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The role of prior mathematical competence in engineering students' academic success

Szilvia Homolya, Erika Rozgonyi

Institute of Mathematics, University of Miskolc
szilvia.homolya@uni-miskolc.hu
erika.szilvasine.rozgonyi@uni-miskolc.hu

Abstract. Experience shows that insufficient foundational knowledge in mathematics poses significant challenges for students entering technical higher education. This issue extends beyond mathematics courses, affecting overall academic progress. In this paper, we analyse data from undergraduate students enrolled in the Faculty of Mechanical Engineering and Informatics (GÉIK) at the University of Miskolc during the first semester of the 2023/2024 academic year. The analysis includes their mathematics school-leaving exam results, scores from an initial mathematical competency test, and performance in two key first-semester courses: Calculus and Descriptive Geometry. Our findings aim to highlight the correlation between students' incoming mathematical preparedness, academic success in these courses and their overall effective progress, underlining the need for targeted interventions and preparatory programs to support students in building a stronger foundation for their studies.

Keywords: mathematical competence, engineering students, calculus, descriptive geometry

2020 *Mathematics Subject Classification:* 97-11

1. Introduction

Experience shows that the mathematical knowledge of students entering higher education is significantly differentiated. One reason for this is that students come from different types of secondary schools, where they have been exposed to different

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curricula and teaching methods. Students from certain types of secondary schools may have an advantage in some university subjects (e.g. Descriptive Geometry) because of the specialized subjects they have already studied, but they often have difficulties in absorbing courses based on mathematical knowledge, such as Calculus or Linear Algebra, because they have learned mathematics at a lower level in their secondary school. The differences are further exacerbated by the fact that it is not necessary to have an advanced level in mathematics to enter technical or IT faculties.

The lack of a solid foundation makes it difficult to master the mathematics curriculum at the university level and progress successfully. A substantial body of research (e.g. [7, 13]) has shown that a significant proportion of students entering higher education in engineering or science fields start their studies with inadequate mathematical knowledge. Lack of basic mathematical thinking and computational skills is an increasing barrier to understanding even the simplest mathematical modelling examples. Meanwhile, the practice of engineering requires more and more mathematical skills ([13]).

It is therefore crucial to identify gaps from the start and provide timely and effective support to students when needed. This is the purpose of the incoming students' mathematics competency assessment.

The analysis of the results of the mathematical competency survey conducted in the first semester of the academic year 2022/2023 among first-year BSc students of the University of Miskolc in the fields of computer science, engineering, and economics has already been presented in a previous article ([5]). In September 2023, we conducted the level measurement and the related catch-up assessment according to a new concept. The measurement of entering students of the GÉIK was carried out on the first day of the registration week. The test was taken by the students via the university e-learning system, full-time students in person, and part-time students online.

In this article, we use the results of the September 2023 entrance survey to compare the level of preparedness of incoming students, the results of the mathematics school-leaving exam, and the performance in the first semester calculus course. Some of the tested group also studied descriptive geometry, so comparisons were also made for this course.

Both courses are taught in the first semester,therefore the students taking the entrance test attend these courses immediately at the beginning of their university studies. The Calculus I course was selected because it is considered one of the critical foundation subjects of the engineering curriculum. Based on our previous experience, a considerable proportion of students face difficulties in completing the course successfully, partly because university-level mathematics introduces a significantly higher level of abstraction and formal reasoning than they typically encountered during secondary education. At the same time, successful completion of Calculus I plays a crucial role in the educational process, as the mathematical concepts and methods covered in the course are essential prerequisites for several further foundation and core engineering subjects, including physics and mechanics. Furthermore, the course requires students to apply mathematical concepts in a structured and rigorous way, which represents a significant transition for many first-year engineering students. The course develops analytical thinking, problem-solving abilities, and mathematical modeling skills that are indispensable in engineering practice. As a consequence, students' performance in Calculus I may serve as an important indicator of their ability to adapt to the academic requirements of higher engineering education.

