# OVERCOMING MATHEMATICAL ANXIETY TO PROMOTE PROGRESS IN MATHEMATICS DURING UNDERGRADUATE ENGINEERING STUDIES AT UNIVERSITY

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**Abstract.** Mathematics (math) is one of the logical and practical academic disciplines, which is one of the basic competencies in engineering. Despite that, some students have difficulty to learn math, which is determined by several cognitive and emotional factors. Math anxiety is one of the emotional factors that causes learning difficulties in math. Many students experience anxiety, fear, tension, or discomfort when faced with math, what affect students' achievement. Math anxiety can be caused by several factors: lack of appropriate math knowledge, learning strategies, application of math in real life, limited exam time, lack of specific materials as well as personality type, lack of confidence, and stereotypes related to math. It is already proved, that achievement in math increases when anxiety is controlled. Therefore, to promote progress in math during engineering studies at university, the aim is to identify the most important factors that cause mathematics anxiety, as well as existing experiences in overcoming them. To develop the methodology of this study, a study of the scientific literature on math anxiety is performed, considering the above-mentioned math learning difficulties. In the case of math anxiety three factors are analysed: student's prior mathematical experience as well as learning strategies at pre-university and university education level. The article looks at three approaches to learning math that are commonly used by students in their studies of math at university: (1) The use of ICT tools and math software to understand the concepts of math and solve independent work tasks; (2) The link between teaching of math and real/ everyday life; (3) Cooperative learning during additional math classes. The effectiveness of these approaches is characterised using the data from the quality monitoring of the math study process at the authors' universities and students' survey results as well as math teachers focused interviews.

**Keywords:** mathematical anxiety, mathematics learning difficulties, math software, collaborative learning.

## Introduction

Good math skills are essential for all engineering students, as maths is widely used in everyday engineering study and practice to solve complex real-world tasks and find the most appropriate technological solutions. Studying math at university develops a person's cognitive abilities, influences the study of special subjects, and contributes to the development of professional competence, providing highly qualified specialists for knowledge-based, skills and technology-intensive industries. Despite this, the maths skills of young people entering university are getting worse year on year, and maths is one of the reasons why young people drop out. In this article, the authors explore the reasons for this by focusing on a learning difficulty such as mathematical anxiety. This is a topical issue in the context of the impact of the Covid-19 pandemic, which caused stress, anxiety, social isolation and loneliness among young people [1].

The term 'mathematical anxiety' is described as a fear of math or as a negative emotional response (fear, tension, and apprehension) to math that can be triggered by several factors: lack of appropriate mathematical knowledge, learning strategies, application of math to life, limited time for test papers, lack of specific materials, as well as personality type, lack of confidence, and stereotypes related to teachers' and parents' approach to math [2-5].

Math anxiety is worry or fear about solving math problems. It is not a distinct medical condition, but the emotional factor that causes learning difficulties in math [6]. If a student feels fear of doing math, he or she overwhelms working memory that allows to remember and think about several things at the same time. Studies on this matter show that perhaps when people feel anxious, the math anxiety they experience consumes some of their working memory, so they do not have enough working memory to solve the maths problem [7]. If students cannot fully use their working memory, it can make it difficult to perform math and leads to a misconception that they are bad at math [8].

Math anxiety can occur at all levels of education, from primary school to university. It has a negative impact on individuals, as many students who suffer from math anxiety have low confidence in their math abilities and usually struggle to complete the math course. It has already been shown that

math achievement increases when anxiety is controlled [9]. Students' performance can improve and the use of certain strategies can significantly facilitate learning mathematics, such as appropriate teaching methods, suitable visual and learning materials and active participation, the use of information communication technologies, etc. Therefore, to promote progress in math during engineering studies at university, the aim of this is to identify the most important factors that cause math anxiety, as well as existing experiences in overcoming them.

**Materials and methods**

To develop the methodology of this research, a study of the scientific literature on math anxiety is performed, considering the above-mentioned math learning difficulties and focusing on factors that may contribute to or facilitate the math anxiety.

