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High school mathematics knowledge level of technical university students

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Abstract

The lack of knowledge of high school mathematics is one of the key problems for students at technical universities. They face this problem not only right after entering the university, but they fight with this handicap during their whole studies. In the first part of this paper, we introduce the results of the questionnaire survey among first-year students which consists of the comparison of their subjective opinion on the level of their knowledge with the true results of the entrance test. The second part of the paper is dedicated to our new online courses of high school mathematics for our students. We believe that our effort will become an effective way how to supply the students with the knowledge, which they should already have and which is expected for further extension in regular university courses.

Keywords: *Mathematics; technical studies; survey; online course.*

1. Introduction

Our technical university provides education for engineers in multiple fields, e.g., civil, safety, mining, mechanical electrical engineering, and material sciences. All studying programs share the same crucial fundamental ingredient - mathematics. Based on our long-standing experience, students are coming to our technical university with various knowledge of high school mathematics. The mastering of this skill is critical in passing more advanced university math courses. Our primal endeavour is to encourage them to discover and identify their deficiencies and reduce them as soon as possible to be able to follow regular university lectures. During our research, we are also interested in their personal and subjective option on their knowledge in boarding at university. It is the reason why we asked them to fill out the anonymous self-evaluation questionnaire, where we asked them how confident they feel in various areas of mathematics. Please, see Section 2 for details. Afterwards, we would like to know their true level of knowledge and therefore, we give them the test consisting of problems typical for high school mathematics. The content of the test is described in Section 3. We compare the results of the self-evaluation and the real results in Section 4. The results are the primal impulse for creating a new online course that covers these topics. Building customized E-learning programs places high demands on design, programming skills, and time (Kotzer & Elran, 2012). The prepared material is available to all students of our university and we hope that they will use it in the case of any problem with high school mathematics in our university. See Section 5 for details. Finally, Section 6 concludes the paper and presents our future work.

2. Self-evaluation survey

We divided selected areas of high school mathematics into short thematic units. In the questionnaire, students answered 40 questions from individual topics. They asked to perform the self-evaluation consisting of grading themself a grade 1-5 based on personal opinion about the given topic. With our survey, we addressed all university faculties, where the members of our Department of Mathematics are teaching, i.e., Faculty of Civil Engineering, Faculty of Mining and Geology, and Faculty of Safety Engineering (Dlouhá, Pokorný & Dlouhá, 2019). Although most of the studying programmes do not require the entrance examination from mathematics, the content of all courses supposes the knowledge of mathematics at least on the level of typical high school. Since the content of this knowledge is defined by the Ministry of Education of the Czech Republic, this assumption is easy to satisfy. However, each high school defines the number of classes of mathematics per week individually based on the type of school, therefore the final level of true knowledge differs. Moreover, the final high school exams from mathematics are not mandatory. This is the reason why we asked students for filling the questionnaire. It has

been finished by 325 students before the deadline, which was set to the first two weeks after boarding the university.

3. Test

One week after finishing the questionnaire, we gave students the entrance test consisting of tasks and problems based on the thematic units corresponding to the survey. Using this way, we compared the subjective opinion of students before the test with the real results after the test.

The test consisted of 20 closed questions, where students could choose between 4 options. In each problem, exactly one answer was correct. The problems were chosen from the following areas:

- sets and set operations,
- basic arithmetic operations with numbers,
- the simplification of algebraic expressions,
- solving equations and inequalities,
- the domain of a function,
- graphs and properties of functions,
- the computation with percentage,
- planimetry,
- stereometry,
- analytical geometry of space.

Students worked on the tests without any previous preparation and the computation had to be performed without a calculator or Handbook of Mathematical Formulas. We were interested in their active knowledge. Students should answer only the questions, where they knew the answer surely to suppress the influence of random guessing. The test was entirely anonymous, therefore students solved problems responsively and without the stress of possible loss of credit. We prepared the content of the test based on our previous experiences (Dlouhá & Kozlová, 2019).

4. The comparison of survey and test results

At first, we divided the students into groups according to the faculties and according to whether they were full-time or part-time students. After collecting data, we shared the results within the groups as well as with the management of the corresponding faculties. However, the differences between the individual faculties were not very significant and therefore, we decided to present in this paper the results for several selected areas as a collection.

In the case of the unit "Basic arithmetical operation with numbers", we observed minor problems in the computation with the substitution. This problem is solved by 63% of students. The problem with compound fraction and exponentiation is solved by 78%. The self-evaluation of students from the survey is corresponding to the success rate in the test.

The problem of "Editing algebraic expressions" is the long term problem with which students coming to our university have problems. Confirming our assumption, the task of this type belonged to the hardest problems in the case of full-time students as well as part-time students. In the case of our test, the correct result was achieved by only 48% of students. The result of self-evaluation was overestimated, students believed in their abilities in 70%.

