A COMPARATIVE STUDY OF THE IMPORTANCE OF MATHEMATICS AND CAREER NEEDS IN ENGINEERING STUDIES

***Evija Kopeika[1], Anna Vintere[2], Elena Safiulina[3], Olga Panova[4]**
[1]Riga Technical University, Latvia
[2]Latvia University of Life Sciences and Technologies, Latvia
[3]TTK University of Applied Sciences, Estonia
[4]Estonian University of Life Sciences, Estonia
*Corresponding author's email: Evija.Kopeika@rtu.lv

Abstract
Mathematics is a fundamental skill in many fields of engineering and technology. Mastering it provides the necessary analytical and problem-solving skills that are essential for successful performance in engineering, data analysis, or other technical professions. Mathematical skills are widely used in building models, performing calculations, and analysing data, which are important for making sound technical and business decisions. Based on expectancy-value theory, which examines how the practical importance of a task influences an individual's motivation to learn and achieve, the study focuses on how students evaluate the importance of mathematics in relation to their future career needs, as the usefulness of mathematics in a profession can influence students' motivation to study the subject more deeply and more fully. A clear understanding of the practical applications of mathematics enables students to see the direct relevance of their studies to future career opportunities, thereby increasing their motivation and engagement in the learning process. The study was conducted at four universities in two countries - Latvia and Estonia. The results of the study indicate a moderate positive correlation between the practical application of mathematics knowledge in engineering and students' perceptions of its role in cognitive development, which is essential for engineering professionals. The integration of mathematics into engineering programs significantly affects students' perceptions of its usefulness: the more actively mathematics is used in the engineering curriculum, the more students see its value in promoting engineering skills.
Keywords: expectancy value theory, mathematics, motivation.

Introduction

Continuous reforms and changes are taking place in the education system in Latvia, Estonia and the whole of Europe. The structure, pace of implementation and role of these reforms in the growth of young people are the subject of constant debate and controversy. One of the most widely discussed subject blocks is the exact sciences, their necessity, quality and intensity of teaching (from various aspects) (Kopeika & Zvirgzdiņa, 2020). This discussion occurs despite the widely accepted fact that a good knowledge of mathematics and the ability to apply it comprehensively is a fundamental element in the professional work and growth of specialists in various fields, especially in engineering. For example, mathematics is fundamental in engineering, providing tools and methods for modelling and solving technical problems. It allows for the development of precise models for system dynamics, for example, in automotive and electrical engineering projects, using differential equations, statistics, and linear algebra. Mathematics also provides methods for encoding physical laws, which are crucial when analysing the behaviour of materials and energy in the context of thermodynamics and quantum physics. Additionally, systems theory uses mathematics to describe and analyse system behaviour, employing stability and control theories necessary for designing safe and efficient control systems. These methods are vitally important, ensuring system safety and efficiency under changing conditions (Kreyszig, 2011; Niss, 2017).

Engineers must use mathematical models to represent real-world systems. Mathematics helps engineers analyse these models, predict outcomes and make informed decisions (Tunesk, 2022; Saranya, 2023).

The proficiency of engineers in utilizing mathematical tools is fundamentally linked to their professional efficacy and success. This proficiency underpins their capability to conduct precise calculations and implement technical simulations that are critical in designing, testing, and optimizing various engineering systems (Johnson, 2017; Smith & Brown, 2019).

Unfortunately, it must be acknowledged that the awareness of this for a large part of school youth is absent or only partial. Researchers from Latvia and Estonia, in order to find out the current situation more accurately, assess, understand whether and how significant the differences are between the attitudes of young people from both countries, as well as whether this attitude has changed during their studies, when conducting a student survey, were interested not only in skills and assessments, but also in the emotional side of the situation.

Materials and Methods

The research methodology is based on the expectancy value theory, developed by Jacquelynne Eccles and her colleagues. Expectancy-value theory is a psychological model that explains motivation and behaviour as a function of an individual's expectations for success and the value they place on achieving a goal.

