DIGITAL TECHNOLOGY IN UNIVERSITY MATHEMATICS EDUCATION

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Abstract
The development of the technology in the past decade, called Industry 4.0 has an effect on every segment of everyday life, as well as on education. However the use of digital technology in education was launched earlier and it has become an increasingly more important part of education in the last decades, the digital education appearing due to the COVID–19 pandemic has stimulated this paradigm shift. Merely integrating digital technologies does not ensure effectiveness. There are solutions required that seamlessly blend with the methodological practices of traditional education to form an organic and cohesive whole. In this paper, we share the insights acquired from the period of distance education and explore additional potential applications of digital technology. Our goal is to show what opportunities these platforms offer.

Keywords: *Digital technology, mathematics education, teaching and learning, blended learning*

1. Introduction

In education, digital technologies are employed to create captivating learning environments that inspire and drive students' motivation to acquire knowledge. These technologies have been widely acclaimed for their potential to revolutionize education (Taylor et al., 2021). Numerous studies (e.g. Fokides et al., 2020; Heindl et al., 2018) have revealed the correlations between digital technologies and enhanced student engagement, motivation, and positive learning outcomes. Furthermore, technology has the capacity to promote inclusivity, equity, and social responsibility by fostering a learning environment that motivates students and equips them for a society focused on technology.

In (Viberg et al., 2023) the authors emphasize "as mathematics is a key school subject, and one which is problematic for many students, it is important to understand if and how digital tools can help to improve student learning outcomes and relevant learner support. The combination of digital tools and effective pedagogy has been suggested to possess the potential for fostering various essential learner skills, including critical thinking and problem-solving. Additionally, these tools can help tackle common challenges in mathematics education by enabling realistic, problem-solving, and collaborative teaching and learning approaches."

The epidemic COVID–19 has had an effect on all areas of our life, especially in the field of education. During the digital education due to the lockdown both the students and the teachers faced new challenges. The necessarily introduced measures did not allow the systematic planning of education process in details, hence the shift into out-of-class digital education caused unexpected issues for the participants in the education process. During interaction between instructors and students, they did not have the communication routines that would have ensured that the teachers' instructions, the precise coordination of tasks as well as the formation of community should take place (Grajczjár et al., 2021). During the Digital education the role of students' learning on their own became more valuable, and instructors had to support students to a greater extent.

The utilization of digitization in education is also justified by the characteristics of Generation Z students engaged in higher education. Members of this generation were practically "born into" the Internet era, which profoundly influences their human interactions and communication. The online world extends the scope of their self and molds their identity. They possess a unique way of processing information, with the ability to rapidly handle multiple tasks simultaneously (multitasking), but they may find it more challenging to maintain persistent focus for extended periods (Takács, 2023).

Due to the unexpected shift in the beginning, in spring 2020, a uniform platform that could have provided a structured framework and enhanced the transparency and traceability of the learning process was not readily available. Instead, different online platforms were utilized, which often exacerbated the difficulties due to the lack of digital competences among both students and instructors.

Online lessons required more extensive preparations compared to face-to-face courses. Instructors not only conducted lectures and seminars but also had to create e-learning materials and assign tasks to students, resulting in additional time spent on compilation and processing. To adapt to the situation, some universities replaced written assignments with oral exams, which posed greater challenges for instructors, particularly in larger groups. The selection of suitable examination methods, especially in Mathematics courses, presented a particularly problematic issue.

Although the purpose of this paper is not to study the social aspects, it is important to mention that during the online education introduced in 2020 – from the students' point of view – in many cases the greatest difficulty was caused by the lack of the appropriate infrastructure and equipment. The problems arising from the adverse situation did not appear only in Hungary. E.g. a Dutch research (Engzell et al., 2020) analyzed that as a result of the school closures, students suffered from learning losses, which particularly affected disadvantaged families. The Dutch research concluded, among other things, that despite the short distance education period, which was characteristic of the first wave of the pandemic and the world-leading broadband Internet access rate, the results were alarming in the Netherlands as well. A significant number of students made little or no progress while studying at home, and problems occured especially among students from less educated homes.

