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Identifying Strengths and Weaknesses in Mathematics Learning: An Analysis of Exam Preparation Course Outcomes

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In Estonia, upper secondary school students are required to take national examinations in Estonian, mathematics, and a foreign language. To support exam readiness, a free 20-week mathematics preparatory course was offered to all interested students. The course concluded with a final test covering key curriculum topics. This study analyzes the test results to identify strengths and weaknesses in students' mathematical knowledge. Quantitative analysis was used to assess accuracy across topic areas, and qualitative examples illustrate frequent and critical errors. Topics such as algebraic manipulation and basic functions were generally well understood, whereas geometry proofs and word problems presented greater challenges. Common errors included misinterpreting problem statements, calculation mistakes, and incomplete reasoning in open-ended tasks. Results are compared with patterns from previous years' national exam statistics to evaluate the course's alignment with exam expectations. While individual exam data are confidential, aggregate comparisons help highlight consistent learning challenges. The study provides practical insights for improving future preparatory programs. It also supports broader educational goals promoted by the Estonian Engineering Academy (INSA), which funded the course and works to increase university applicants and reduce dropout rates by strengthening foundational skills in STEM education.

Keywords: *mathematics education, national exams, student performance analysis, error patterns, exam preparation*

Introduction

The mathematics national examination is one of the three compulsory final exams that upper secondary school students in Estonia must take. The aim of these exams is to assess students' knowledge and skills in accordance with the national curriculum and to provide feedback to students, schools, policymakers, and the general public on the effectiveness of teaching and learning. Over the years, mathematics exam results have shown considerable variation, and certain topic areas have consistently posed greater challenges for students.

To support students in preparing for the exam, a free 20-week preparatory course was organized and made available to all interested participants. The course aimed to offer systematic revision of key topics from the national curriculum and to help students better understand complex problems. At the end of the course, students

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completed a final test that included a variety of question types and closely mirrored the structure of the national examination.

The purpose of this study is to analyze the results of the final test to identify which mathematical topics were better mastered and which proved more challenging for students. Additionally, the study examines common errors and their possible causes. The results are compared to trends from previous years' national examination data, which are published annually in official overviews by Estonian education authorities (Ministry of Education and Research 2022, 2023, 2024). These yearly reports provide aggregated feedback on exam performance and common problem areas. This study draws on those reports to evaluate the alignment between course outcomes and broader national trends. While individual exam data are confidential and cannot be directly linked to course participants, aggregate patterns allow meaningful comparison.

This study was guided by the following research questions:

1. In which areas of mathematics did participants demonstrate the greatest proficiency, and which topics proved to be the most difficult?
2. What recurring error patterns were observed in participants' responses, and what do these suggest about underlying conceptual difficulties?
3. How do the results of the final test align with or differ from previous national exam trends, and what can be concluded from this comparison to improve the structure of future preparatory courses?

Previous research has explored various factors influencing mathematics exam performance. Scholars at the University of Tartu (Aaviste and Täht 2022) have examined how students' self-perceptions and attitudes relate to outcomes, while researchers at Tallinn University of Technology (TalTech 2025) have studied how mathematics exam results predict later success or dropout in higher education. Similar findings were reported by Kenosi et al. (2024), who found a statistically significant positive correlation between students' attitudes toward mathematics and their performance, based on a study among Form Three students in Botswana. This study complements those efforts by focusing on learning outcomes in the context of a preparatory course, helping to identify the most problematic content areas and typical mistakes.

Several international studies have helped to contextualize the present findings. Greefrath et al. (2017) examined preparatory courses in engineering and computer science education in Germany and concluded that structured participation, both in-person and online, was linked to significantly better academic performance. Fatawu et al. (2023) focused on secondary school students and used Newman's Error Analysis to identify frequent mistakes in solving word problems. Their findings pointed to difficulties in understanding problem statements and translating them into solvable equations, which closely match the patterns observed in this study. Most notably, Lin et al. (2024) conducted a systematic review of mathematical error patterns among students with learning difficulties. They categorized common mistakes into conceptual, procedural, and interpretive types, providing a valuable framework that aligns well with the types of errors identified here. Together, these studies show that the challenges observed in this preparatory course reflect wider issues found across different educational contexts.