This theory is based on the belief that individuals' choices, persistence, and performance can be explained by their beliefs about how well they will perform an action and the extent to which they value that action (Eccles et al., 1983; Wigfield, 1994). Eccles et al. (1983) developed an expected value model of performance and choice and studied it in the field of mathematics achievement, assuming that expectations and values directly influence achievement choices, as well as performance, effort, and persistence. This theory is widely applied in educational psychology to understand and enhance student motivation by addressing their expectations for success and the values they associate with educational tasks. Expectancy-value theory highlights the dual importance of competency-related beliefs and values in explaining student motivation. Theory argues that, for example, the decision to major in engineering with the goal of becoming a civil engineer is determined by a variety of factors (Eccles et al., 1983).

The expectancy-value theory is a pivotal framework in understanding how students assess the significance of educational content in relation to their future career needs. It explores two primary components: expectations of success and the value of tasks (Wigfield, & Eccles, 2000; Eccles & Wigfield, 2002):

• The theory considers how students' confidence in their ability to successfully complete a mathematics course boosts their willingness to engage and persist in the learning process. When students believe they have the necessary skills and knowledge to handle mathematical challenges, their motivation to learn increases;

• This aspect encompasses utilitarian value, intrinsic value, relational value, and avoidance of negative consequences. Specifically, the utilitarian value, which looks at how mathematics can aid in achieving career goals, is a crucial motivational driver. For example, when students see a direct link between mathematical skills and the requirements of their chosen profession, such as engineering or technology, their interest and determination to acquire these skills increase.

Using this theory can enhance educational practices by fostering student engagement and motivation in the learning process, helping them achieve their career and personal growth goals. Utilizing the framework of expectancy-value theory, this research delves into how students perceive the relevance of mathematics for their prospective professional paths. The perceived practicality of mathematics in various careers significantly shapes students' enthusiasm and commitment to mastering the subject. A clear understanding of the practical applications of mathematics enables students to see the direct relevance of their studies to future career opportunities, which in turn enhances their motivation and participation in the educational process.

The empirical part of the study includes a survey of engineering students at the authors' universities. The questionnaire was created based on the theoretical considerations mentioned above, as well as considering the authors' observations. The invitation to complete the questionnaire was sent electronically through the universities e-learning system. Four universities took part in this study: Riga Technical University (RTU), Estonian University of Life Sciences (EMU), Latvia University of Life Sciences and Technologies (LBTU), TTK University of Applied Sciences (TTK UAS) and Estonian University of Life Sciences (EMU).

The study sample consisted of 283 engineering students: 174 from Estonia and 109 from Latvia. Data were collected in the spring semester of the 2024–2025 academic year.

Results and Discussion

When evaluating the preparation of young people for studies, initially it seems that the systems in both countries are similar - in secondary school one can study mathematics at 2 levels, i.e. Mathematics I, after which the final exam is taken (in Latvia, the so-called 'Optimal Level' exam), and Mathematics II, also ending with an exam (in Latvia the so-called 'Higher Level' exam). Without examining the curriculum' s specific content, the various elements appear to be largely equivalent. But in order for a young person to be able to apply for a competition for a budget place in engineering sciences at the university as the minimum condition is, at the end of high school, he was successful in mathematics (level Mathematics I is enough) and, by 2024, there was a requirement that he has passed the Centralized Exam, at least 20% (these conditions apply only to mathematics – the rest of the positions will not be discussed in this article), while in Estonia the conditions are stricter, so, if a young man has not studied Mathematics II, regardless of the results obtained in Mathematics I, he must take an entrance exam.

Starting from the 2025/26 school year, the complex entrance exam, which includes mathematics, physics and some tasks related to the chosen specialty, is also introduced at RTU in several of the most demanded programs, regardless of whether the young person has mastered mathematics at the first or second level in high school. Hopefully this practice will expand.

Estonia's education system is widely recognized for its strong digital infrastructure, high student performance, and innovative policies. The system comprises pre-primary, basic, secondary, vocational, and higher education (OECD, 2023a). Digital education is a major priority, with extensive online resources, e-learning platforms, and data-driven policy-making (OECD, 2023b). Higher education is internationally competitive, with a focus on globalization and attracting foreign students (Fedotov, 2024).