In addition to the difficulties, it should be highlighted that the online transition also brought results that will fundamentally determine the education of the future, including the methodology of university mathematics education. In the document "Paradigm Shift in Higher Education" already in 2016, it was stated as an objective that it is necessary to introduce forms of training extensively which create more flexible opportunities for learning while working, and one of them is distance learning. According to the medium-term political strategy, the proportion of teaching materials available online and the number of online (MOOC) courses must be significantly increased by 2030. Digital education outside the classroom, which was introduced due to the epidemic situation, became the catalyst for this paradigm shift.

This paper aims to share the insights gained from Analysis courses during the period of distance education and explore additional potential applications of digital technology.

2. Experiences of online education in mathematics

Digital education introduced during the epidemic posed new challenges for university students, too. Prospective students who passed their school-leaving exam in May 2020 and then continued their studies in higher education also studied mathematics both with personal presence and in an online learning framework, and they were able to compare the two forms of education. In spring 2021 a survey was completed involving 1st year BSc engineering students. The questionnaire was sent to 59 BSc students at the Faculty of Mechanical Engineering and Informatics of the University of Miskolc, majoring in vehicle engineering, logistics engineering, and electrical engineering, to which 31 responses were received, i.e. more than half of those questioned responded. The survey was made at the end of the academic session of the second semester in the academic year of 2020/2021. In the autumn semester, all the students participating in the survey successfully completed the course in Analysis 1 and the course Analysis 2 had not been finished yet. In the first semester, the students spent two months in “traditional” face-to-face education, then in the second half of the semester and in the second semester they studied online again. The students received the questionnaire electronically, the Google form was filled in voluntarily and anonymously, thus ensuring that the students should not be influenced by any external factors in their responses. They had five days to answer, so respondents had enough time to collect their experience and send reasoned answers.

The survey consisted of 3 parts, in the first part we asked four questions, the purpose of which was to collect statistical data, namely in what type of secondary school, at what level and with what result students completed their studies, and what grade they achieved in the subject of Analysis 1. The eight questions in the second section included opinions about secondary school online mathematics education. In four of the questions, online education at secondary school had to be evaluated on a five-point Likert scale. Multiple-choice questions were applied to the used online platform, we also asked a ‘yes/no’ question, and students could also describe difficulties or positive experience they had in secondary school mathematics education in the form of a text response. The twenty-one questions of the third section focused primarily on observations related to university online mathematics education, the comparison of online and face-to-face attendance, and secondary school and university mathematics education. Obviously, this part contained the most questions, but the participants could progress quickly in this section as well, since in the majority of cases the answers had to be given on a five-point scale, in a single or multiple choice manner, but there was an opportunity to express their opinion about the online teaching of Analysis in detail in the case of five questions.

In (Árvai-Homolya, 2022) the author compiled the findings of this survey and conducted an analysis of students’ experiences with online mathematics education, basing the analysis on the survey results. In the following, the key findings of the results are emphasized. Previously we have mentioned, in the initial period, non-uniform platform choices were common, and this fact was also confirmed by the survey *(Figure 1)*.

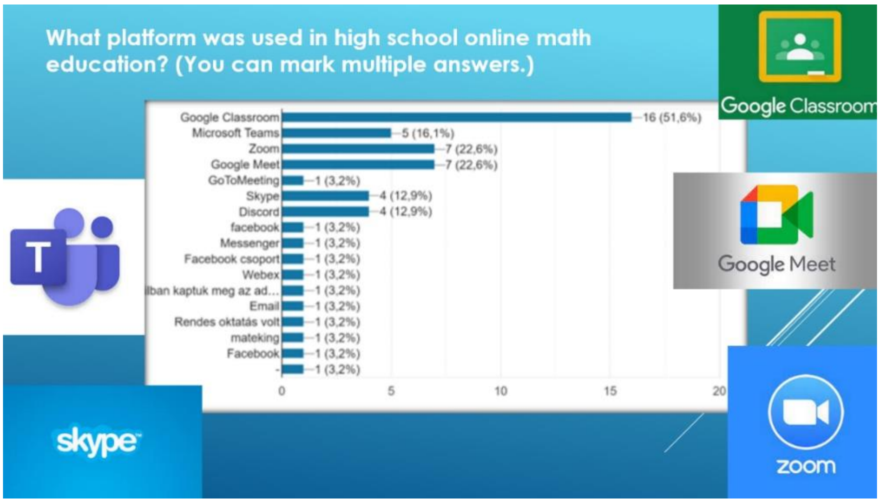

Figure 1. *The applied platforms in high school online math education*

One of the survey questions addressed whether students were apprehensive about online university education based on their experiences during the last semester of secondary school. For those who answered 'yes,' their reasons were as follows:

