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# Evaluation and Remediation Opportunities for High School Mathematics Knowledge Among Students Entering a Technical University

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***Abstract***

*With the increasing interest in technical fields and the advent of the digital era, ensuring the effective preparation of students for technical universities becomes an utmost goal. Disciplines at these institutions necessitate strong mathematical knowledge, which, in turn, requires a solid foundation in high school mathematics. Insufficient skills in fundamental mathematics are a key challenge for a significant portion of students in technical universities. This paper focuses on comparing the subjective perception of mathematics knowledge among students entering our institution, VSB-Technical University of Ostrava (Czech Republic), with the objective state of their skills. As a possible solution to this unfavorable state, we introduce the potential use of a distance online course and targeted consultations as tools for bridging the gap in high school mathematics among students entering technical universities.*

***Keywords:*** *basics of mathematics; knowledge; survey; technical university.*

## 1. Introduction

Educational programs at technical universities always require a strong foundation in mathematics. During our teaching, we observed that students enter VSB-Technical University of Ostrava (Czech Republic) from various specialized high schools, resulting in the a significant disparity in their knowledge of mathematics (Dlouhá & Hamříková, 2018). There is a varying allocation of both time and content in teaching mathematics across different types of high schools. Despite the fact that students complete their high-school studies with the final state examination, the insufficient emphasis on mathematics in the curriculum of some high schools leads to a small number of students opting for the final comparative maturita examination upon completing their secondary education.

It is essential to highlight that students can choose between final examination in mathematics and a foreign language (typically English). In 2022, when our survey was conducted, only 17% (11.9 thousand) of graduates registered for the mathematics examination, indicating objectively low motivation to focus on mathematics. As a consequence, students entering their first year of higher education have varying levels of preparedness for university-level mathematics due to differences in their prior knowledge. Long-term efforts have been made to assist students in quickly identifying their gaps in basic mathematics knowledge and providing them with opportunities for remediation. In Chapter 2, we introduce a group of our students who underwent a questionnaire survey upon arrival, focusing on their perception of their individual knowledge of basic mathematics and subsequent testing of these skills. The obtained data are compared, and the results are presented in Chapter 3. The presented survey and results identify gaps in knowledge and also shows how students overestimate their actual knowledge. In the following chapters, we present two different options to complement the knowledge and fill the gaps. Moving on to Chapter 4, we introduce a distance course in basic mathematics available to our students to help them acquire the necessary mathematical skills they should have possessed before entering university but may lack. Chapter 5 is dedicated to presenting the Math Support Centre at our university. This centre provides the opportunity for individual consultations. This paper builds upon our previous (Dlouhá et al., 2022), where we analysed the anonymous data. At the university, there is no longer space to substitute high school, but we can provide students with self-study materials or additional consultations. In this paper, we present data from students who have provided consent for the processing of the provided information.

## 2. Questionnaire Survey and Test

The research sample comprises students who enrolled in our technical university. Since the questionnaire survey and subsequent testing were not part of their curriculum, we sought their explicit consent for processing the information and results obtained from them. Our survey, conducted in the first week of the academic term, involved 128 students. However, we received the necessary data for analysis from 91 students who granted us permission. At the beginning, we queried students about the high school they attended (Figure 1a) and whether they graduated with a maturita examination in mathematics (Figure 1b). Furthermore, they were asked to rate, on a scale from 1 (best) to 5 (worst), their responses to the questions: "How much do I like mathematics?" (Figure 1c) and "What grade would I give to my mathematics knowledge?" (Figure 1d).