Despite strong interest in national mathematics exam preparation, dropout rates from voluntary courses remain high, and it is unclear which content areas cause the most difficulty or what types of mistakes students most often make. There is also a lack of data on how such preparatory efforts align with national exam trends. This study addresses these gaps by analyzing student performance in a structured preparatory course and identifying both strengths and recurring challenges. The findings aim to inform future course design and contribute to broader discussions on how to improve mathematics readiness among upper secondary students.

In addition to its educational aims, the course also served broader strategic objectives aligned with national STEM priorities. It was supported by the Estonian Engineering Academy (INSA), a national cooperation initiative involving the government, universities, industry, and professional associations. INSA aims to enhance the quality of engineering education, ensure an adequate supply of qualified professionals, and raise interest in STEM fields. Its key goals include increasing the number of university applicants, improving the relevance of higher education to labor market needs, and reducing dropout rates. By providing evidence-based insights into how preparatory programs can strengthen foundational skills and improve exam readiness, this study contributes directly to those goals.

Materials and Methods

In November 2024, a free online preparatory course for the Estonian national mathematics examination was launched at the Estonian University of Life Sciences, supported by the Estonian Engineering Academy (INSA). The course was open to all individuals interested in strengthening their upper secondary school mathematics skills in preparation for the national exam. A total of 470 participants from across Estonia registered for the 20-week course, which was delivered once a week in an online format.

While registration numbers were high, the subsequent analysis in this study is based solely on the 78 participants (16.6%) who chose to complete the final test at the end of the course.

The course curriculum was designed to systematically cover all major topic areas included in the national upper secondary mathematics syllabus. These topics were: Expressions and number sets; Equations and systems of equations; Inequalities and Trigonometry I; Trigonometry II; Vectors in the plane and linear equations of curves; Probability and statistics; Functions and numerical sequences; Exponential and logarithmic functions; Trigonometric functions, limits and derivatives; Applications of derivatives; Integration and planar geometry; Lines and planes in space; Solid geometry; Applications of mathematics in real-world processes.

The final written test resembled the structure and content of the national examination and was completed on paper in person at the university. Tasks were selected to ensure coverage of the full curriculum. Of the 78 test-takers, 27 were male and 51 female; 66 were current upper secondary school students (abiturients), and 12 were graduates from previous years. The average score achieved was 37.3 out of a maximum of 100, with scores recorded in whole numbers. All test submissions were anonymized prior to analysis.

Descriptive statistics were used to assess performance across different topic areas. In addition, qualitative analysis was conducted to identify and categorize common errors, misconceptions, and incomplete reasoning. The results were compared with national trends based on summary reports of previous years' mathematics examinations published by the Estonian Education and Youth Board.

As participation in both the course and the final test was entirely voluntary, the results may reflect a self-selected group of more motivated or confident learners. Therefore, the findings may not be fully generalizable to the broader population of upper secondary students.

Results

A total of 470 individuals registered for the preparatory mathematics course, of whom 189 (40.2%) were male and 281 (59.8%) female. Among all registrants, 278 (59.2%) were final-year upper secondary school students (abiturients), while 114 (24.3%) were graduates from previous years. Demographic information was unavailable for 78 individuals, either due to incomplete registration data or because they did not provide their background details.

Table 1 presents the demographic composition of all 470 registered course participants.

Table 1. *Participant Distribution by Category and Gender*

	Male	Female	Total	Share of total (%)	Male (%)	Female (%)
Graduates	139	217	356	75.74%	39.04%	69.96%
Other	50	64	114	24.26%	43.86%	56.14%
Total	189	281	470	100.00%		

Of all registered participants, 78 individuals (16.6%) completed the final test. Among these test-takers, 27 were male (34.6%) and 51 were female (65.4%). To better understand performance variation, the results were analyzed by gender, year of birth, and student status. The overall average score for the 78 test-takers was 37.3 out of a maximum of 100. These comparisons, including mean values, standard deviations, score ranges, and confidence intervals, are summarized in Table 2.

Gender-based performance showed relatively similar mean values: males achieved an average score of 38.0 (SD = 24.1), while females had a slightly lower mean of 36.9 (SD = 23.6). The score range was wide in both groups, with minimum scores of 2 and maximums of 85 (male) and 90 (female), respectively.