– Some students felt that in face-to-face classes, instructors could promptly address difficulties that arise, and students are more actively engaged in the learning process.
– Certain students were worried that practical lessons might not be effectively conducted online, and they anticipated strict exam requirements to prevent cheating.
– Comparing the experience of preparing for the school-leaving exam online during the spring of 2020, which involved reviewing previously acquired material, they found higher education demanded acquiring new knowledge and covering more material in a shorter timeframe.
– Many individuals were already apprehensive about the challenges posed by the new learning environment, and they believed that distance education might exacerbate these challenges further.

Since in September 2020, university education began with face-to-face attendance and we switched to online education at the beginning of November, students could compare the two forms of education in Analysis 1. The preferences of the respondents are illustrated in the following pie chart *(Figure 2)*:

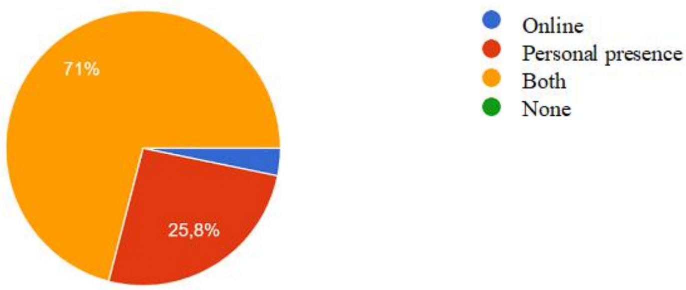

Figure 2. *Comparision of different forms of education in the case of Analysis 1*

Figure 2 illustrates that none of the respondents expressed dissatisfaction with both forms of education. The question regarding the effectiveness of traditional and online education was also asked separately, which aligns with the trend observed in *Figure 2*. Specifically, while the majority (71%) were content with both forms of education, a higher number of individuals preferred attendance education.

According to the students' responses, both the electronic teaching materials for the course and online classes significantly contributed to their preparation for the end-of-term test paper and the exam. Additionally, the majority of students did not encounter any issues while completing Analysis 1 in the online format of education. However, some difficulties were identified, such as the absence of in-person interactions with group mates and spending excessive time in front of the computer. In summary, the first-year engineering BSc students who participated in the survey expressed a high level of satisfaction with the online learning format for the subject Analysis at the university. However, despite this satisfaction, only a third of them indicated they would choose exclusively online education in the future. Nevertheless, all the surveyed students unanimously agreed that it would be beneficial to incorporate the methodologies and tools utilized during online teaching into face-to-face instruction. They highlighted that these methods, along with various online game elements like the use of Kahoot, contribute to a deeper understanding of the learning material and make the classroom experience more engaging and interesting.

3. Some examples for digital technology in mathematics education

In (Viberg et al., 2023) the authors draw attention to the fact that digital tools are creations intended to assist humans in carrying out a range of activities involving technology, individuals, and goal-oriented tasks that require information handling. These components – people, technology, and activities – come together to constitute an information system, where the design of technology, activities, and the roles and responsibilities of individuals are interrelated. Within the realm of education, the technical artifact encompasses diverse software employed for learning and teaching, and nowadays, it often includes hardware provided by schools (e.g., tablets) and learners' personal devices (e.g., smartphones). Additionally, commonly used tools like books are also frequently employed in the educational context.

Educational researchers and practitioners are increasingly showing interest in utilizing mobile technologies, such as smartphones and tablets, for teaching and learning mathematics. The unique features of mobile devices, including portability, internet access, wide popularity among young individuals, and others, have established them as emerging tools with the potential to extend the boundaries of mathematics instruction and learning beyond the confines of traditional educational institutions (Borba et al., 2016).

As evident from the results presented in Chapter 2 of the survey, students also express a demand for the use of digital supplementary methods in traditional classroom education. This demand also requires instructors to continually expand their toolkit, seek out and become familiar with modern teaching possibilities, and deepen their proficiency in using various platforms. Hence I aim to introduce in Chapter 3 some platforms and software that I have either utilized in the past or plan to incorporate into education in the near future. However, it is essential to emphasize that these examples represent only a tiny fraction of the extensive range of digital possibilities available.