Descriptive geometry plays a fundamental role in engineering education by developing students' spatial visualisation and geometric reasoning skills, which are essential for interpreting and creating technical representations. It provides a theoretical foundation for disciplines such as computer-aided design, structural analysis, and engineering graphics, thereby supporting both conceptual understanding and practical problem-solving. Consequently, proficiency in descriptive geometry significantly enhances students' ability to model, analyse, and communicate complex spatial structures in professional engineering contexts.

2. School-leaving exam in Mathematics

Although from 2020 the advanced level school-leaving examination was introduced as a requirement for admission to all fields of studies, even in the technical and IT fields, it was not compulsory to pass it in mathematics. In 2023, the admission system underwent another transformation, and it became the responsibility of the institutions to decide whether to require the school-leaving examination as a requirement for admission. As a result, for the majority of courses offered by the University of Miskolc, since the general admission procedure in 2023, it has been sufficient to have an intermediate level school-leaving examination. In a five-part series of articles for *Érintő*, Csaba Csapodi explains how the new National Core Curriculum (in Hungarian NAT) introduced in 2020 and the changes to the related framework curriculum will transform the requirements for the mathematics school-leaving exam from 2024. The changes to the GCSE system are presented in a tabular form, broken down by subject and level, and in a clear and concise manner (e.g. [2, 3]), so we will not deal with the changes in detail in this article. The topics for the intermediate level are drawn from the following fields of mathematics:

- Thinking methods, sets, logics, combinatorics, graphs
- Number theory, algebra
- Functions, elements of analysis
- Geometry, coordinate geometry, trigonometry
- Probability calculation, statistics

The students admitted in the academic year 2023/2024 graduated according to the examination requirements set under the previous NAT, and many correspondence students passed their exams before the introduction of the two-level GCSE system. Thus, we need to take into account the previous graduation requirements and prepare for the changes in the content of mathematics under the new NAT. Several subjects, particularly relevant to technical and IT subjects in bachelor's degrees, have been transferred from the intermediate level examination requirements to the advanced level requirements or have been removed from the compulsory secondary school curriculum [4].

Students' advanced level results do not only highlight narrow specific knowledge and skills, but also the overall preparedness and learning abilities of students in general. Students who scored higher in the school-leaving examinations were more likely to be better able to adapt to the curriculum and requirements of secondary school and to have developed more effective learning strategies to prepare for examinations. Several studies show that different entry requirements have an impact on the learning strategies of first-year students (see e.g. [9]). The preparation for the advanced level exam generally requires a deeper understanding and critical thinking, which can be an outstanding advantage at the university level. These students often have stronger problem-solving skills, better analytical thinking, and higher levels of motivation, which can contribute to their success at university and high performance in their exams. Advanced level results can be a good predictor of how someone will do at university. Students who come in with better advanced results are often more confident and better prepared for the challenges of university. This can, of course, also help them to be less exposed to academic failure or drop-out during their university years. There are several links between better mathematics results and university studies, which can be summarized, for example, as follows:

- Importance of prior preparation: a good mathematics advanced level result usually indicates that the student has basic mathematical knowledge and skills, which can be essential for university studies, as many training programs require these foundations in several courses. [12] However, as the analyses show, the level of the school-leaving examination is crucial.

- Career relevance: for certain professions, such as engineering, IT, mathematics, or science, an adequate level of mathematical knowledge and skills is essential. [11, 14] Students with a higher mathematical background are often more successful and effective in these fields, and then in the workplace, where they can put the knowledge they have acquired to good use.

- Problem-solving and analytical thinking: problem-solving and analytical thinking skills acquired during your secondary studies in mathematics are generally useful during your university studies, regardless of the field of study. [1]

The importance of the advanced level has been mentioned above, and below we highlight some of the points that support this:

- Deeper knowledge and skills: the advanced level exams require students to acquire a higher level of knowledge and skills in solving problems, giving them a deeper understanding of mathematical concepts, which can be beneficial for their university studies. The more demanding tasks in the advanced level exam are more challenging, which develop problem-solving skills and can encourage students to perform better and study harder.

