{MERAA} Mathematics in Education, Research and Applications
ISSN 2453-6881
Math Educ Res Appl, 2022(8), 1

Received: 2022-10-26
Accepted: 2022-12-14
Online published: 2022-12-30
DOI: https://doi.org/10.15414/meraa.2022.08.01.24-32

Original Paper

The results of the university competence measurement in mathematics in the view of the tasks

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ABSTRACT
Experience shows that students applying to higher education have a highly differentiated knowledge of mathematics. They come from different types of secondary school, and it is not a general requirement to have an advanced level secondary school certificate in mathematics. However, adequate basic knowledge is essential for mastering the university mathematics material, so it is important to identify the shortcomings in time and, if necessary, to make interventions. This is the reason for measuring the mathematical competence of incoming students. In our article, we analyze the results of the mathematical competence measurement made in the 1st semester of the academic year of 2022/2023, among the 1st year BSc students of the University of Miskolc in the fields of IT, engineering and economics, highlighting the problematic areas and the parts of the academic material acquired at the appropriate level. 513 students completed the test, their average performance was 65% and only 5 students achieved the maximum point.

KEYWORDS: mathematical competence, measuring, university mathematics material, competence

JEL CLASSIFICATION: I21, C02

INTRODUCTION

The eternal questions of teaching mathematics are as follows: What should we teach? How should we teach? What level should we teach at? In terms of secondary education the question ‘What should we teach?’ can be answered on the basis of the National Basic Curriculum (NAT), the curriculum requirements, as well as the lesson plans, and in the case of universities the answer is given by the previously prepared syllabi for the given major. The answer to the question ‘How to teach?’ depends significantly on the age of the given students,

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as it is not the same thing whether we want to explain a particular subject to a young elementary school pupil or a university student, a student who already understands a lot of things using his mathematical knowledge. The third question asking at what level we should teach is not easy to answer either, but if we know the solution, we will get a partial answer to the other two questions as well [4].

Several years of experience show (the authors of the article have been teaching at the Institute of Mathematics for more than twenty years) that the mathematical knowledge of students applying to higher education in engineering, IT, and economic studies is highly differentiated. On the one hand, it is inherent to the fact that it is not compulsory to take an A-level exam in mathematics to get admission to university, and on the other hand, the type of secondary school the students come from (secondary technical school or secondary grammar school) is also crucial. It may happen that students coming from certain secondary technical schools have an advantage in technical drawing and mechanical drawing that they have already learnt in certain university subjects, such as Descriptive Geometry, however, in their case it is often observed that it is more difficult for them to acquire subjects based on mathematical knowledge, such as Analysis or Linear Algebra, since in their secondary school they studied mathematics in a lower number of hours.

In general, however, there are areas of mathematics that cause problems for many people, which makes it difficult for them to adapt to university studies. Furthermore, even for those students who are able to reproduce the knowledge they gained at an adequate level, applying it in new situations is problematic in some cases.

We tried to assess these shortcomings and strengths by the competence-based test to be completed by students at the very beginning of the year. We tried to compile the tasks in such a way that they should cover all topics and get a realistic picture of the students' adequate knowledge and their shortcomings. The purpose of our article is to explore the critical areas based on the results of the entrance competence test paper written by 513 people.

About competence in general

The changes taking place in the society and the entire world have fundamentally changed the expectations towards education. We can quite often hear that schools are demanded to provide useful knowledge to the students studying there. The term increasingly used to describe this demand is the development of competence [6].

In general, competence means a preparedness that enables us to act effectively in different situations [8]. We mean the preparedness that is based on knowledge and skills, but also on experience, values and attitudes. The role of the thinking ability is one of the most significant in terms of mathematical competence, but it relies on several abilities, such as systematization, combinativity, deductive and inductive approaches and reasoning. These properties must be components that also work in other areas, i.e. the ability to think mathematically must become an ability that can be used in other subjects as well, and vice versa, e.g. an analytical ability developed in literature or history classes must also be adaptable in mathematics classes. It can be read in several researches ([5], [7]) that it is advisable to develop the following abilities in order to improve mathematical competence.