3.1. Moodle

Moodle LMS (Learning Management System) is a widely adopted open-source education management platform primarily designed for higher education institutions. It serves as a versatile tool for storing, editing, and organizing course materials, as well as for monitoring and evaluating individual students' activities. Additionally, Moodle enables online digital collaboration between instructors and students.

The role of the Moodle-based online learning framework at the University of Miskolc (https://elearning.uni-miskolc.hu/) is increasingly significant, especially in face-to-face education following the implementation of distance education during the pandemic. The e-learning system serves as a defining element of blended learning, which is steadily gaining ground and holds promise for the future. The e-learning system courses offer participants the flexibility to pursue their individual learning paths at their own pace and according to their own schedules.

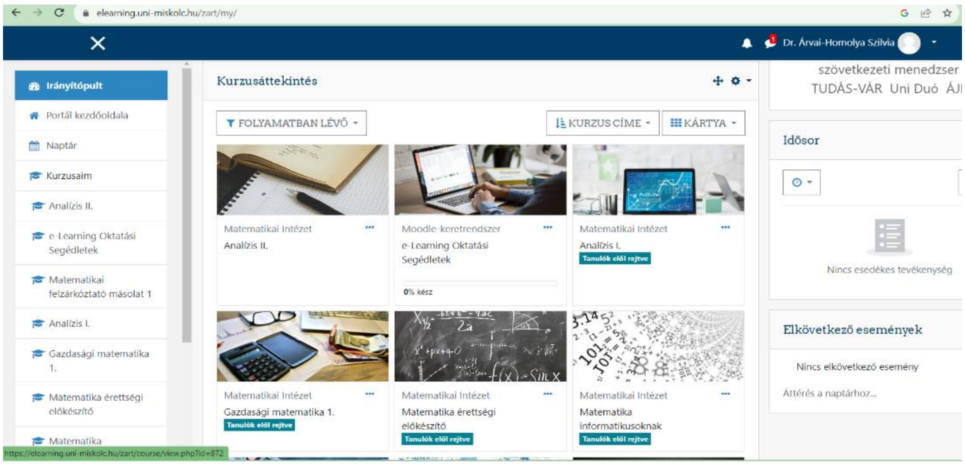

Figure 3. *Instructor course overview page in the e-learning system*

- With help of Moodle's built-in course material editor, we can create various content types such as text, web pages, external and internal links, labels, and incorporate multimedia elements such as images, audio, video files, and animations. Additionally, it allows for the inclusion of documents created with text editors or spreadsheets, by choosing the H5P activity type, we can create many interactive tasks (or a whole series of tasks) for the students.
- The system incorporates its own exam editor, which allows for the compilation and combination of various task types, such as true-false, multiple-choice, additional text, and essay questions, within the exam module. Additionally, we can assign self-checking questions, as well as time- or time-interval-related exams, to the courses and study materials.
- In Moodle, students have access to polls, forums, and chat features. The forum serves as a platform for asynchronous discussions, while the chat module facilitates real-time web-based conversations among participants.

From the perspective of mathematics education, it is worth noting that Moodle supports editing and inserting mathematical equations using the MathType plugin.

3.2. Kahoot!

Many teachers recognize the difficulty of maintaining students' motivation, engagement, and concentration during a lecture. This challenge becomes even more significant in higher education, especially in large groups with limited interaction. Educational research has consistently demonstrated that actively engaged students in the learning process tend to acquire more knowledge than passive learners (Wang et al., 2020). There are various approaches to enhance interactivity during lectures, such as dividing the class into smaller groups, engaging the audience with questions and audience response systems, introducing student workable cases, utilizing written material, organizing debates, reaction panels, and guest talks, incorporating simulations and role-plays, utilizing video and audiovisual aids, and employing effective presentation skills.

The concept behind Kahoot! is to amalgamate an student response system (SRS) with the existing technical infrastructure in schools/at universities, students' personal digital devices, social networking, and gaming into a single interactive learning platform. The primary objective of Kahoot! is to enhance engagement, motivation, enjoyment, and concentration to improve learning outcomes and create a dynamic classroom environment.