Age-based analysis revealed that participants born between 2000 and 2010 (N = 70) performed better on average (M = 37.9) than older age groups. By contrast, those born between 1980 and 1989 (N = 4) had the lowest mean score (M = 19.0), but this result should be interpreted with caution due to the very small sample size and wide confidence interval.

Student status appeared to be a stronger differentiating factor. Current abiturients (N = 66) had a significantly higher average score (M = 39.3) than graduates from previous years (N = 12, M = 26.3). This suggests that active school engagement may contribute positively to exam readiness.

Table 2. *Final Test Performance by Gender, Birth Year, and Student Status*

		N	Lower CI	Mean Score	Upper CI	Std. Dev.	Min	Median	Max
Gender	Male	27	28,50	38,04	47,58	24,11	2	35	85
	Female	51	30,25	36,88	43,51	23,58	2	31	90
Birth year	1980-1990	4	-10,20	19,00	48,20	18,35	2	14,5	45
	1990-2000	4	17,32	45,00	72,68	17,40	28	42	68
	2000-2010	70	32,22	37,91	43,61	23,90	2	31	90
Graduates	Graduates	66	33,41	39,27	45,13	23,84	4	33,5	90
	Others	12	13,75	26,33	38,92	19,81	2	21	68

As illustrated in Figure 1, the largest group of students (17 individuals) achieved only 11–20 points, followed by 13 students in the 21–30 range and 7 in the 0–10 range. In turn, very few students reached the higher intervals: for example, only two participants scored between 51–60 points, and no one achieved above 90. Although some participants did obtain moderately higher results (up to 85–90 points), the overall distribution shows that most students remained in the lower and middle ranges. This outcome highlights not only the considerable difficulty of the test tasks but also suggests that stronger preparation would be needed to help a larger proportion of learners move into the higher performance bands.

Figure 1. *Distribution of Participants by Score Ranges in the Final Test*

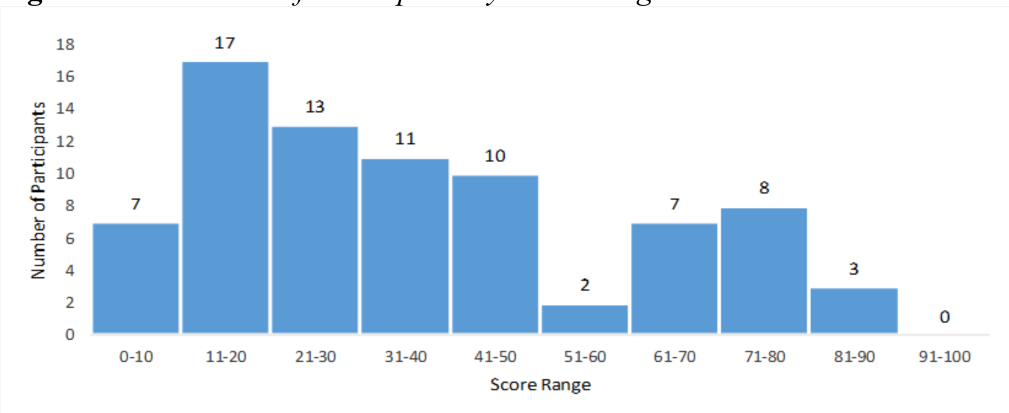

Table 3 presents summary statistics for each task in the final test, including the maximum score, average score, standard deviation, task content, and the percentage of students who did not attempt each task. The results reveal considerable variation in both task difficulty and student engagement, reflecting clear differences in how well participants mastered various mathematical topics. For instance, Task 1, which covered irrational and exponential expressions, had one of the strongest outcomes, with a relatively high average score of 5.8 out of 10 and a very low non-attempt rate of only 2.6%. This indicates that students felt more confident in basic algebraic manipulations compared with other areas.

In contrast, Tasks 8 and 9, involving planimetry, stereometry, derivative applications, and analytical geometry, were clearly the most difficult. They produced the lowest average scores (1.5 and 3.1, respectively) and the highest non-attempt rates (53.9% and 50.0%). Task 2, which focused on word problems, percentages, and systems of equations, also showed weak performance (3.4 on average) and a high non-attempt rate of 44.9%. These figures suggest that many students lacked confidence in setting up equations from verbal statements and struggled to translate real-world contexts into solvable mathematical form.