- Admission advantage: The results of students who have passed advanced level exams increase the chances of the applicant in the university admission procedures. On the one hand, in the admission system in effect from 2024, the score for the advanced level exam will be equal to the percentage of the exam, while at the intermediate level, the score will be two-thirds of the exam result ($100\% = 67$ points). In addition, several institutions demand an upper secondary school leaving certificate as an admission requirement.

3. About the competency test

As mentioned in the Introduction the entrance competency test was completed by the first-year BSc students belonging to engineering and IT programmes in September 2023. The students were given 45 minutes to complete the test, which consisted of 15 multiple-choice questions. For each question, students had to select one correct answer from five possible 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 options, distractors representing solutions obtained through typical incorrect reasoning or common computational mistakes were intentionally included. [5]

The entrance competency test primarily serves as a diagnostic assessment of the secondary-school-level mathematical knowledge and competencies required for engineering and IT education. The questions are not mainly intended to measure advanced theoretical knowledge; rather, they assess whether students possess the fundamental competencies on which university-level mathematics, computer science, and engineering courses are built. The tasks included in the test cover several key areas that are essential for successful university studies, including:

- algebraic operations and equation solving,
- the concept and analysis of functions,
- basic trigonometric knowledge,
- coordinate geometry,
- sequences,
- geometric reasoning and unit conversion skills.

The test measures not only specific mathematical knowledge elements but also a range of general competencies and cognitive abilities that are essential for successful progression in engineering and IT education. One of the most important of these competencies is analytical thinking. A significant proportion of the tasks require students to break problems down into smaller parts, recognize relationships, and select appropriate solution strategies. For example, the following task of quadratic equation with a parameter:

"For which values of the real parameter p does $px^2 + 2x + 2 = 0$ have no real roots?"

requires not only knowledge and formal application of the quadratic formula, but also the ability to recognize, based on the discriminant, that the equation has no real solution when the discriminant is negative. In addition, due to the nature of mathematical tasks, the test also measures problem-solving ability, logical reasoning, and abstraction skills. Working with mathematical objects - such as functions, parameters, or algebraic relationships - requires abstract thinking. Students must independently recall previously acquired knowledge (which, even in the case of full-time students, may have been learned several years earlier) in order to determine which mathematical method is applicable. The test also partially examines attention and accuracy-related competencies. Many tasks contain elements - such as sign handling, intervals, domain restrictions, or unit conversions - where inattentiveness can easily lead to incorrect results. Furthermore, the test measures cognitive flexibility, since students must switch rapidly between different mathematical domains. In one task, students may apply geometric reasoning; in the next, algebraic transformations; and then trigonometric or functional analysis concepts. To a certain extent, the test also reflects self-monitoring and estimation skills. Due to the multiple-choice format, students can often check whether their results are realistic and determine whether they can eliminate obviously incorrect answer options. This type of metacognitive activity is an important component of independent learning and engineering problem-solving. [8]

The competency elements listed above play a key role in how successfully students can adapt to the higher level of abstraction in higher education and to the complexity of engineering and IT-related problems. The competencies assessed by the entrance test are closely connected to the demands of both Calculus I and Descriptive Geometry. Success in Calculus I mainly depends on students' algebraic skills, understanding of functions, and ability to think abstractly, whereas Descriptive Geometry requires strong spatial visualization and precise geometric reasoning. For this reason, examining the relationship between entrance test results and later achievement in the foundation courses Calculus I and Descriptive Geometry appears to be well justified.

4. Results

4.1. Research questions

In the following section, we will use the results of the input mathematics assessment of first-year undergraduate students to demonstrate the relevance of the mathematical knowledge acquired in secondary school, the gained mathematical competences and the level of the school-leaving examination. To explore the relationship between prior mathematical education, the results of the assessment and the results of the first semester of university studies in the Calculus course, we ask the following questions:

- RQ1: Did the students who passed the higher level in mathematics score better on the competency test?
- RQ2: Did the students who scored higher on the mathematics school-leaving exam do better on the competency test?
- RQ3: Did the students who passed the competency test do better in Calculus I?