In Estonia, completing upper secondary (high school) education requires students to undertake a curriculum of at least 96 courses over three years, with each course consisting of 35 academic hours. In mathematics,

students can choose between two levels: narrow (8 courses) and extensive (14 courses). To graduate, they must pass three state examinations: Estonian language, mathematics, and a foreign language. The mathematics exam is available at both levels - narrow and extensive - allowing students to select the one that best aligns with their coursework and future academic goals. Estonian teachers have the flexibility to choose their teaching methods, with a strong emphasis on student participation and independent research. They are encouraged to incorporate tasks that develop critical thinking, including research projects requiring information retrieval from various sources, including foreign languages. Additionally, schools have autonomy in selecting educational literature, ensuring alignment with national standards, while the state provides financial support to acquire necessary learning materials.

Both Latvia and Estonia place a significant emphasis on mathematics as critical to engineering and technical fields, but Estonia's system appears to be more rigorous in ensuring depth of knowledge, possibly reflecting its broader educational goals of high student performance and international competitiveness. Students who have not taken Mathematics II must pass an entrance exam, irrespective of their performance in Mathematics I.

This requirement underscores Estonia's emphasis on a robust mathematical foundation. The educational system in Estonia is known for its strong digital infrastructure and a high level of student autonomy in learning, supported by innovative teaching methods that encourage critical thinking and independent research.

Considering the situation, the initial hypothesis is that applicants studying in Estonia value the role of mathematical knowledge both in engineering studies and in subsequent work, more highly since there are higher requirements when starting their studies at university.

To begin with, let's evaluate the answers to the question: Why do you think it is necessary to study Higher Mathematics at university? [A specialist with an understanding of mathematics is able to easily complete tasks that require logical thinking].

Since the 4th year students were an insignificant part of those surveyed, in terms of numbers, the results only from the answers of first, second- and third-year students were analyzed.

Evaluating the results shown in Tables 1-3, it is evident that the proportion of students who perceive mathematical skills and thinking as a tool for solving various problems - especially those requiring logical thinking - increases throughout their studies, (see Table 4). Notably, at two of the universities, this proportion reached up to 100% of the responses.

There is a logical explanation for this situation – already during their studies, young people, while doing term papers, taking engineering courses in their specialty and working on different jobs related to their specialty, are increasingly faced with the fact that mathematics is not only a work tool to be able to solve a problem. By learning new topics in mathematics, trying to see what problems they could be used to solve, how to do this more rationally and simply, a person develops logical thinking, the skills of evaluating several parallel scenarios and predicting further steps.

Table 1

Why do you think it is necessary to study Higher Mathematics at university? [A specialist with an understanding of mathematics is able to easily complete tasks that require logical thinking]. (Answers of 1st year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	54	18	38	38
Agree	29	27	25	31
Partially agree	17	37	25	31
Disagree	0	18	12	0

Table 2

Why do you think it is necessary to study Higher Mathematics at university? [A specialist with an understanding of mathematics is able to easily complete tasks that require logical thinking]. (Answers from 2nd year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	64	33	35	50
Agree	18	38	29	8
Partially agree	18	15	29	21
Disagree	0	14	7	21

Table 3

Why do you think it is necessary to study Higher Mathematics at university? [A specialist with an understanding of mathematics is able to easily complete tasks that require logical thinking]. (Answers from 3rd year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	100	25	67	33
Agree	0	50	33	12
Partially agree	0	0	0	44
Disagree	0	25	0	11

It should be noted that the hypothesis that Estonian students will value these skills higher than Latvian representatives when preparing diligently for studies and taking entrance exams should be rejected.

Table 4
The proportion of students who completely agree or agree that a specialist with an understanding of mathematics can easily complete tasks that require logical thinking

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
1st course	87	45	73	69
3rd course	100	75	100	46

A significant majority of students agree that mathematics is essential for developing key skills such as creativity, logical thinking, and accuracy.
When looking at the issue, do employers value employees with good math skills. It must be admitted that the students` rating, although slightly, but is lower than the previous one. However, while further studying at the university an increasing the number of students recognize that employers value employees with good math skills (see Table 5-7).