Table 3. *Summary Statistics of Final Test Tasks, Including Average Scores, Standard Deviations, and Task Engagement Rates*

Task No.	Max Possible Points	Average Score (points)	Standard Deviation	Task Content (Course Topics)	Not Attempted
Task 1	10	5,8	3,6	Irrational expressions (I), exponential expressions (VIII)	2.56%
Task 2	10	3,4	4,2	Word problems (II, XIV), percentage (I), system of equations (II)	44.87%
Task 3	10	6,4	4,2	Inequalities (III), word problems (II), planimetry (XI)	16.67%
Task 4	10	4,8	3,5	Probability theory (VI)	6.41%
Task 5	10	4,8	3,7	Function analysis (VII, IX, X)	16.67%
Task 6	10	2,7	3,4	Arithmetic and geometric sequences (VII)	32.05%
Task 7	10	4,8	4,3	Integral (XI)	21.79%
Task 8	15	1,5	3,6	Planimetry (XI), stereometry (XIII, XVI), derivative applications (X)	53.85%
Task 9	15	3,1	4,8	Analytical geometry (V)	50.00%

Overall, the evidence from Table 3 highlights a consistent pattern: geometry-related and application-heavy tasks were among the most challenging for students, both in terms of performance and willingness to attempt them. This finding emphasizes the importance of strengthening instructional support in these content areas in order to improve exam readiness.

Table 4 provides a more detailed view of how students performed on each task, including average scores by gender, the most common mistakes, and the percentage of non-attempts. The results reveal marked contrasts between tasks, with geometry and multi-step problem-solving questions standing out as particularly difficult. Planimetry and analytical geometry, for instance, had some of the highest rates of skipped tasks, suggesting that these topics caused uncertainty or felt too demanding. In several cases, recurring mistakes pointed to deeper issues with understanding concepts or applying procedures correctly.

Task 1, which dealt with irrational and exponential expressions, had a moderate average score of 5.8 out of 10 (58%). Male students performed slightly better (60.7%) than female students (56.5%), and only 2.6% left the task unanswered. The most common mistakes included misusing product identities, struggling to simplify fractional expressions, confusing exponent base conversions, and losing track when moving from simplification to solving. These errors indicate that many students still have difficulties with basic algebraic skills.

Task 2, focusing on setting up and solving systems of equations, turned out to be one of the most difficult in the entire test. The average score was only 3.4 out of 10 (34%), and 44.9% of participants did not attempt it. This suggests that many either lacked confidence or found the task too complex to approach. Typical errors included difficulties in translating word problems into equations, trouble expressing ratio-based relationships, and incomplete solutions. These patterns highlight the need to strengthen skills in problem interpretation and system-solving strategies.

Slightly better performance was observed in Task 3, involving systems of inequalities, where the average score was 6.4 (64%) and 16.7% left it blank. Nevertheless, frequent issues included unjustified variable selection, misinterpretation of the solution sets, and partial answers that failed to address all components.

Probability (Task 4) produced an average score of 4.8 (48%), and 6.4% of students skipped it. Mistakes often stemmed from confusion between multiplication and addition rules, as well as incorrect use of permutations and combinations, suggesting limited mastery of basic probability concepts.

Function analysis (Task 5) yielded a similar average score of 4.8 (48%), with 16.7% not attempting it. Frequent errors included omitting key steps such as identifying zeros, extrema, and intervals of positivity, as well as incomplete graphs and insufficient explanations. These issues reflect broader challenges in clearly communicating function properties.

Task 6, on arithmetic and geometric sequences, appeared particularly demanding. Students averaged only 2.7 points (27%), and 32.1% left it blank. Errors often included omitting multiplication steps, neglecting geometric sequences, or misapplying formulas, especially for decreasing series, indicating weak procedural fluency in numerical patterns.

Integration (Task 7) produced a moderate average score of 4.8 (48%), with 21.8% non-attempts. Common mistakes involved solving quadratic equations incorrectly when finding intersection points, plotting parabolas inaccurately, omitting parentheses in integrals or antiderivatives, and reversing limits of integration without explanation. These show that students struggled with both the mechanical and conceptual aspects of integration.