Based on the authors' long experience, students who are bad at math say they do not like math. Educational research shows that there is a negative correlation between prior mathematical likes/dislikes and self-assessment of math ability [10]. Self-assessment helps students identify their strengths and weaknesses in math. The higher the student values his knowledge in mathematics, the higher the self-assessment of math competence [11].

There is also coherence of students' mathematical competence with self-esteem of learning experience and attitude. When students become aware of themselves, math anxiety and its consequences, their ability to cope can increase [12]. The teacher plays a key role here, making lessons more attractive and using different teaching strategies which reduce anxiety not to portray math as difficult and incomprehensible. It is necessary to create a learning environment in which students can develop a positive attitude towards math thus reducing math anxiety [13]. It has also been shown that making mistakes in front of peers can also cause embarrassment or feelings of inferiority, which can develop into math anxiety [14].

There are some strategies that can help reduce math anxiety. For example, using tests that are not timed or graded; giving immediate feedback; demonstrating the application of maths to real-life situations rather than pure maths can reduce anxiety [15]. Cooperation, implemented through collaborative learning, also reduces anxiety and develops positive attitudes [16].

At university, math classes often cover a lot of material in a short amount of time. Due to poor math background, students often cannot keep up. To promote progress in math studies, very often different software or materials on the Internet are used. They are used not only to complete individual homework, but also to understand math concepts that seem incomprehensible. And nowadays, when technologies are developing rapidly, their range is abundant.

Based on the theoretical considerations mentioned above, a questionnaire was created (available at: https://forms.gle/ZHA4aigi1ibDxmfe6). This questionnaire involved 112 engineering students who responded at the Latvia University of Life Sciences and Technologies and 87 engineering students at the Estonian University of Life Sciences. In the questionnaire students had to rate:

1. feelings about mathematics
2. mathematics' learning experience at the pre-university and university level,
3. learning strategies at the pre-university level,
4. the ICT tools and maths software students use to understand maths concepts and solve independent work tasks.

Questions 1, 3, and 4 had these multiple-choice answers: regularly, often, rarely and never. Question 2 had these answer options: strongly agree, agree, disagree and strongly disagree.

For the analysis, descriptive statistics is used while all measured variables are in ordinal scale. Kruskal-Walls test in computer package R, that evaluates differences between groups based on medians, is included in the analysis. When the p-value is less than the significance level 0.05, we can conclude that there are significant differences between the treatment groups and at the same time chi-squared must by positive. The higher the chi-squared value, the more significant is the difference. What groups are different is evaluated with the pairwise Wilcoxon test.

**Results and discussion**

All questions were analysed separately to find out the differences by country. Answers were compared at pre-university level and at university level.

Feelings about mathematics (Table 1). Pre-university level 44% of students chose the answer for the first question that they have often easily felt frustrated when completing a math problem. Regularly frustrated are 29% of Estonian students, while 34% of Latvian students are rarely frustrated by math problems. To the second question 45% of Estonian students answered that they often feel nervous before a test or task and 35% students answered that they feel it rarely. Most of Latvian students (42%) never feel nervous before tests. The answer to the third question was similar for Estonian and Latvian students that half of them are rarely determined and persistent while completing their math tasks. To the fourth question, 52% Estonian students answered often and 20% regularly that they feel humiliated for not being able to keep up, whereas 43% Latvian students had the same feelings often and 29% regularly.

When comparing all four questions by country the test results show these differences: Q1 (chi-squared = 7.9839, p-value = 0.004), Q2 (chi-squared = 21.51, p-value = 0.000), Q3 (chi-squared = 6.0701, p-value = 0.013) and Q4 (chi-squared = 9.1344, p-value = 0.0025).

The university level answers to questions Q1 and Q3 are similar. Q2 and Q4 are answered differently. To the second question 34% of Estonian students answered that they feel often nervous before test or task and 42% students answered that they feel it rarely. Latvian students (42%) are never feeling nervous before test and 36% are feeling rarely. For that question the test shows a difference (chi-squared = 6.0701, p-value = 0.0137). The fourth question was answered by 38% Estonian students often and by 28% rarely that they feel humiliated for not being able to keep up when the same feelings are felt by 33% Latvian students often and by 35% regularly. The test result is (chi-squared = 9.1344, p-value = 0.0025). Frustration with math problems and persistence while completing math tasks has not changed before and during university. Nervousness before math tasks and feeling humiliated for not being able to keep up has changed.