4.2. Comparison of the mathematics school-leaving exam results and the competency test results

We compared the results of 377 full-time first-year students at the Faculty of Mechanical Engineering and Information Technology in September 2023 in terms of level and grade of the school-leaving examination and competency test. Since some of the students admitted to the correspondence part-time courses took the final examination before the introduction of the two-level school-leaving examination system, only the students at the full-time course were included in the comparison.

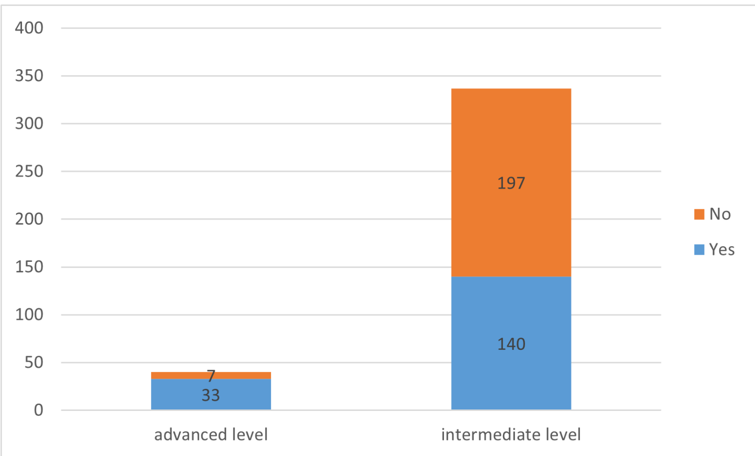


Figure 1. Comparison of the school-leaving examination level and the success rate of the competency test.

Figure 1 shows that 82.5% of the students with the Mathematics advanced level examination passed the competency test, while 41.5% of the students with the intermediate level examination passed the test. The chi-squared test is used to examine whether there is a significant association between the level of the examination and the success rate of the competency test. The results of the test are $\chi^2 = 22.53$ and $p = 2.06 \cdot 10^{-6}$. Since $p < 0.05$, there is a significant association between the level of the exam (advanced or intermediate) and the success rate of the competency test. This answers question RQ1, i.e., students who passed the school-leaving exam at the advanced level were more successful in the competency test than their peers who passed the school-leaving exam at the intermediate level in mathematics. The following chart illustrates the results of the competency assessment by secondary school graduation level and the grade achieved.

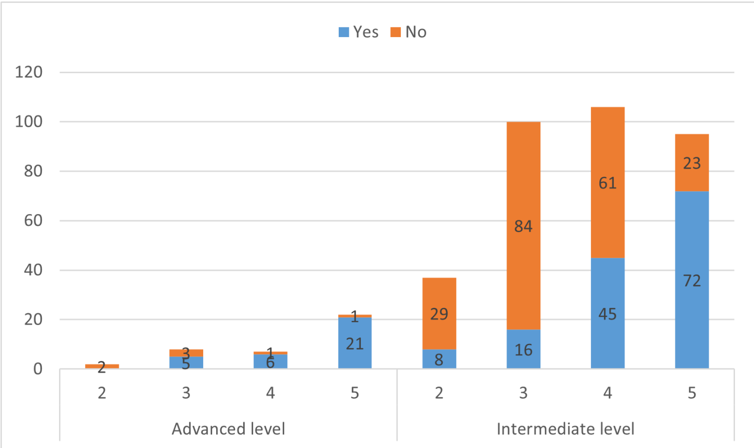


Figure 2. Competency assessment results by graduation level and achieved grade.

We also used the chi-squared test to examine whether there is a significant association between the grade at the school-leaving exam and the success rate at the competency test. The results of the test are $\chi^2 = 96.01$ and $p = 1.01 \cdot 10^{-16}$, which show a highly significant association between the grade of the school-leaving examination and the success of the competency test. This answers question RQ2, i.e., students with a better school-leaving examination score performed better in the competency test.