Task 8, covering planimetry, stereometry, and derivative applications, was the most difficult overall, with an average of 1.5 (10%) and more than half (53.9%) not attempting it. Errors included neglecting relevant geometric elements (e.g., a semicircle in axial sections) and failing to verify results against problem conditions, pointing to conceptual gaps in spatial reasoning and calculus.

Finally, Task 9, which focused on analytical geometry involving line and circle equations, had an average score of 3.1 (20.7%) and a 50% non-attempt rate. Students often struggled with formulating equations of parallel or perpendicular lines, calculating midpoints correctly, and recognizing the geometric meaning of segment lengths as radii of circles. These difficulties point to gaps in both procedural fluency and spatial understanding.

Table 4. *Task-wise Performance, Gender Differences, Common Errors, and Rates of Non-attempt in the Final Test*

Task no	Max points	Avg Points	Avg %	Gender		Not Attempted (%)	Task content
				Male	Female		
1	10	5,8	58	60,7	56,5	2,6	Irrational expression, exponential expression.
	Did not apply product identities correctly Simplifying a fractional expression involving a sum Did not know how to convert the base of an exponent Incorrectly shifted from simplifying an exponential expression to solving an equation						
2	10	3,4	34	45,6	27,3	44,9	Setting up and solving systems of equations
	Could not translate the word problem into equations Was unable to write a ratio equation between the unknowns Was unable to solve the system of equations						
3	10	6,4	64	71,5	59,8	16,7	Formulating and solving a system of inequalities
	The choice of unknowns was not justified Did not interpret the solution of the inequalities correctly The specific question was not addressed						
4	10	4,8	48	44,8	49,4	6,4	Probability
	Did not solve the subtask requiring the multiplication rule Used the addition rule instead of the multiplication rule Applied permutations instead of combinations						
5	10	4,8	48	45,2	49,8	16,7	Analyzing functions
	Did not write the conditions for identifying zeros, positivity intervals, and extrema Completely lacked explanations Graph was presented incompletely						
6	10	2,7	27	34,1	23,9	32,1	Arithmetic and geometric sequences
	The multiplication resulting in a^2 was omitted in the equation $5a_1 \cdot 11a_1=220$ Did not start solving the geometric sequence problem The formula for the sum of a decaying geometric series was not applied						
7	10	4,8	48	35,9	54,5	21,8	Integral
	Mistake made in finding the intersection points of the lines (error in solving the quadratic equation) Did not plot the parabola in the correct position Missing parentheses in the integrand and the antiderivative Integration limits were swapped and the resulting negative value was not explained						
8	15	1,5	10	9,9	10,5	53,9	Planimetry, stereometry, and applications of derivatives
	In the case of the axial section, the semicircle was not taken into account The result was not verified (the found value does not meet the problem conditions)						
9	15	3,1	20,7	19	21,3	50	Analytical geometry (line in a plane, equation of a circle)
	Formulating the equation of a line parallel or perpendicular to a given line Finding the midpoint of a segment Did not understand that the length of segment BC is the radius of the circle						

Tasks 8 and 9, taken together, yielded notably low average scores and were the most challenging items in the test. Positioned at the end of the paper, they required extensive problem-solving, which may have made them particularly vulnerable to time-related constraints. It is therefore plausible that many students did not attempt them because of time limitations rather than a complete lack of understanding. This interpretation is supported by years of teaching experience and by previous national exam analyses, which consistently show that optimization problems are perceived as highly demanding and are among the least favored tasks for students. For instance, in the 2024 national mathematics exam, the average completion rate for an optimization problem was only 4.9%. Similarly, performance on stereometry tasks has remained low across years, a trend once again confirmed by the present test results.

Overall, these findings highlight distinct strengths and weaknesses in students' mathematical abilities, as reflected in their performance across diverse topics aligned with the national curriculum. While algebraic manipulations and inequalities showed relatively higher success rates, substantial difficulties were evident in geometric reasoning, calculus applications, and multi-step problem solving. The considerable proportion of unattempted tasks in complex topics further emphasizes areas in need of targeted instructional support.

This comprehensive error analysis provides valuable insights for educators designing preparatory courses and instructional materials, underscoring the importance of enhanced focus on problem translation, conceptual clarity, and multi-step reasoning in mathematics education and exam preparation.