Table 1

**Questions that needed to be rated of feelings about mathematics**

| | |
|---|---|
| **Q1.** Did you get easily frustrated, or unnaturally upset? | **Q3.** Were you determined and persistent while completing your math tasks? |
| **Q2.** Did you present nervousness or agitation before facing an assessable test or task? | **Q4.** Did you feel humiliated for not being able to keep up? |

Learning experience. Pre-university level 31% of Estonian students and 46% Latvian students waited for math lessons and respectively 44% and 37% of students did not wait for it, and half of students in both countries liked math (chi-squared = 13.075, p-value = 0.0002). Students who like math were in Estonia 14% and in Latvia 21%. In both countries, 60% of students think that math content is boring. In Estonia 12% and in Latvia 24% of students assess that the math content is not boring and incomprehensible (chi-squared = 15.541, p-value = 0.0000). Almost 50% of students in both countries thought that the pace was too hurried and a third estimated the opposite. Half of students thought that there was a lack of diversity in teaching and opposite opinion was from 28% of Estonian students and from 34% of Latvian students. The same percentages are in student's answers, "the first thought was that I cannot solve the task" and "I did not understand most math concepts that I studied".

University level 41% of Estonian students and 46% Latvian students waited for math lessons and respectively 34% and 38% of students did not wait for it, and not liking math was half of students in both countries. University mathematics content seemed boring for 47% of students in Estonia and 57% of students in Latvia. The opposite opinion had 26% of students in Estonia and 24% in Latvia. A third of students in both countries thought that the pace was too hurried. Mostly students estimated that the pace was not too hurried, respectively 41% and 36%. "There was a lack of diversity in teaching", 50% of Estonian students and 58% of students in Latvia thought so. Disagreement was respectively by 26% and 21% of students. A third of students in both countries had the first thought that they cannot solve the task and the same percentage of students had the opposite opinion. Math concepts that they studied are not understandable by 44% of students and 27% disagree with that, and 20% strongly disagree.

When comparing the questions by country with the test the differences are for Q7 (p-value = 0.008), Q8 (p-value = 0.0000) and Q10 (p-value = 0.0008).

Table 2

**Questions that needed to be rated about mathematics learning experience**

| | | | |
|---|---|---|---|
| **Q5.** I waited for math lessons | **Q7.** The content of school mathematics seemed boring and incomprehensible | **Q9**. There was a lack of diversity in teaching | **Q11**. I did not understand most math concepts that I studied |
| **Q6.** I did not like math | **Q8.** The pace was too hurried | **Q10.** The first thought was that I cannot solve the task | - |

Learning strategies at the pre-university level. Students' opinion in Estonia and Latvia is different (respectively 21% and 44%) for Q12 and opposite opinions are for respectively 42% and 35% of students. It seems in Estonia the teacher can vary the teaching process more. In Latvia 35% of students and in Estonia 22% of students agree to Q13. Disagreeing to Q13 are 53% of students from both countries. It is very clear proof that the teacher has no time to repeat the topic again with same level tasks. Also 47% of students in both countries disagree that the teacher gave a summary of the recent content. A third of students agree with that question. In Estonia 16% of students strongly agree, in Latvia it was only 8%. That shows how differently the teachers work. Half of students in both countries disagree and 21% in Estonia and 14% in Latvia strongly disagree that the teacher gave immediate feedback when students worked at lessons. With this agreed respectively 23% and 33%. Currently, the classes are large, and the teacher cannot monitor everyone during the lesson.