Three main components of mathematical competence:

- Knowledge of mathematics as a subject
- Mathematics-specific skills and abilities
- Motives, attitudes

The following table shows the most important ability and skill components of mathematical competence [4].

Table 1 Ability and skill components

Skills	Thinking ability	Communication skills	Knowledge acquisition skills	Learning skills
• counting • calculation • quantitative inference • estimation • measurement • measurement unit conversion • solving word problems	• systematization • combinativity • deductive inference • induction • probabilistic inference • reasoning • proof	• mathematics vocabulary • reading comprehension • text interpretation • spatial vision, spatial conditions • representation • presentation	• problem sensitivity (questions) • problem representation • originality, creativity • problem solving • metacognition	• attention • part-whole perception • memory • task performance • speed of task solving

Topics of the school leaving exam

The school leaving exam system underwent a significant change in 2005, when the two-level exam was introduced. At intermediate level, the mathematical knowledge of a person with the ability to navigate and create must be required in today's society, which primarily means the knowledge and application of mathematical concepts and theorems in practical situations. The advanced level includes the requirements of the intermediate level, but among the requirements formulated in the same way, the advanced level is more difficult, also, tasks requiring more ideas are included. In addition, among the requirements of the advanced level, there are also special parts of the material, since the advanced level mainly prepares students who use and study mathematics in higher education [3].

In parallel with the introduction of the new school leaving system, the entrance exams required for admission to higher education were abolished. According to the original concept, the advanced-level school leaving exam would have been a condition for applying to higher education institutions, while the intermediate-level exam would have been intended for the completion of secondary studies. However, this idea did not come true [1]. Even though since 2020 the advanced level exam has been the admission requirement for all fields of study, it is not compulsory to complete it in mathematics.

The topics of the school leaving exam come from the following chapters of mathematics:

- Thinking methods, sets, logic, combinatorics, graphs
- Number theory, algebra
- Functions, elements of analysis
- Geometry, coordinate geometry, trigonometry

- Probability calculation, statistics

In the case of engineering and IT BSc courses, compulsory subjects usually include a course on analysis for two semesters, courses on linear algebra and discrete mathematics at least for one semester. In the case of BSc courses belonging to the field of economics, the topics of the two-semester mathematics subjects include the elements of analysis, probability calculation, applied linear algebra and operations research. For most students, these foundational mathematics courses are difficult to complete, as they have to account for the acquisition of a significant amount of new knowledge, and the good mathematical foundations acquired in high school are essential for successful graduation. In the absence of these, it is significantly more difficult for students to solve the tasks set in written examination papers and in exam papers. In order to successfully complete the courses, students arriving with insufficient mathematical knowledge must not only master the new material, but must also make up the corresponding chapters of the secondary school material. Therefore, it is justified to measure the entrance mathematical competence of freshers at the beginning of their university studies, so that intervention and bringing them up to the level can be carried out if necessary, thus avoiding later dropouts.

MATERIALS AND METHODS

The entrance competency test was written by a total of 697 first-year BSc students belonging to engineering, IT, and economics fields of study. 513 people participated in the first measurement. It took 60 minutes to write the test, and the set of tasks contained 20 multiple-choice questions, which were selected in connection with the above-mentioned secondary school exam topics of mathematics, namely:

- Thinking methods, sets, logic, combinatorics, graphs: 3 questions
- Number theory, algebra: 5 questions
- Functions, elements of analysis: 7 questions
- Geometry, coordinate geometry, trigonometry: 5 questions

The students completed the test online on the e-learning interface of the University of Miskolc. They could choose one out of five options, each correct answer was worth 4 points, an incorrect answer resulted in a deduction of 1 point, no points were given for the unanswered task. Among the answer we have hidden solutions that can be obtained using the typical incorrect methods.
Out of the maximum possible 80 points, the respondents achieved an average of 52 points, which means an average performance of 65%, but there were only 5 students who achieved the maximum point.