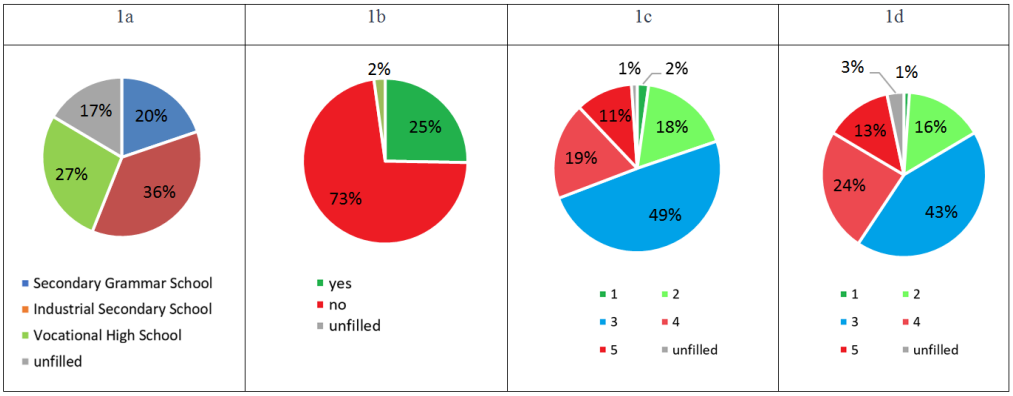



*Figure 1. 1a) High School Type, 1b) Final High-school examination in Mathematics, 1c) "How much do I like mathematics?", 1d) "What grade would I give to my mathematics knowledge?". Source: Own (2024).*

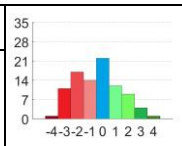
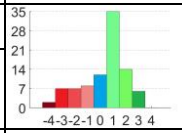
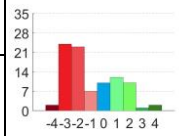
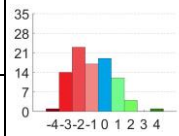
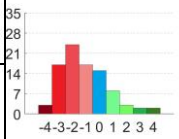
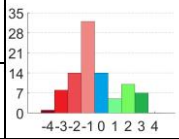
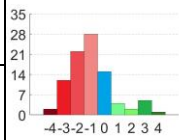
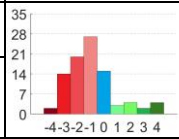
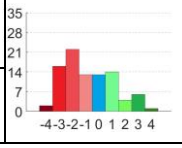
In the second part of the questionnaire, students responded to 20 questions related to specific thematic areas selected to cover the necessary knowledge of high school mathematics at our school. They were instructed to self-assess their knowledge of each topic by assigning a grade on a scale of 1 to 5, where 1 means the best and 5 means the worst. The evaluation was entirely subjective without defining any assessment criteria.

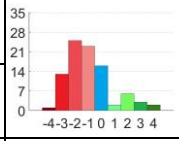
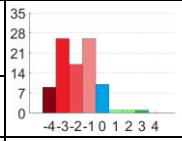
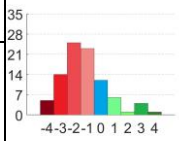
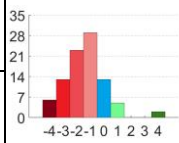
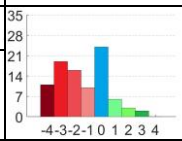
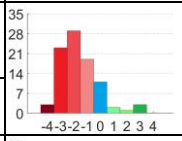
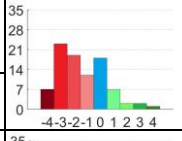
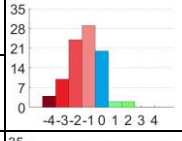
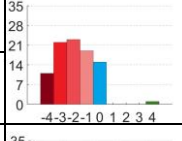
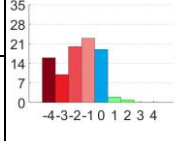
Additionally, to obtain objective information about the students' knowledge and compare it with the questionnaire survey, we designed a test consisting of 20 open-ended, straightforward tasks. The thematic content of the test corresponded to the questions in the questionnaire where students self-evaluated. Students took the test without any prior preparation, and they were not allowed to use calculators or mathematical tables for computations. Our aim was to assess their immediate knowledge. Considering the choice of very straightforward tasks in the test, it was assumed that a student who self-evaluated with a grade of 3 should be able to handle them. Similarly to self-evaluation, students were assessed on a scale of 1-5.

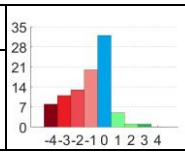
## 3. Results of the Comparison

We conducted a comparison between self-assessment and actual performance for each thematic area individually, considering each student separately. For each student, we subtracted the grade they assigned themselves from the grade they achieved in the test. If the result was a negative value, the student overestimated their abilities. If the result was a positive value, the student underestimated their abilities. A result of 0 indicates that the test performance corresponds to the self-assessment in the questionnaire. The comparison results are presented in Table 1 alongside the questionnaire question and the corresponding test task.