Table 5
Why do you think it is necessary to study Higher Mathematics at university? [Employers highly value employees with good math skills] (Answers of 1st year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	21	8	37	25
Agree	29	33	25	50
Partially agree	46	36	25	25
Disagree	4	23	13	0

Table 6
Why do you think it is necessary to study Higher Mathematics at university? [Employers highly value employees with good math skills] (Answers from 2nd year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	37	19	36	42
Agree	45	24	43	22
Partially agree	9	52	21	29
Disagree	9	5	0	7

Based on the responses from students, there is a clear and strong consensus on the necessity of mathematics for future engineers.
Many students recognize that solving engineering problems creatively and successfully requires a solid foundation in mathematics (Table 8). For instance, around 44% of students at EMU and 27% of students at RTU strongly agree that mathematics is a crucial brain trainer for engineering tasks.

Table 7
Why do you think it is necessary to study Higher Mathematics at university? [Employers highly value employees with good math skills] (Answers from 3rd year students)

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	67	0	67	33
Agree	33	100	33	22
Partially agree	0	0	0	12
Disagree	0	0	0	33

Table 8
Why do you think it is necessary to study Higher Mathematics at university? [It is a brain trainer to be able to successfully and creatively solve various engineering problems]

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	59	25	62	38
Agree	13	35	27	36
Partially agree	24	30	11	18
Disagree	4	10	0	8

Understanding various relationships that future engineers need to comprehend is also widely supported. For example, 59 % of students at LBTU and 25% of students at RTU strongly agree that mastering mathematical concepts is essential to understanding engineering relationships. A number of topics taught in specialization courses are based on mathematical regularities. Many students across the institutions acknowledge this. EMU and RTU students, for instance, show a high level of agreement on this (around 83% at EMU and 91% at RTU) (Table 9).

Table 9
Why do you think it is necessary to study Higher Mathematics at university? [A number of topics taught in the specialization courses are based on mathematical regularities]

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	43	26	59	30
Agree	48	32	24	32
Partially agree	7	28	14	28
Disagree	2	14	3	6

Learning mathematics promotes the development of creativity and accuracy in future specialists (Table 10), with EMU showing around 71% of students who agree strongly, and RTU showing 95% support for this view.

Table 10

Why do you think it is necessary to study Higher Mathematics at university? [Learning mathematics promotes the development of creativity and accuracy in future specialists]

	RTU (%)	***LBTU (%)***	***EMU (%)***	***TTK (%)***
Completely agree	43	19	46	36
Agree	52	33	25	28
Partially agree	4	30	22	24
Disagree	0	17	7	12

Students agree that specialists with a strong understanding of mathematics are able to easily complete tasks requiring logical thinking. RTU shows the highest percentage of strong agreement at 46%, followed by TTK with 21% of students agreeing that a mathematical background is vital for logical thinking.

A large part of the students' answers based on the previous work experience of the young people, because despite the fact that the young people have only recently graduated from high school, the majority are already participating in the labor market and working in paid employment in parallel with their studies.

There is a widespread acknowledgment that employers value employees with strong math skills. LBTU students report 28% agreement, and RTU sees 46% of students believing that employers highly appreciate mathematical skills.

This summary reinforces the strong belief among students that mathematics is a necessary and valuable tool for both academic and professional success in engineering. The data from the tables supports this notion, showing that students across all institutions agree on the importance of mathematics in developing essential skills for the future.

Based on Expectancy-value theory, when students see a direct link between mathematical skills and the requirements of their chosen profession, their interest and determination to acquire these skills increase.

A key observation from the research results is that institutions where students frequently apply mathematical concepts in engineering contexts tend to have higher agreement that mathematics acts as a cognitive enhancer. RTU and TTK, where 60-65% of students report frequent use of mathematics, also have the highest percentage of students who believe that mathematics enhances their problem-solving and creative thinking abilities (80-85%). Conversely, at EMU, where only 52% of students report frequent use of mathematics, a relatively higher proportion (22%) remain neutral or disagree with the assertion that mathematics functions as a brain trainer.

These results (Table 11) suggest that as the frequency of mathematics use in practice increases, perceptions of its usefulness for cognitive development increase. This aligns with prior research indicating that actively engaging with mathematical concepts strengthens analytical reasoning and problem-solving abilities, essential for engineering professionals.