RESULTS AND DISCUSSION

The analysis of the most successful tasks

The following Figure 1 shows the number of correct answers to each task. It can be seen that most of the students managed to solve the 8th task in the test, a question related to percentage calculation.

The task was as follows:

The price of a television has been increased by 25%. By what percentage must the new price of the television be reduced to return to the original price?
Students could choose a solution out of five options:

- 91.62% of the students chose the solution of 20%
- the solution of 25% was chosen by 6.43% of the students
- the solution of 15% was chosen by 0% of the students
- 0.97% of the students chose 22.5%
- 0.58% of the students chose 30%
- 0.39% of students did not answer the question

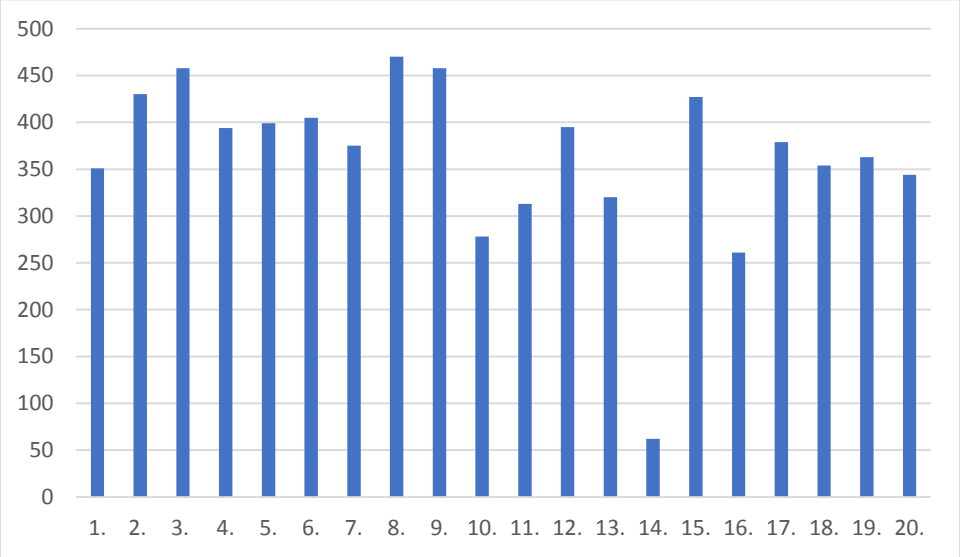

Figure 1 The number of correct answers

It is clear from the above results that almost everyone was able to do the basic percentage calculation task, with few exceptions. The correct solution of 20% was chosen by 470 out of 513 people. Based on this fact, we can expect that the solution of tasks related to percentage calculation occurring during university mathematics education will not cause difficulties either.

The other very successful task was task number 3, which belongs to the topic of the series:
The first element of a geometric series is 4, its quotient is 3. What is the sum of the first five elements of the series?
The students' five possible answers and their percentage distribution are as follows:

- 484 was chosen as the solution by 89.28% of the students
- 3.12% of students chose 324 as the solution
- 2.53% of students chose 16
- 476 was chosen as the solution by 1.17% of the students
- 1.36% of students did not choose a solution

Out of 513 students, 458 students answered this task correctly. Within the subject of analysis, in the topic of series, as well as in the material based on it, such as numerical series, it is hoped that most of the students will not have any problems when using and applying the

knowledge about geometric series learned at secondary school. They were probably able to master this topic much better, and it is closer to them. This is good news for us university teachers, since we can rely on this knowledge and use these connections without repeating them in class assignments.

The third most successful task type was task 9 belonging to the area calculation topic:
One side of the rectangle is 120 cm, and the other side is a quarter of that. How many dm^2 is the area of the rectangle?