Additionally, we were interested in the topic of "Solving equations and inequalities". One of the presented problems was an equation in product form, where one of the terms was a quadratic triplet. This problem was successfully solved by 53% of students and therefore, the difficulty of this problem can be considered as moderate. Since the offered options of possible answer were presented in the form of product of roots, it was not sufficient to only straightforwardly substitute into the given original equation. The problem was necessary to solve.

Based on the results, the logarithmic equation with square root was the fourth hardest problem and its solution was successfully passed by 48% of students. This number approximately corresponded to the results of the survey. The simple equation with absolute value was solved by 65% of students. Since the question was again about the product of roots, we could suppose that the problem was truly solved. The success rate corresponded to the survey.

We included two inequalities in the test. Based on the results, we could imply that the simple system of linear inequalities belonged to the simplest problems and that most of the students had no problem in finding the solution (it was correctly solved by 83% of students). On the other hand, quadratic inequality was the serious problem for students and only 52% were successful. Overall, students achieved better results in the real test than they were expecting in the self-evaluating survey (45%).

The next topic, which is a long term well-known problem for students, is the "determination of the domain of the given function". The analysis of the results showed that this was also the hardest task in our test. The first problem, where the domain was defined by the solution of one trivial linear inequality, was solved only by 52% of students. Moreover, we observed an even more significant drop in the case of the second problem, which solution was not as trivial. This problem was solved only by 33% of students. On the other hand, 70% of students in the survey thought that they know how to solve this type of problem and they hardly overestimated their true knowledge. This type of problem is particularly

important for us since the first course in mathematics in our university starts with the mathematical analysis of the real functions of one real variable and determination of the function domain plays a crucial role. Additionally, this course consists also of the determination of function properties and graph drawing of a given function. In the test, we covered these topics with two additional questions. We were pleased to see the results, 78% of students could handle the graph of a linear function and 73% of students were familiar with the graph of a quadratic function. In the case of this question, the results corresponded to the survey.

The conclusion of the comparison is clear - students can self-evaluate their knowledge quite objectively. However, this evaluation is rather insufficient for studies at a technical university. We aim to help incoming students clarify their real knowledge of high school mathematics as soon as possible and allow them to eliminate any shortcomings quickly. They have to be able to focus on the extension of high school topics rather than burying into the basics.

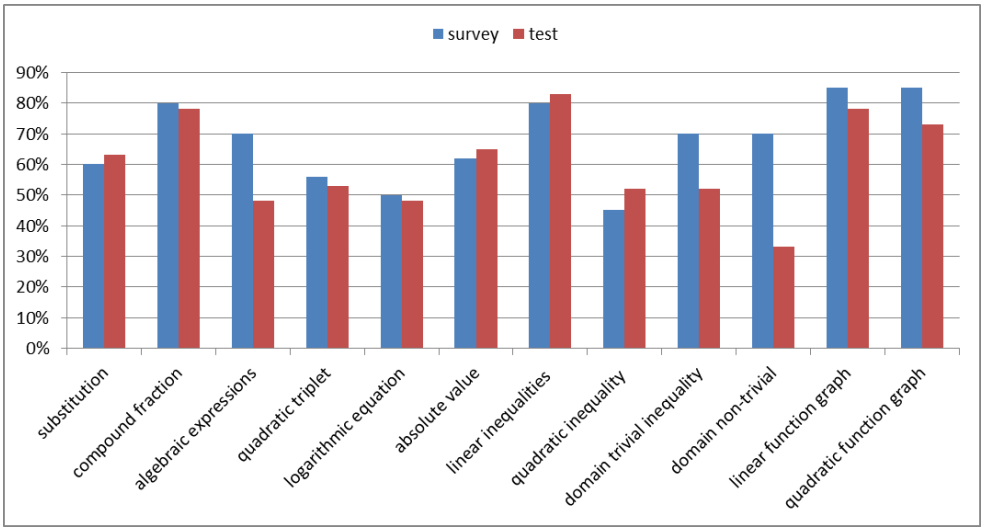

Figure 1. The comparison of survey and test results of selected problems discussed in the paper. Source: own.

5. The supplement of knowledge

For the knowledge level supplementation and facilitation of further studies for our students, we create 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, Pospíšil & Dlouhá, 2021).

Students can begin or end their studies in the online course by the test, which evaluates the student's level of knowledge of the basics of mathematics. If the results are insufficient in some topics, the students can directly click through the hyperlinks to online worksheets. This studying material guides students through theoretical background (approximately 60 pages) followed by the practical exercises that are dedicated to practical computation (around 260 problems). Additionally, visitors of worksheet pages have an opportunity to watch prerecorded videos with commentary on the solution process (120 problems). Our survey proved the prevailing trend of our times: “When I do not know something specific, I will check YouTube.” (Hamříková & Dlouhá, 2017). We did our best to meet the demands of students and therefore, we have incorporated videos as one of the key features. After the study, a student can practice newly gained knowledge on exercises without a given solution process, but with a given solution for final verification (520 problems). After finishing the chapter of the e-learning course, the student has an opportunity to verify the understanding of the problematics by the test.