Summary of Results

The analysis of final test performance in the mathematics preparation course revealed clear differences in student achievement across topic areas. Students generally performed better in algebraic tasks, such as irrational expressions, while more complex topics like systems of equations, planimetry, stereometry, and analytical geometry proved more challenging. Average scores varied noticeably between tasks, with lower results and higher rates of non-attempts particularly common in mathematical analysis and sequence-related problems. Gender differences were minimal and seemed to relate more to task complexity and content than to any underlying ability.

Evaluator feedback highlighted frequent conceptual misunderstandings and procedural errors, especially in multi-step problem solving, optimization, and spatial reasoning. The fact that a large proportion of students left complex problems unanswered suggests not only conceptual gaps but also time management difficulties during test-taking. Student comments reinforced this interpretation, pointing to insufficient time for thorough engagement with challenging problems.

These findings emphasize the need to strengthen instructional strategies that focus on interpreting mathematical problems, applying step-by-step solutions, and developing spatial visualization skills. In particular, geometry, sequences, and calculus topics require greater emphasis in preparatory instruction. The results also confirm that teacher support plays a critical role in shaping students' confidence and attitudes, aligning with earlier studies that link supportive learning environments to improved performance and motivation.

From a curriculum development perspective, better alignment between preparatory course content and national examination formats is essential. This includes not only coverage of key topics but also pacing, familiarity with problem types, and practice with integrated tasks. Incorporating retrieval-based learning strategies and increasing opportunities for formative assessment may further enhance knowledge retention and conceptual understanding.

Overall, the results suggest that well-structured, supportive, and diagnostically informed preparatory programs can help bridge persistent gaps in mathematical proficiency and better equip students to succeed in high-stakes examinations. These insights are also valuable for national education policy efforts aimed at strengthening STEM readiness and reducing dropout rates in higher education.

Discussion

The analysis of the online preparatory mathematics course and its final test results offers important insights into student readiness for the Estonian national upper secondary mathematics examination. The data reveal several key themes related to participant engagement, performance variability, and specific content area challenges. Although 470 individuals initially registered, this study focuses solely on the 78 participants who completed the final test. All results, comparisons, and interpretations refer exclusively to this group of test-takers.

Firstly, the high initial interest in the course, with 470 registrants from across Estonia, reflects a clear demand for accessible preparatory resources. However, the relatively low proportion (16.6%) of participants who completed the final test suggests potential issues with sustained motivation, course difficulty, or external factors limiting full engagement. The predominance of female participants (59.8%) throughout the course and even more so among test-takers (65.4%) aligns with broader educational trends but may also warrant further exploration to understand gender-specific learning preferences and barriers.

Performance analysis showed that active engagement in school (current abiturients) was a strong predictor of better test outcomes, with abiturients scoring significantly higher than previous graduates. This finding underscores the importance of ongoing academic involvement and suggests that preparatory courses might benefit from closer integration with school curricula or additional support for adult learners.

The distribution of scores and task-specific results pointed to considerable variation in difficulty across topics. Algebraic areas, such as irrational expressions, generally yielded higher scores and greater attempt rates, indicating stronger student familiarity and procedural skills, whereas systems of equations remained among the more challenging topics. Conversely, geometry-related tasks (planimetry, stereometry) and advanced topics involving calculus and analytical geometry had notably lower success rates and higher non-attempt frequencies. This pattern is consistent with international research highlighting spatial reasoning and multi-step problem solving as persistent challenges in mathematics education.

Qualitative error analysis further elucidated common conceptual misunderstandings and procedural difficulties, especially in tasks requiring translation of word problems into mathematical models, stepwise reasoning, and geometric visualization. Errors such as confusion between permutation and combination rules, incorrect application of derivatives, and failure to fully articulate function properties point to gaps in both foundational knowledge and application skills. These findings are consistent with international research by Lin et al. (2024), who identified systematic error patterns among students with mathematical difficulties and grouped them into three main categories: conceptual misunderstandings, procedural errors, and misinterpretation of tasks. The same patterns appeared frequently in our results. For example, procedural errors were common in algebra tasks, while misinterpretation often occurred in geometry and optimization problems, and conceptual difficulties were evident when students misused formulas or misunderstood the properties of functions. Lin et al. also emphasized that meaningful error analysis should go beyond checking whether an answer is right or wrong, but instead explore the reasoning behind students' thinking. This perspective matches the aim of the present study and highlights the importance of teaching strategies that help students understand not only how errors occur but also why they happen.