**Table 1. Table of Self-assessment and Actual Knowledge Comparison.** Source: Own (2024).

| | | |
|---|---|---|
| 1 | Grade your knowledge in the field of set operations.<br>Sets **A**=(-∞;0⟩, **B**=(-2;3), **C**=⟨−3; −2⟩ are given. Determine the intersection of sets **A** and **B**, and the union of sets **A** and **C** both graphically and by expressing the results in interval notation. |  |
| 2 | Grade your knowledge in the field of operations with numbers.<br>Calculate and express the result in its simplest form as a fraction $\frac{2-1\frac{3}{10}}{\frac{5}{3}-0,5}$. |  |
| 3 | Grade your knowledge in the field of powers and roots manipulation.<br>Simplify the expression $\sqrt{4n^5 . 9n^5}$ for n∈**N**. |  |
| 4 | Grade your knowledge in the field of algebraic expressions simplification.<br>For a∈**R** - {-5;5}, simplify the expression $\frac{5a}{5-a} - \frac{10a^2}{25-a^2}$. |  |
| 5 | Grade your knowledge in the field of equation solution with an unknown in the denominator.<br>Solve the equation $\frac{x-2}{3x} = \frac{x+1}{6}$ in the domain of real numbers. |  |
| 6 | Grade your knowledge in the field of logarithmic equations.<br>Solve the equation $\log_5(3x+1) = 2$ in the domain of real numbers. |  |
| 7 | Grade your knowledge in the field of logarithmic equations solvability.<br>Determine the conditions for the solvability of the equation $\log_3 3x = 4$ in the domain of real numbers. |  |
| 8 | Grade your knowledge in the field of exponential equations.<br>Solve the equation $3 \cdot 9^x - 9^x = 6$ in the domain of real numbers. |  |
| 9 | Grade your knowledge in the field of quadratic equations.<br>Solve the equation $x^2 = -3x$ in the domain of real numbers. |  |

| | | |
|---|---|---|
| 10 | Grade your knowledge in the field of trigonometric equations.<br>Solve the equation $\sin 2x = -1$ in the domain of real numbers. |  |
| 11 | Grade your knowledge in the field of domains of functions.<br>Specify the domain of the function $y = \frac{9-x^2}{x-3} + \sqrt{4-x}$ . |  |
| 12 | Grade your knowledge in the field of quadratic function graphs.<br>The graph of the quadratic function f : $y = 9 - x^2$ for x∈R is a parabola. Determine the coordinates of its vertex. |  |
| 13 | Grade your knowledge in the field of the range determination of function values from the graph?<br>The graph of the quadratic function f : $y = 9 - x^2$ for x∈R is a parabola, determine its range of values. |  |
| 14 | Grade your knowledge in the field of maps scales.<br>The cyclist is traveling at a constant speed of 18 km/h. The route he covered in half an hour measures 18 cm on the map. What is the scale of the map? |  |
| 15 | Grade your knowledge in the field of general equation of a linear function.<br>Determine the general equation of the line p from Fig. 2a. |  |
| 16 | Grade your knowledge in the field of a planar figure area calculation.<br>Determine the area of the shaded region in Fig. 2a. |  |
| 17 | Grade your knowledge in calculation of the deviation between two lines.<br>Express the deviation of the line p from Fig. 2a in relation to the $o_x$. |  |
| 18 | Grade your knowledge in calculation of the cylinder volume.<br>The height of a rotational cylinder is 4 cm. The cross-sectional area of the cylinder is 24 cm$^2$. Determine the volume of the rotational cylinder. |  |
| 19 | Grade your knowledge in the determination of the point coordinates.<br>In the Cartesian coordinate system in Fig. 2b, the line $p$ is depicted. Numerically determine the missing coordinate of the point A[6; a$_2$]. |  |

| | | |
|---|---|---|
| 20 | Grade your knowledge in the field of trigonometry.<br>The rectangular and triangular plots in Fig. 2c share a common boundary. The dimensions on the plan are given in meters. Determine the area of the rectangular plot with an accuracy of square meters. |  |