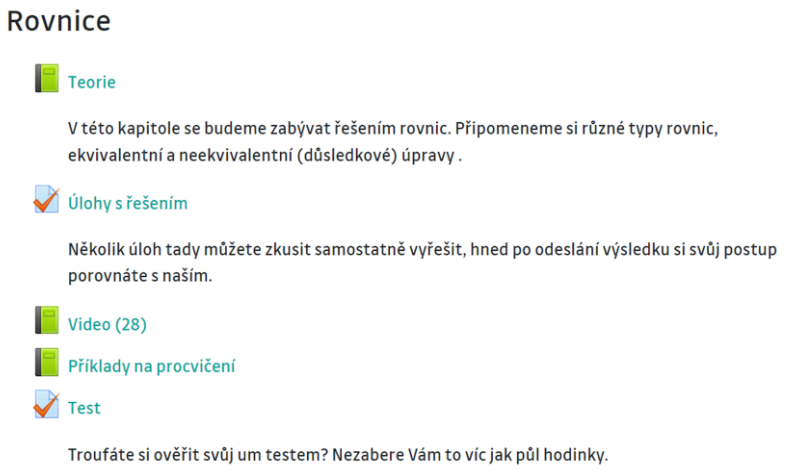

Figure 2. Example from our new e-learning course: we provide several types of studying material; students choose from theory, problems with solution, video with voice commentary, problems without solution process, or tests. Source: own.

All theories and solved examples are embedded directly in the LMS environment. We recorded videos with voice commentary on a tablet with the ProMotion function. The style of the video is chosen so that the notation and explanation of the solution process mimic the regular school teaching on the board as close as possible. The solution process is written using the application Notability, the screen is recorded by the iPad Control Center, the voice commentary is recorded via the "Record it!" application, and the final video is edited in "iMovie".

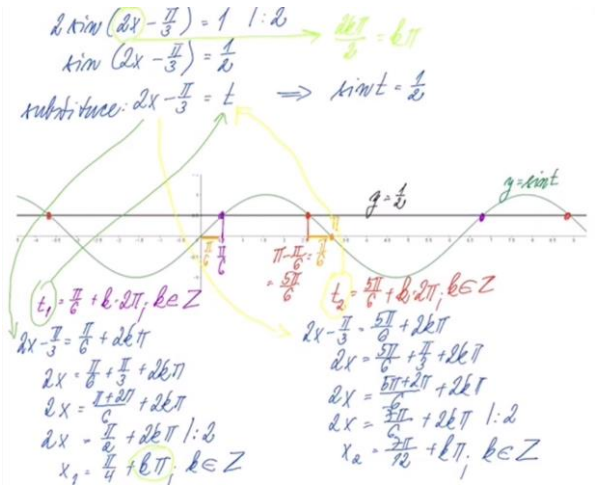

Figure 3. Example from our new e-learning course; the snapshot of video: the problem is real-time solved on the screen with corresponding voiceover. Students can stop, rewind, or fast forward the video. Source: own.

Problems in the test are designed in such a way that students are asked to write or assign the correct result or choose one of the predefined options of answer.

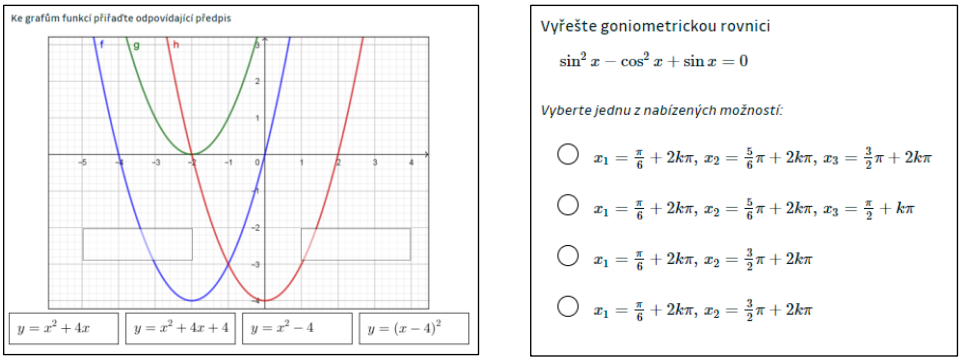

Figure 4. Example of test questions: students are asked to assign formula to the graph (left), choose right solution of goniometric equation (right). Source: own.

6. Conclusion

In this paper, we shared the results of the survey performed at our technical university, which suggest that students can identify the shortcomings in their knowledge of high school mathematics. To help them to overcome the first difficulties in their studies, we designed and implemented the new online course. We hope that our work will help them to reduce their lack of knowledge as soon as possible. However, our course is entirely new, and therefore, we are looking forward to the first feedback to be able to summarize the

consequences of our attempt. In the case of success, we will continue in the preparation of online material also for the following courses of mathematics at our university.

Acknowledgments

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