The similarity of performance between male and female participants suggests that gender is not a major factor influencing exam readiness, though subtle differences in task engagement and error types may exist. Age-related differences were less clear due to small sample sizes in older cohorts but generally showed younger participants performing better, possibly reflecting more recent exposure to the curriculum.

These findings have important implications for designing future preparatory courses and instructional strategies. Emphasis should be placed on reinforcing problem interpretation skills, providing scaffolded multi-step solution approaches, and enhancing spatial reasoning through targeted geometry exercises. Additionally, encouraging continuous engagement and providing differentiated support for diverse learner groups, including adult returnees, could improve overall effectiveness.

In conclusion, while the preparatory course successfully attracted a broad audience and covered the full national curriculum, student performance results indicate substantial room for improvement, particularly in complex, application-oriented topics. Addressing these challenges through refined course design, pedagogical focus on conceptual clarity, and ongoing evaluation will be crucial to better prepare students for the national mathematics examination and foster deeper mathematical competence.

Another noteworthy aspect concerns the role of learning strategies and psychological factors in students' performance. Prior research has shown that curiosity and perseverance (The Australian 2022), as well as active recall through retrieval-based learning (Chan et al. 2020), are positively associated with academic achievement in mathematics. While these aspects were not directly measured in the current study, the high dropout rate and frequent non-attempts on complex problems may indicate challenges in self-regulation, persistence, and strategy use. These are all factors worth addressing in future course design. Incorporating these elements could help students manage cognitive load and build deeper, transferable skills.

Furthermore, the importance of teacher support as a motivating and stabilizing factor was reflected in student feedback and aligns with findings by Ober et al. (2021), who emphasize the impact of perceived support on student engagement and attitude. Future preparatory courses should therefore prioritize clear communication, emotionally supportive learning environments, and access to instructor feedback, especially in online or asynchronous formats. These adjustments may not only improve participation but also foster greater confidence and resilience in approaching difficult mathematical content.

One limitation of the current study is that, although trigonometry was included in the course curriculum, it was not represented among the evaluated test tasks. This omission likely limited the comprehensiveness of the course evaluation and should be addressed in future iterations of the preparatory program. Including trigonometry is essential to ensure full alignment with curriculum requirements and to adequately prepare students for all components of the national exam.

Conclusions

Although 470 individuals registered for the free online preparatory course, this study is based solely on the 78 participants (16.6%) who completed the final test. All reported results, comparisons, and conclusions refer to this group of test-takers. The relatively low completion rate highlights challenges in sustaining motivation and ensuring full participation, even when the initial interest is high.

Most participants who completed the test were current upper secondary school students, and they performed better than previous graduates. This suggests that ongoing academic engagement positively influences exam readiness. In addition, female participants were more numerous both in registration and test-taking, which aligns with broader participation trends but may also warrant further exploration regarding learning preferences and engagement patterns.

The low completion rate raises valid questions about the long-term effectiveness and perceived value of voluntary preparatory courses. Similar concerns were addressed by Greefrath et al. (2017), who found that while preparatory course participation was only modestly linked to later academic success, these courses played a key role in identifying students who might need more support. Their study suggests that preparatory programs do more than just review content. They also help students build learning habits, identify weak areas early, and reduce the risk of falling behind, especially in STEM-related subjects.

With this in mind, future versions of the course could benefit from built-in progress checks, more personalized feedback, and closer ties to school curricula. Preparatory courses should not be seen simply as optional refreshers but as useful tools for early support and guidance.

Students in this study performed best in algebra-related tasks, particularly in working with irrational expressions. By contrast, tasks involving systems of equations, geometry, calculus, and analytical geometry proved more difficult, as seen in lower scores and a higher rate of unattempted questions. Students often struggled with interpreting complex instructions, completing multi-step solutions, and visualizing geometric relationships. These issues point to persistent gaps in both understanding and execution that call for more structured and focused instruction.

Gender did not seem to play a major role in performance, as male and female students scored similarly. While data on older participants was limited, younger students generally performed better. This may reflect their more recent exposure to the curriculum. Looking ahead, preparatory courses should place more emphasis on teaching students how to break down problems, build solutions in steps, and improve spatial reasoning. Chan et al. (2020) found that retrieval-based learning, where students actively recall information instead of passively reviewing it, can significantly strengthen long-term understanding. Adding such strategies may help students better retain and apply knowledge during exams. Motivation and ongoing encouragement also remain essential, especially for those who struggle with confidence or self-regulation.