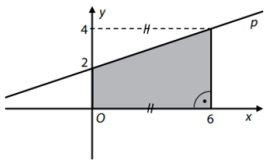
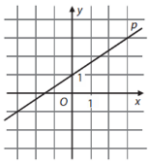
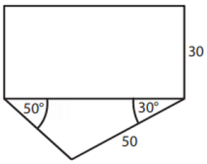
| 2a | 2b | 2c |
|---|---|---|
|  |  |  |

*Figure 2. 2a) Image for solving test problems 15, 16, and 17, 2b) Image for solving test problem 19, 2c) Image for solving test problem 20. Source: Own (2024).*

Results indicate that the only area where students underestimated their knowledge is in the 2nd category, 'Basic numerical operations with numbers.' Conversely, the area where they overestimated themselves the most is in the 11th category, 'Domain of a function.' Unfortunately, in all other categories, students overestimated their abilities. Therefore, it is crucial to provide them the opportunity to quickly assess the actual state of their knowledge upon entering university and offer the possibility of rapid improvement.

## 4. Distance Course

To bridge the gap in required knowledge of high school mathematics among such a diverse group of students, there is not enough time during standard university mathematics courses. Therefore, we have decided that one suitable way of remediation is asynchronous learning through a distance online course. E-Learning environments may contribute to the teaching and learning process if the integration is done within the framework of proper pedagogy. Building customized E-learning programs places high demands on design, programming skills, and time (Kotzer & Elran, 2012). For the knowledge level equalization and facilitation of further studies for our students of university mathematics, we created a new e-learning course in LMS (Moodle-based university online platform), which is accessible for all students and employees of the university. This LMS-embedded online environment is interconnected with the school portal for students and employees (Dlouhá et al., 2021).

The course we have developed provides a flexible and individualized form of preparation, allowing motivated students to acquire the necessary mathematical skills at their own pace as soon as possible after entering university. ‘The Basics of Mathematics’ course includes videos and interactive elements such as graphs and exercises that help students visualize abstract

mathematical concepts and better understand them. End-of-chapter tests provide immediate feedback on tasks and exercises, allowing students to track their progress and identify areas where they need to improve their skills. Designed in this way, the online course gives students the opportunity for self-study and the development of self-learning skills, which are important for lifelong learning.

A key component of the course is videos of solved problems with teacher voice commentary, as videos have become a preferred form of information acquisition among students in recent years. The success of the video tutorial is ascribed to its design, which attended to and even incorporated key qualities of paper-based tutorials, while also capitalizing on the strengths of video (Meij & Meij, 2016).

Although the online course offers many advantages, it is also important to take into account individual learning styles and preferences of students. Combining online learning with traditional methods can provide a balanced and effective approach to mathematics education. In addition to regular consultations, our students can benefit from the services of the Math Support Center at our school.

## 5. Math Support Centre

Math Support Centres (MSC) are open to all students regardless of their skill level. They assist students in overcoming potential math anxiety and gaining confidence in their study of mathematics. The goal is to provide an environment where students can work on their mathematical development without stress. These centers are typically designed to help students develop their mathematical skills, improve understanding of mathematical concepts, and successfully handle math courses or assignments. They offer personal or group consultations with experienced math tutors, teachers, or peers who are capable and willing to work in the center. We are very happy that our gifted students work with us, who not only teach their classmates mathematics, but can also ensure them that they will need mathematics during their further studies (Dlouhá et al., 2019). This allows students to receive individual assistance with specific questions or topics. The centers provide access to textbooks, educational materials, online resources, and exercises that enable students to study independently and review. MSC at VSB-Technical University of Ostrava offers both in-person and online consultations and additional sessions covering the basics of mathematics, university-level mathematics, statistics, and descriptive geometry. In the year 2022, during which our survey was conducted, a total of 1748 individual consultations and 52 group consultations (tutorials) took place, both in-person and online.

## 6. Conclusion

Our goal is to promptly assess incoming students' high school mathematics proficiency and promptly address any deficiencies. This paper outlines a method to gauge students' mathematics understanding, pinpointing areas where they may lack insight. We propose two solutions for filling identified gaps. Survey results reveal a tendency for students to overestimate their knowledge. We advocate for employing online courses and individual consultations to enhance high school mathematics proficiency among technical university students, thereby bolstering their academic achievements.

## Acknowledgments

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