Kahoot! is a game-based student response system (GSRS) that temporarily transforms the classroom into an interactive game show, with the teacher as the host and the students as the contestants. The platform originated from the Lecture Quiz research project initiated at the Norwegian University of Science and Technology in 2006, where multiple prototypes were developed and evaluated through experiments over several years. These early prototypes demonstrated that Lecture Quiz effectively increased student motivation, engagement, and perceived learning through entertaining social learning activities. In 2012, a start-up company was founded to develop a new game-based learning platform, named Kahoot!, based on the foundations of Lecture Quiz. The Kahoot! platform was officially released in September 2013. The platform was designed to meet essential requirements: it should be user-friendly for teachers to create their own content, conduct quizzes, and assess students; students should be able to join without the need to register, play anonymously to avoid embarrassment, have fun, engage in healthy competition, and learn effectively (Wang, 2015).

One of the most crucial features of the Kahoot! platform is its creator tool, enabling users to design what is referred to as a "kahoot". This kahoot can incorporate various question types, including Quiz questions, True or False questions, Open-ended questions, Puzzles, Polls, Word clouds, or Slides. Additionally, the creator tool offers the option to use a question bank to add relevant questions through topic-based searches. Another alternative is to import questions and answers from a spreadsheet. Furthermore, the creator tool allows for customizing each question by setting a specific time limit (ranging from 5 to 120 seconds), specifying the number of points awarded for each question, and adding media content, such as pictures or YouTube clips. Additionally, users can choose to reveal the pictures gradually over time. *Figure 4* shows a screenshot of a single choice question during the game, the The upper left corner displays the number 12, indicating the remaining seconds to answer.

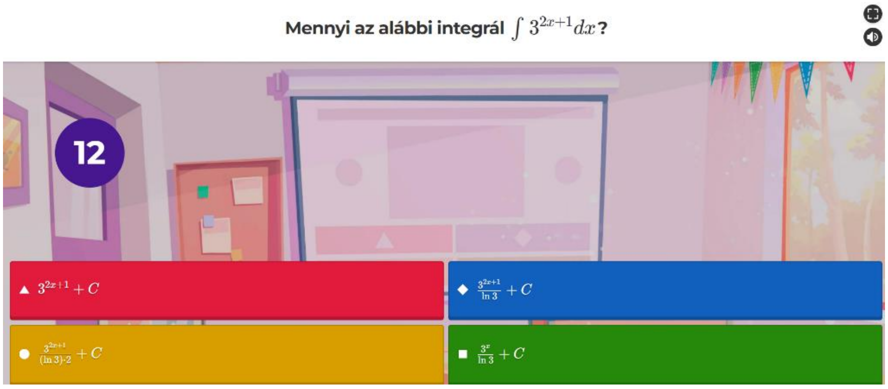

Figure 4. *Single choice question in the topic of integration*

To initiate Kahoot!, the host, usually a teacher, will open Kahoot! in a web browser on a digital device connected to a large screen visible to everyone in the room. During the game launch, the host will be presented with various options that impact the gameplay, such as selecting whether it will be player vs. player or team vs. player, as well as choosing the lobby music. Students can access Kahoot! without the need for logging in; they simply need to enter a game PIN, which serves as a unique identifier for the specific game, and select a nickname through a web browser or the Kahoot! app. Once the students have entered their chosen nicknames, their animated names will be displayed on the lobby screen, and a player counter will be updated accordingly. In the event that the host (teacher) identifies any inappropriate nicknames, they have the option to remove the respective player from the game. (Wang et al., 2020)

At the end of the game a podium displays the final results, which, based on my experience, the participating students always look forward to with great enthusiasm.