4.3. Comparison of the results of the Calculus I course and the competency assessment

Out of the 377 full-time undergraduate students who completed the entrance assessment, 29 dropped out by the end of the first semester. Thus, the results of the sample curriculum for the first semester of the BSc courses in Calculus I of the GÉIK are analysed in the case of 348 students.

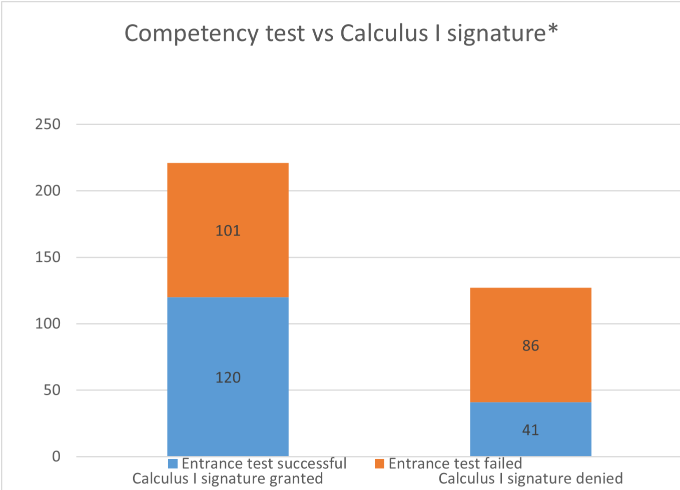


Figure 3. Comparison of Calculus I course completion results with entrance assessment performance.

*Signature means that the student has met the minimum requirements of the course; it is a prerequisite for taking the exam.

As before, applying the χ^2 test to the data in Figure 3, the results of the test are $\chi^2 = 14.85$ and $p = 1.2 \cdot 10^{-4}$. This suggests that there is a significant association between the success of the input measurement and the achievement of signatures.

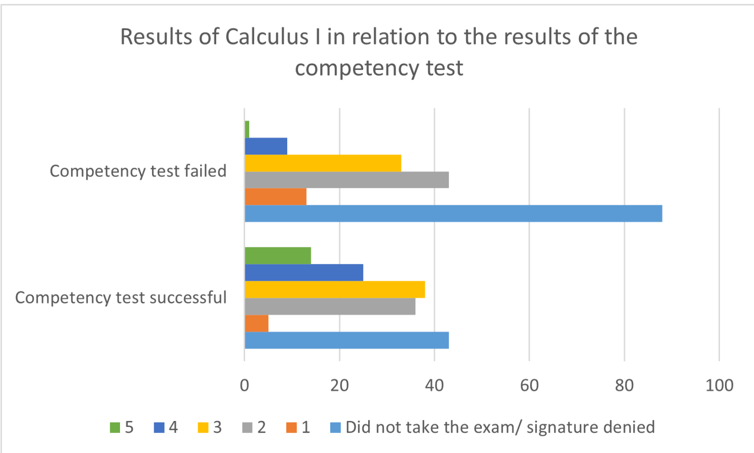


Figure 4. Comparison of the success rate of the competency test and the Calculus I course completion results (examination grade)

In order to examine the relationship between competency success and secondary school graduation scores (exam grades), we again use a chi-squared test to determine whether there is a statistically significant relationship between the two variables. Based on the data, $\chi^2 = 37.05$ and $p = 5.86 \cdot 10^{-7}$. This means that at the significance level of 0.05, we can reject the null hypothesis, i.e. we can state that there is a significant relationship between the success of the competency test and the performance in Calculus I. This also answers question RQ3.

4.4. Analysis of performance in Descriptive Geometry course based on the school-leaving exam grade in Mathematics

As mentioned in the introduction, some of the students studied descriptive geometry in the first semester. The 63 first-year, full-time mechanical engineering students who participated in the competency test were compared to their mathematics school-leaving exam results in the first semester of the compulsory first-year course in Descriptive Geometry. The data show a clear correlation between intermediate and advanced mathematics graduation scores and success in the Descriptive Geometry course. The diagram below shows the results of 63 first-year mechanical engineering students at the University of Miskolc in the course of Descriptive Geometry as related to their school-leaving examination results. While about half of the students with a satisfactory result could not even obtain a signature in the course, more than 80% of those who graduated with an excellent grade received at least a passing mark in the course.