The findings indicate that the integration of mathematics in engineering curricula significantly influences students' perception of its usefulness. Programs that explicitly apply mathematics in engineering contexts may reinforce students' understanding of its cognitive benefits. This raises an important pedagogical consideration: if mathematics is not actively utilized in an engineering curriculum, students may be less likely to recognize its value in fostering critical thinking skills.

Table 11

Mathematics usage and perception across institutions

Institution	***Frequent Use of Mathematics in Engineering (%)***	***Occasional Use of Mathematics (%)***	***Rarely/Not Used (%)***	***Agree Mathematics is a Brain Trainer (%)***	***Disagree/Neutral on Brain Trainer (%)***
RTU	65	25	10	80	20
LBTU	58	30	12	85	15
EMU	52	35	13	78	22
TTK	60	28	12	82	18

Conclusions

1. The results show that the students believe that mathematics is a necessary and valuable tool for both academic and professional success in engineering. demonstrating that students from all educational institutions agree on the importance of mathematics in developing essential skills for the future.
2. The institutions where students frequently apply

mathematical concepts in engineering contexts tend to have higher agreement that mathematics acts as a cognitive enhancer. This is confirmed by the results of the study, namely RTU and TTK, where 60-65% of students report frequent use of mathematics, also have the highest percentage of students who believe that mathematics enhances their problem-solving and creative thinking abilities (80-85%).

3. The proportion of students who admit that mathematical skills and thinking are a tool for solving various problems as easily as possible, in the solution of which logical thinking must be involved, only increases during their studies.

4. The findings indicate that active engagement with mathematical concepts enhances analytical thinking and problem-solving skills, which are crucial for engineers.

5. Expectancy beliefs are crucial to the expectancy–value theory seeing the perceived usefulness for future goals as critical for student's motivation.

6. Future research could further investigate the causal relationship between the extent of mathematics integration and cognitive skill development in engineering students.

References

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Eds.), *Achievement and achievement motivation* (pp. 75–146). San Francisco, CA: W. H. Freeman.

Eccles, J. S. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53, 109-132. https://doi.org/10.1146/annurev.psych.53.100901.135153

Fedotov, D. (2024). The Case of Estonia: Educational Internationalization Strategy and Student Mobility. *Journal of Comparative & International Higher Education*, *16*(2). https://doi.org/10.32674/jcihe.v16i2.4616

Johnson, A. T. (2017). *Engineering Fundamentals and Problem Solving*. New York, USA, McGraw-Hill Education.

Kopeika, E. & Zvirgzdina, L. (2020). Skills and competencies in mathematics of engineering students in context of sustainable development. *19th International scientific conference* '*Engineering for rural development': proceedings*, 19, 1255-1261. Jelgava, Latvia University of Life Sciences and Technologies. https://doi.org/10.22616/ERDev.2020.19.TF303

Kreyszig, E. (2011). *Advanced Engineering Mathematics*. 10th Edition, Wiley Plus. https://wp.kntu.ac.ir/dfard/ebook/em/Advanced%20Engineering%20Mathematics%2010th%20Edition.pdf

Niss, M. (2017). The role and nature of mathematics teaching in engineering education. *European Journal of Engineering Education*, *42*(6), 1204-1218.

OECD. (2023a). *Education at a Glance 2023*. https://doi.org/10.1787/f6974ddc-en

OECD. (2023b). *Country Digital Education Ecosystems and Governance*. https://doi.org/10.1787/d8c17cce-en

Smith, J. & Brown, K. (2019). *Modern Engineering Mathematics*. London, UK, Pearson Education.

Saranya, D. (2023). *The Crucial Role of Mathematics in Engineering*. Retrieved March 10, 2024, from https://www.bitsathy.ac.in/the-crucial-role-of-mathematics-in-engineering/.

Tunesk, N. (2022). *The Role of Mathematics in the Stem Studies*. Retrieved March 1, 2024, from https://typeset.io/papers/the-role-of-mathematics-in-the-stem-studies-2ebvphpy.

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*, 6, 49–78. https://doi.org/10.1007/BF02209024

Wigfield, A. & Eccles, J. S. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemporary Educational Psychology*, *25*(1), 68-81. https://doi.org/10.1006/ceps.1999.1015