research on electronically developed research results, one must understand their operating principles, be able to evaluate them objectively, and only then professionally interpret the obtained results.

Although significant differences were observed between the answers of the students of the two universities, these results will not be analyzed in this study, taking into account the significant numerical superiority of RTU students in the survey.

Conclusions

1. Mathematics serves as the foundation upon which engineering principles are developed and applied.
2. High-level math skills form the foundation of engineering studies, empowering engineers to conceptualize, analyze, and innovate in a variety of fields.
3. As engineering continues to evolve, the need for mathematical knowledge in the field remains paramount in driving progress and innovation forward.
4. Recommendations to the persons from the State Educational Content Center responsible for the mathematics learning program in schools is to find an opportunity to schedule more contact hours for learning the basic mathematics course.
5. Recommendations for municipalities and school management is to organize optional classes, during which opportunities for solving various practical tasks, using the material to be learned in mathematics, would be organized for students who find it difficult to learn this subject.
6. Although the audience of the research is only engineering students and future specialists, the trend was clearly marked that topics such as exponent functions, logarithms, graphs and properties of various functions, but especially trigonometry, are taught too little in secondary educational institutions.
7. It should not be forgotten that competence-based education will be effective only if it is based on fundamental knowledge.
8. This study is a case study and it only reflects the views of the respondents who participated in it. The results could be used to identify problems/ directions for in-depth research.

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