Feedback from participants largely supported these findings. Many appreciated the clarity and encouraging tone of the instruction, which echoes research by Ober et al. (2021) showing that perceived teacher support improves attitudes and engagement in mathematics. Several students mentioned that the course helped them organize their knowledge and feel more prepared.

At the same time, some students expressed a wish for more frequent sessions. One hour per week was often not enough to master complex topics. This matches the test data, which showed particular difficulties in stereometry, sequences, and trigonometry. These observations reflect wider international findings: low confidence and emotional stress, especially in difficult math tasks, can reduce performance. A report by *The Australian* (2022) also emphasized that qualities like curiosity and perseverance are closely associated with success in mathematics.

Overall, both the test data and student feedback point to the value of improving the course's structure. Increasing the number of sessions, offering more guidance for difficult content, and maintaining academic and emotional support would help students feel more confident and better prepared. A well-balanced focus on both knowledge and mindset is essential to help students succeed in national exams and develop lasting mathematical competence.

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References

Aaviste G, Täht K (2022) Relationships between mathematics state exam results and students' self-perceptions. Presentation at the *Estonian Mathematics Days 2022*. Available at: https://matemaatika.eu/wp-content/uploads/2022/11/Matemaatika-riigieksami-tulemuste-seosed-oppijate-enesekohaste-hoiakutega.pptx89.pdf.

Chan JCK, Meissner CA, Davis SD (2020) Retrieval potentiates new learning: A theoretical and meta-analytic review: Correction to Chan, Meissner, and Davis (2018). *Psychological Bulletin* 146(12): 1202.

Fatawu IA, Alhassan MN, Owusu-Darko I (2023) Analysis of senior high school students' errors in solving word problems using Newman's Error Analysis (NEA) procedure. *International Journal of Mathematics and Computer Research* 11(8): 3685–3693.

Greefrath G, Koepf W, Neugebauer C (2017) Is there a link between preparatory course attendance and academic success? A case study of degree programmes in Electrical Engineering and Computer Science. *International Journal of Research in Undergraduate Mathematics Education* 3(1): 143–167.

Kenosi K, Mutweleli SM, Wambua RM (2024) Relationship between attitudes towards mathematics and mathematics performance among Form Three students in the Southeast Sub-Region, Botswana. *International Journal of Research and Innovation in Social Science* 8(8): 1836–1845.

Lin TH, Riccomini PJ, Liang Z (2024) Mathematical error patterns of students with mathematics difficulty: A systematic review. *Journal of Learning Disabilities.* Advance online publication. https://doi.org/10.1177/07319487241310873.

Ministry of Education and Research (2022) *Data on state examinations and student academic progress*. Available at: https://projektid.edu.ee/pages/viewpage.action?pageId=142575079.

Ministry of Education and Research (2023) *Mathematics State Exam Report 2023*. Available at: https://projektid.edu.ee/display/THO/Matemaatika+riigieksami+aruanne+2023.

Ministry of Education and Research (2024) *Mathematics State Exam Report 2024*. Available at: https://projektid.edu.ee/display/THO/Matemaatika+riigieksami+aruanne+2024.

Ober TM, Coggins MR, Rebouças-Ju D, Suzuki H, Cheng Y (2021) Effect of teacher support on students’ math attitudes: Measurement invariance and moderation of students' background characteristics. *Contemporary Educational Psychology* 66: 101988.

TalTech (2025) *Analysis of the relationship between university students' progress, state exam results, and mathematics course outcomes*. Tallinn University of Technology. Available at: https://haldus.taltech.ee/sites/default/files/2025-02/Üliõpilaste%20edasijõudmise%2C%20riigieksamite%20ja%20matemaatika%20ainete%20tulemuste%20seosed_analüüs2024_0.pdf.

The Australian (2022) *Curiosity and perseverance the key to high marks: new study reveals*. The Australian. Available at: https://www.theaustralian.com.au/nation/curiosity-and-perseverance-the-key-to-high-marks-new-study-reveals/news-story/be6464acf28356472573a0b1e2effab1.