- 36 was chosen as the solution by 89.28% of the students
- 4.29% of students chose 3600 as the solution
- 3.9% of students chose 360
- 0.78% students chose 300
- 30 was chosen as the solution by 1.17% of the students
- 0.58% of students did not choose any of the solutions

Out of the 513 people who wrote the test, 458 people calculated this task correctly, i.e. solving this simple geometric task did not cause any problems for most of the students and they were able to give a good solution within the maximum 3 minutes allotted for one task. During their university mathematics studies, they will encounter many tasks based on geometry, such as area, surface, and volume calculations in the applications of integral calculus. Of course, we could list other examples, especially for students studying in the field of engineering training, not only mathematical tasks, but also tasks related to physics or descriptive geometry.

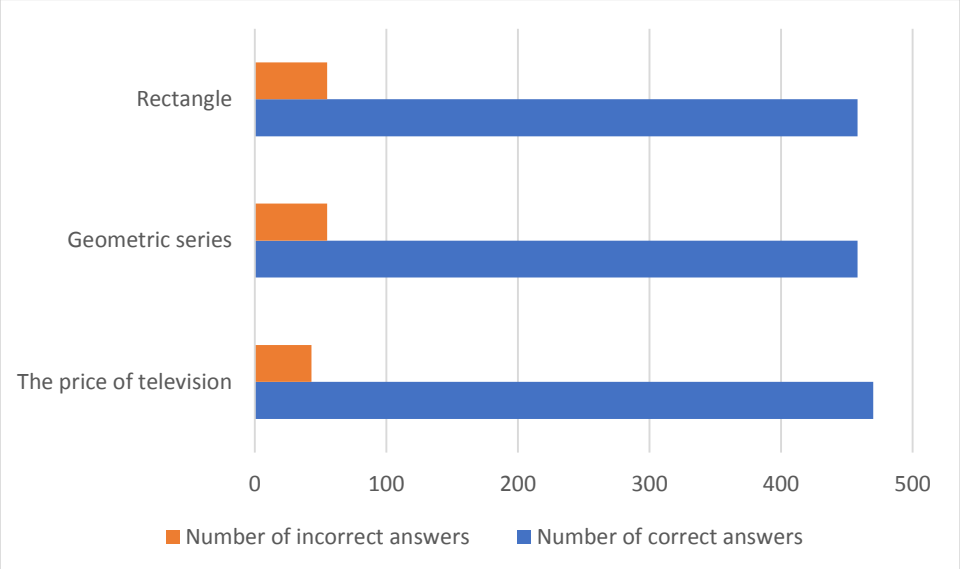

Figure 2 Number of correct and incorrect answers by the most successful tasks

Analysis of problematic tasks

A problem of combinatorics was the least successful among the tasks. Solving the task did not require the automatic application of basic knowledge, but it rather demanded logical thinking. The text of task 14 was as follows:
Bea makes bouquets. Each bouquet contains three types of flowers. For the bouquets, you can use 15 lilies, 25 gerberas, 25 roses and 35 tulips. How many bouquets will Bea make if there are as many as possible?

- 32 (the correct answer) was chosen by 12.09% of the students
- 25 was chosen as the solution by 57.31% of the students
- 23 was chosen as a solution by 1.17% of the students
- 33 was chosen as a solution by 20.66% of the students
- 35 was chosen as a solution by 4.48%% of the students
- 4.29% of students did not choose any of the solutions

Out of 513 respondents, only 62 solved the task correctly. It is instructive that most people chose 25, from which it can be concluded that they did not interpret the task correctly, they did not combine the four types of flowers, but only automatically used the three flowers with the highest number. As mentioned in the introduction, the majority of students find it difficult to apply knowledge in new situations. Our experience was confirmed by the answers to this task of the entrance competence measurement.