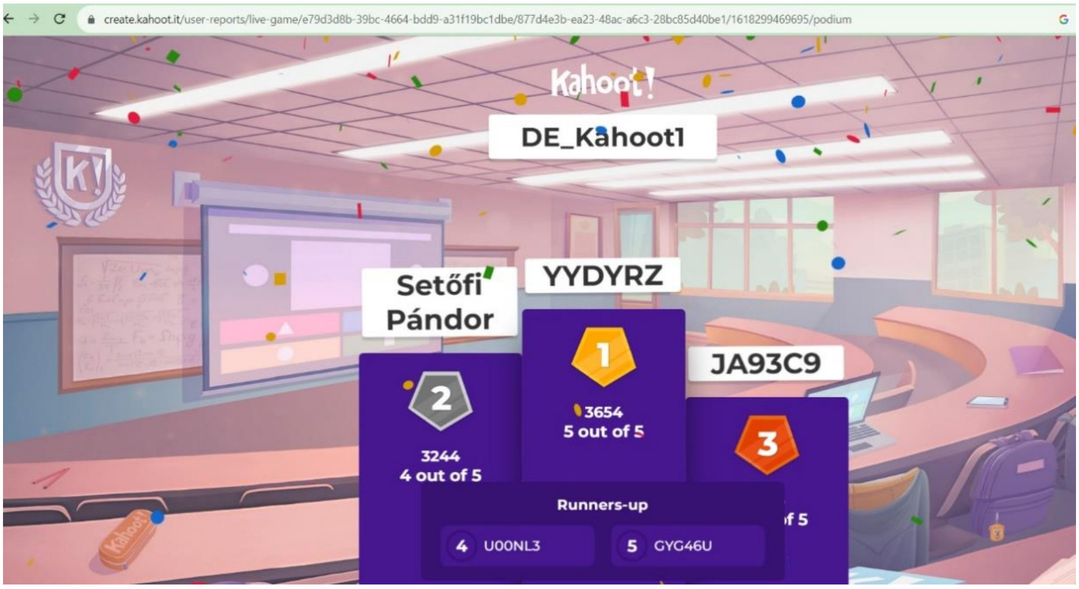

Figure 5. *Podium of a game in topic Differential equations* (Analysis 2, 2021)

Kahoot! offers a downloadable mobile app for both iOS and Android devices. With the app, students can create kahoots, track their progress, and enjoy the flexibility of playing Kahoot! at any location and whenever they prefer. While listing all of Kahoot's plans (https://kahoot.com) for teachers, students, and companies is beyond the scope of this article, it is important to note that they offer AI-assisted solutions.

3.3. Geogebra

GeoGebra is a dynamic mathematics software suitable for all levels of education, seamlessly integrating geometry, algebra, spreadsheets, graphing, statistics, and calculus in a unified engine. Moreover, GeoGebra provides an online platform that hosts an extensive collection of over 1 million free classroom resources, contributed by GeoGebra's multilingual user community. These valuable resources can be easily shared through the collaborative platform called GeoGebra Classroom, enabling real-time monitoring of student progress.

Due to its comprehensive features and user-friendly interface, GeoGebra has emerged as one of the leading providers of dynamic mathematics software. It plays a vital role in supporting STEM education and fostering innovation in teaching and learning worldwide (https://www.geogebra.org).

GeoGebra has gained considerable attention due to its robust combination of Dynamic Geometry System (DGS) and Computer Algebra System (CAS) functionalities (Gökçe et al., 2022). It proves to be a highly effective software for teaching and learning arithmetic, geometry, algebra, and calculus, offering meaningful learning opportunities for both students and teachers (Zulnaidi et al., 2020). The software not only encourages creative exploration from a geometrical perspective but also from an algebraic standpoint.

For instance, students can draw circles and adjust their equations, observing how changes in the equation affect the circle's properties in the geometry window. This dynamic feature of GeoGebra promotes exploratory learning, enabling students to modify constructions, introduce new elements, and rearrange them, which enhances their comprehension of functional relationships. However, it is important to note that merely drawing mathematical objects and figures is insufficient for a comprehensive understanding of fundamental mathematical concepts; creative dynamic practices are equally essential. GeoGebra facilitates such practices by dynamically navigating through multiple mathematical representations (Velichová, 2011).

Figure 6 provides an illustrative example of surface representation. GeoGebra demonstrated its exceptional utility as a visualization tool, and students found it valuable for their learning, they also used it at home during digital education.