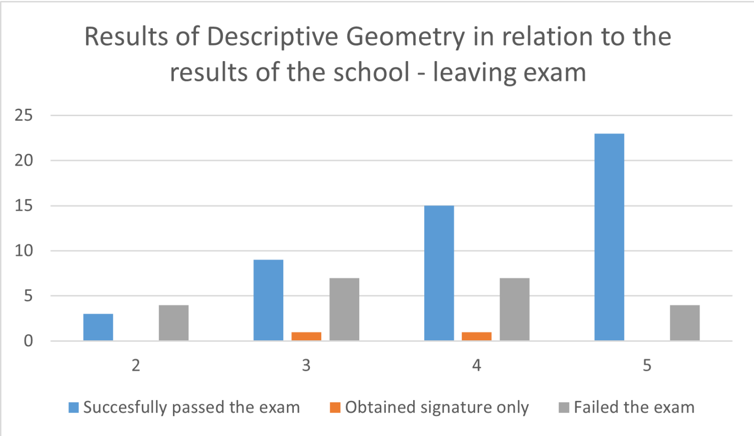
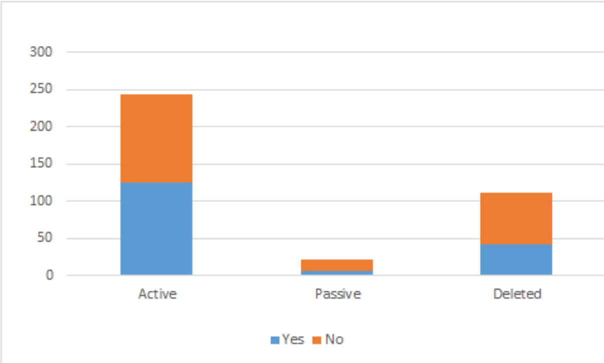


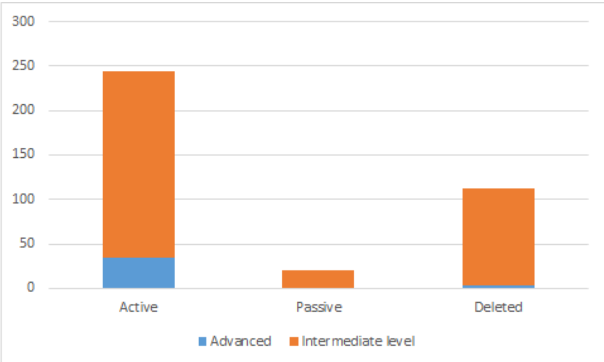
Figure 5. Descriptive Geometry course results by final grade achieved in the Mathematics school-leaving exam.

4.5. Academic progress review

In addition to the completion of first-semester courses, it is important to examine students' subsequent progress. Experience shows that the first two years are critical for the successful completion of studies; accordingly, we focused on this period. On the one hand, we summarized the overall performance (total creditpoints) of the students who participated in the September 2023 assessment during their first two semesters (academic year 2023/2024), as well as their student status in the second semester of the 2024/2025 academic year (the 4th semester according to the curriculum). These were compared with the results of the entry-level assessment and with the level of the mathematics school-leaving exam.



(a) Student status vs competency test.



(b) Student status vs level of the school-leaving exam.

Figure 6. Relationship of competency test and school-leaving exam performance with student status in 2024/2025/2.