A little more than half of the students gave the correct answer to task 16; the question related to the following trigonometric equation:
How many solutions of the equation $cosx = \frac{1}{2}$ *are there at* $[0; 3\pi]$ *interval?*

- 3 (the correct answer) was chosen by 50.88% of the students
- 2 was chosen by 30.02% of the students as a solution
- 4 was chosen by 3.9% of the students as a solution
- 1 was chosen by 5.26% of the students as a solution
- 6 was chosen by 4.0% of the students as a solution
- 5.85% of the students, i.e. 30 people, did not choose any of the solutions

Most of the students' knowledge of trigonometric functions and identities is incomplete, which is a problem especially for students in the field of IT and technical education. Angular functions appear, for example, in the description of periodic phenomena, but in countless areas of technical life, knowledge of basic trigonometric relationships is also necessary for the successful completion of analysis subjects.

The question related to analytic geometry (task 10) was the third least successful task:
For which value of the parameter are the lines $3x + 2y = 4$ *and* $4x – ay = 17$ *perpendicular to each other?*

- 6 (the correct answer) was chosen by 54.19% of the students
- - 6 was chosen by 18.32% of the students as a solution
- $\frac{8}{3}$ was chosen by 3.9% of the students
- $-\frac{8}{3}$ 4.87% of students chose it as a solution
- $\frac{17}{4}$ 3.31% of students chose it as a solution
- 15.4% of students did not choose any of the solution

Based on the answers, it can be seen that the second largest number of tips came for the opposite of the correct solution. The parameter $-\frac{8}{3}$, which would be the correct answer in the case of a parallel line was chosen by 25 people. It should be noted that 79 people did not answer at all. The results of the test have also confirmed that analytic geometry is a difficulty in many cases. One of the reasons for this may be that in order to be good at this subject, one must have solid geometric and algebraic foundations, since the task of analytic geometry is to solve geometric problems with algebraic tools [2].

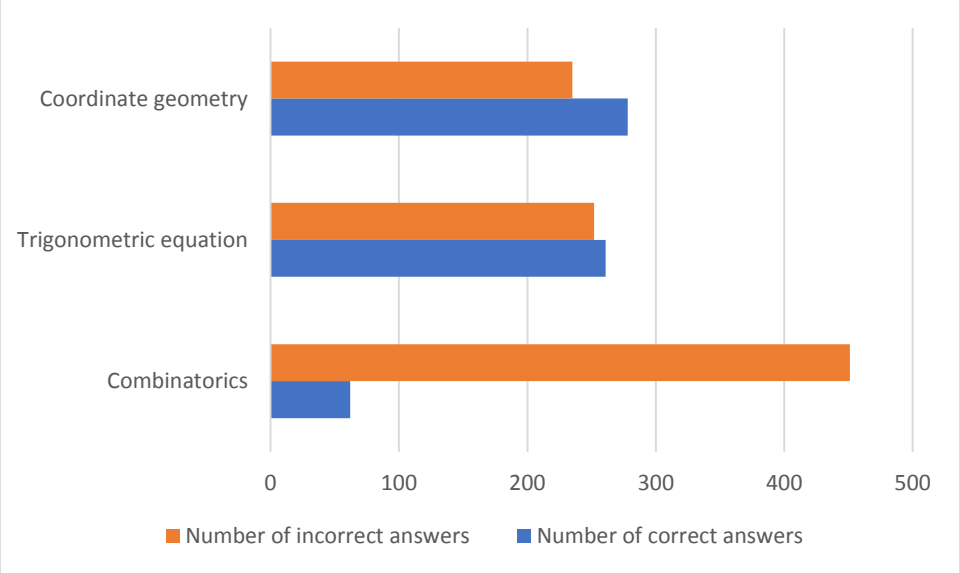

Figure 3 Number of correct and incorrect answers by the problematic tasks

CONCLUSIONS

The results of the competence measurement have confirmed our experience gained during university mathematics education. The newly recruited students proved to be less effective in the tasks that we had previously expected. Although as a result of the online implementation of the test, the tasks had to be solved in the form of multiple-choice questions, in the case of problematic topics, the offered options basically did not help the students either. Students who did not write the test at a sufficient level must participate in a competence development course. Within this framework, we can already focus on the shortcomings that need to be solved, thus helping those concerned to pass university mathematics subjects and to successfully acquire the professional knowledge relying on them.

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