Table 3

**Questions that needed to be rated about learning strategies at the pre-university level**

| | |
|---|---|
| **Q12.** The teacher gave different work to the students who have difficulties learning and/or to those who can advance faster | **Q14.** The teacher gave a summary of the recent content |
| **Q13.** The teacher let us do similar tasks until we understood everything | **Q15.** When we worked on particular tasks, the teacher observed us and provided immediate feedback |

ICT tools and maths software. Most often students of both countries (in Estonia 38% and in Latvia 45%) answered that they use rarely lecture recordings in e-studies and never use respectively 24% and 33%. Regularly 13% and 6% of students use respectively. The test shows the difference by country (chi-squared = 5.4846, p-value = 0.01918). The percentages are quite similar for Q17 as well. The students like to watch video tutorials online, 44% of Estonian and 37% of Latvian students do that often and regularly do this respectively 17% and 21% of students. However, respectively 13% and 23% of students never do this. The students use materials from other universities regularly 21% of students in Estonia and 22% in Latvia and often respectively 31% and 42% of students. About 10% use never. In Estonia only 10% of students use regularly specific math software (except Matlab / Mathcad) when in Latvia 29% do and often use respectively 28% and 31% of students. Never use 33% in Estonia and 13% in Latvia. There is a statistically significant difference by country (chi-squared = 15.462, p-value = 0.0000).

Table 4

**What ICT tools and maths software do you use to understand maths concepts and solve independent work tasks?**

| | | |
|---|---|---|
| **Q16.** I use lecture recordings / study materials in e-studies | **Q18.** I look for video tutorials online (YouTube, etc.) | **Q20.** I use specific math software (except Matlab / MathCad) |
| **Q17.** I learn from the problem-solving examples in e-learning | **Q19.** I use materials from other universities available on the Internet | - |

Students use math software MathCad for math studies in Estonia and in Latvia Matlab. Only a third of students use different math software like Photomath, Desmos, Geogebra, Symbolab, Wolfram Alpha in addition and some of them use also Excel and only calculator. Many students use nothing.

The second approach most commonly used in the authors' universities is collaborative learning which is most often used during additional math classes. Collaborative learning is defined as "the instructional use of small groups so that students work together to maximize their own and each other's learning" [17]. According to Swan, learning is a collaborative activity in which learners are challenged and arrive at understanding through discussion [18]. Usually, students work in groups of two or more, mutually searching for understanding, solutions or meanings, or solving independent homework, as well as exploring the application of the course material. When students study together, there is a direct and immediate picture of how they learn and what experiences they use.

According to Golubs, a key feature of cooperative learning is talking: "students are supposed to talk with each other....and it is in this talking that much of the learning occurs" [19]. Collaborative learning creates intellectual synergy between many minds working on a problem. It is this mutual exploration, meaning-making, and feedback that often leads to better understanding of math concepts.

A significant benefit of collaborative learning is that group students get to know each other in teams and expand their activities outside of class. Students contact each other for help with questions or problems they have, and often continue to communicate outside the math course [16].

## Conclusions

1. The feelings about mathematics are different in Estonia and Latvia. Latvian students are rarely frustrated by math problems whereas Estonian students are regularly frustrated. Also, Latvian students feel less nervous than Estonian students before math tests.
2. Frustration with math problems and persistence while completing their math tasks has not changed before and during university. There are the same percentages who like math and wait for a math lesson and who do not like math.
3. Pre-university level students estimated "that math content is boring" more than at the university level. Half of students assessed that the pace was too hurried in both levels.
4. Currently, the classes are large and the teacher cannot monitor everyone during the lesson and cannot give tasks with different levels. MathCad is used for math studies in Estonia and Matlab in Latvia.
5. In both universities, the two main approaches to reducing anxiety and developing positive attitudes towards math are the use of information technology and collaboration through collaborative learning.

## Author contributions:

Conceptualization, A.V.; methodology, E.A. and A.V.; software, E.A.; validation, E.A. and A.V.; formal analysis, E.A. and A.V.; investigation, E.A. and A.V.; data curation, E.A. and A.V.; writing – original draft preparation, E.A. and A.V.; writing – review and editing, E.A. and A.V.; visualization, E.A.; project administration, E.A.; funding acquisition, E.A. All authors have read and agreed to the published version of the manuscript.

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