Figure 6a shows that student status is closely related to the outcome of the entry assessment. Active students are present in both groups, but passive status appears almost exclusively among those who did not pass the assessment. Deleted status is also more frequent among students who failed, suggesting that success in the entry assessment strongly influences student status. In the active category, it is also visible that the later preparatory course supported students' academic progress. Students who did not achieve a satisfactory result on the test were required to participate in a remedial course. This allowed us to focus specifically on the identified deficiencies and thereby support the affected students in successfully completing university mathematics courses and acquiring the related professional knowledge built upon them. Following participation in the course and the completion of the electronic learning materials, the number of students who were subsequently able to pass the competency test at a satisfactory level increased significantly. [4] It should be noted, however, that academic difficulties resulting from insufficient prior knowledge and competencies are not the only reasons why students may suspend or terminate their studies. Besides academic and study integration difficulties, student dropout may also be influenced by social, sociocultural, and economic factors, such as financial hardship, the necessity of employment during studies, loss of motivation, dissatisfaction with the institution, or inappropriate career choice. [6, 10] Figure 6b presents the student status in terms of the level of mathematics school-leaving exam. It can be seen that the proportion of the students who passed the advanced-level exam is small. However, the majority of them are in active status, out of 39 students only 4 students' status is deleted.

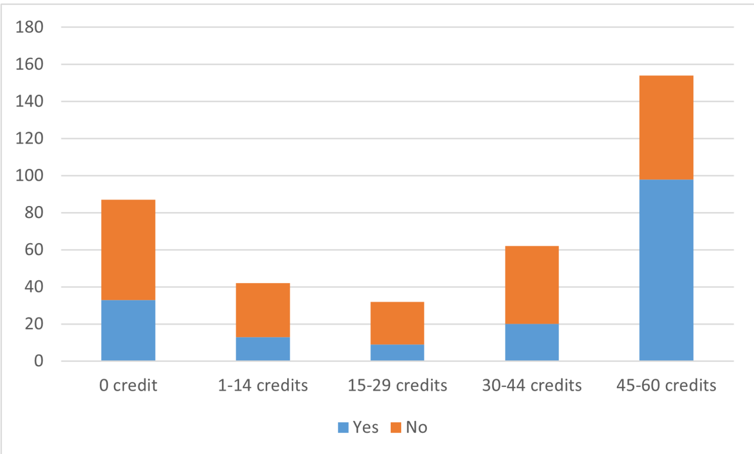


Figure 7. Relationship between the result of the competency test and the earned creditpoints in the first two semesters.

Figure 7 represents that the students who passed the competency test on the first attempt did well not only in mathematics courses, but in all their subjects. Almost two-thirds of the students with 45-60 creditpoints succeeded in the competency test. Besides that, it can be stated that the students taking part in the preparatory cours profited from it, as there were 56 students, who didn't pass the competency test at the first sitting, were able to catch up with the others.

5. Conclusion

The results of the competency assessment confirmed our experience in teaching mathematics at the university level and highlighted the need for a solid mathematical foundation. We compared the results of the competency test with those of the mathematics final examination (level and grade), the results of the first-semester analysis course, and the performance in the compulsory course in descriptive geometry for a certain part of the group. This comparison also demonstrated that both the level and the grade of the school-leaving examination were significantly related to the results of the competency test and, subsequently, to the performance in the courses studied by us.

The results showed that when the advanced level school-leaving examination is not the part of the admission requirements, it is essential for the successful progress of students to revisit the basics of mathematics, address knowledge gaps, organize remedial courses, and possibly include them as criteria in the model curriculum. The study also showed that targeted preparatory courses can be particularly effective in narrowing knowledge gaps among students.

It is important to continue to carry out the competency assessment on a regular basis and to integrate its results into the development of educational strategies and processes. The regular use of competency assessments is not only a valuable tool for monitoring student performance but also provides a basis for the continuous improvement of educational programs. Using the results of the input measures makes it possible to better understand students' needs and to adapt their teaching methods accordingly. It should be stressed that continuous analysis of objective student assessment data is essential for the long-term improvement of education. A thorough evaluation of the data provides the university with the opportunity to refine appropriate teaching strategies and thereby improve the quality and effectiveness of educational processes. The results also show that targeted reinforcement of mathematical foundations is key to reducing student drop-out rates. Students who were allowed to remedy their deficiencies in preparatory courses were more likely to stay in university and to succeed. Based on the results of the competency assessment, the development of education programs should be targeted to ensure that students with weaker foundations receive adequate support. This will not only improve performance but also significantly reduce the student attrition rate at universities.

References

[1] E. Alyahyan, D. Düştegör: *Predicting academic success in higher education: Literature review and best practices*, International Journal of Educational Technology in Higher Education 17.3 (2020), pp. 1–21, doi: 10.1186/s41239-020-0177-7.

[2] C. Csapodi: *A matematika érettségi követelményeinek változása 2024-től – III. rész*, Érintő-Elektronikus matematikai lapok 29 (2023).

[3] C. Csapodi: *A matematika érettségi követelményeinek változása 2024-től – IV. rész*, Érintő-Elektronikus matematikai lapok 30 (2023).

[4] S. Homolya, E. Rozgonyi: *The expected impact of the modified mathematics graduation requirements according to the NAT 2020 on university education*, in: Proceedings of the Conference on Problem-based Learning in Engineering Education, Debrecen, Hungary: University of Debrecen, Faculty of Engineering, 2023, pp. 4–9.

[5] S. Homolya, E. Rozgonyi: *The results of the university competence measurement in mathematics in the view of the tasks*, Mathematics In Education, Research And Applications 8.1 (2022), pp. 24–32, doi: 10.15414/meraa.2022.08.01.24-32.

[6] A. Hrabéczy: *Students in Hungarian Higher Education and Their Perception of Difficulties During Their Studies*, Central European Journal of Educational Research 3.3 (2021), pp. 101–113, doi: 10.37441/cejer/2021/3/3/9990.

[7] L. Á. Kun, S. Berezvai, E. Lógó, T. D. Laet, B. Szilágyi: *Novel Adaptive Entry-Level Maths Assessment Test for Sorting Students to Different Level Courses*, in: Proceedings of the 53rd Annual Conference of the European Society for Engineering Education, Bruxelles: European Society for Engineering Education (SEFI), 2025, pp. 588–596, doi: 10.5281/zenodo.17631398.

[8] Z. Ç. Özcan: *The relationship between mathematical problem-solving skills and self-regulated learning through homework behaviours, motivation, and metacognition*, International Journal of Mathematical Education in Science and Technology 47.3 (2016), pp. 408–420, doi: 10.1080/0020739X.2015.1080313.

[9] M. Pinxten, C. V. Soom, C. Peeters, T. D. Laet, P. Hockicko, P. Pacher, G. Langie: *Learning and study strategies of incoming science and engineering students. A comparative study between three institutions in Belgium, Slovakia, and Hungary*, in: Proceedings of the 44th SEFI Conference, Tampere, Finland: SEFI, 2016, pp. 1–9.

[10] G. Pusztai, H. Fényes, F. Szigeti, K. Pallay: *Dropped-out Students and the Decision to Drop-out in Hungary*, Central European Journal of Educational Research 1.1 (2019), pp. 31–40, doi: 10.37441/CEJER/2019/1/1/3341.

[11] H. Rose, J. R. Betts: *The effect of high school courses on earnings*, Review of Economics and Statistics 86.2 (2004), pp. 497–513, doi: 10.1162/003465304323031076.

[12] P. M. Sadler, R. H. Tai: *The two high-school pillars supporting college science*, Science 317.5837 (2007), pp. 457–458, doi: 10.1126/science.1144214.

[13] D. Sipos, I. Kocsis: *On a method for measuring the effectiveness of mathematics teaching using delayed testing in technical contexts in engineering education*, Annales Mathematicae et Informaticae 60 (2024), pp. 262–277, doi: 10.33039/ami.2024.03.003.

[14] B. Svraka, J. J. Lasker, P. Ujma: *Cognitive, affective and sociological predictors of school performance in mathematics*, Scientific Reports 24.26480 (2024), pp. 1–10, doi: 10.1038/s41598-024-77904-7.