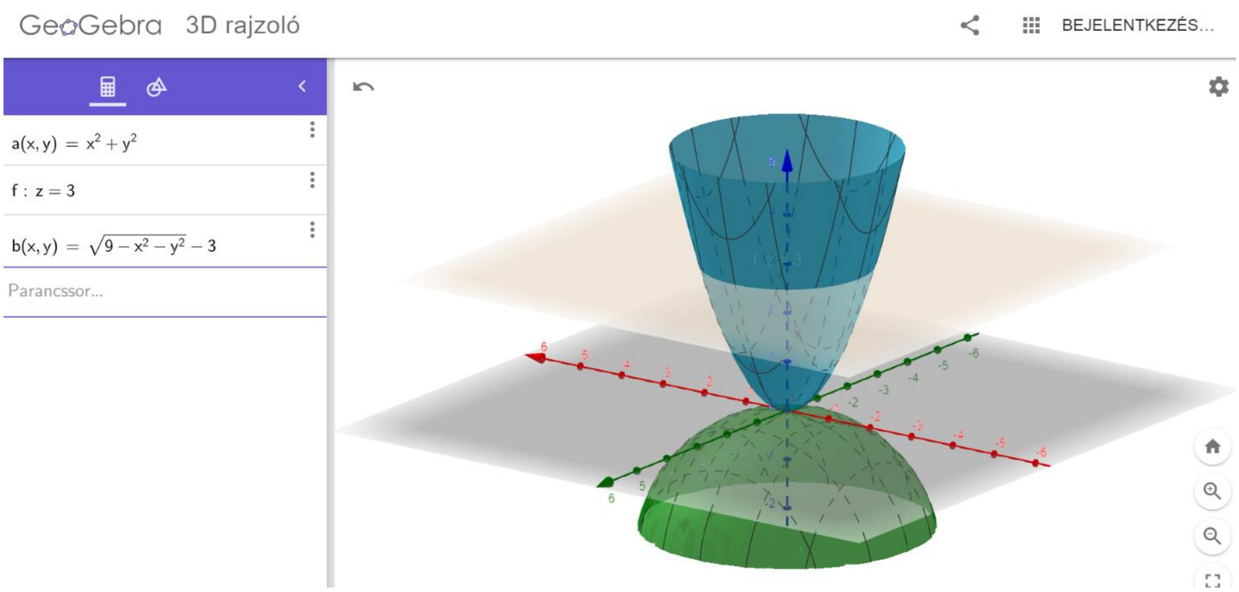

Figure 6. *Screenshot of using GeoGebra during an Analysis 2 course*

3.4. Some other digital options

Finally, in addition to the previously mentioned platforms, we list some easily available options that can be incorporated into the teaching and learning process.

- **Khan Academy** (https://www.khanacademy.org) Khan Academy offers complete free access to its platform, presenting a personalized learning experience that empowers students to study at their preferred pace. With a wide range of college math topics presented in a user-friendly manner, it facilitates easy comprehension. Moreover, Khan Academy allows for both online and offline usage, enabling students to study mathematics even without an active Internet connection. Khan Academy empowers teachers to identify their students' areas of improvement, customize their instruction, and cater to the unique needs of each individual learner. The resources are currently being translated into over 40 languages, including Hungarian. As a result, you can find some lessons available in Hungarian on the website.
- **OER Commons** (https://oercommons.org) is a public digital library of open educational resources. Open Educational Resources (OER) refer to teaching and learning materials that are readily accessible, allowing for downloading, editing, and sharing, with the aim to cater to the diverse needs of all students. These resources encompass a wide array of content, including textbooks, lesson plans, assignments, games, and various educational materials. OER is not limited to a specific format and can be produced in various mediums, such as paper-based text, video, audio, or computer-based multimedia.
- **Wisc-Online** (https://www.wisc-online.com) provides an expanding collection of freely accessible learning objects for students and learners at all levels, teachers, parents, and individuals worldwide. The digital library of resources has been primarily created by subject matter experts affiliated with the Wisconsin Technical College System (WTCS). The content is developed and produced by a collaborative team consisting of instructional designers, technical

editors, and multimedia developers from Fox Valley Technical College's Learning Innovations team.

– **Mathcad** (https://www.mathcad.com/en) is user-friendly and intuitive mathematical software that enables students to solve and comprehend engineering problems by emphasizing the phenomenon itself rather than getting bogged down by mathematical complexities. By using Mathcad, the main hindrance to successful resolution of engineering problems lies not in their mathematical intricacy.

4. Summary

The rapid advancement of digitalization in the world around us demands the implementation of new methods in education, including university-level mathematics instruction. Digital education means much more than merely supporting traditional education with digital tools: it entails a new mindset, new pedagogical methodologies, innovative learning approaches, the traceability of learning paths, and the creation of an open educational environment that reflects the challenges of the digital age.

The survey conducted among first-year engineering students during the 2021/2022 academic year, as discussed in this article, reaffirmed that digitization is not the end goal but a tool. The students clearly expressed the need for personal presence and direct instructor explanations, while also considering the integration of new digital possibilities into the teaching and learning process necessary.

The main objective of the article, beyond presenting the results of the survey related to digital education, was to provide a brief insight into some learning-supporting digital platforms that can be utilized in both university mathematics education and home learning environments. The range of available, easily accessible digital platforms and software is almost inexhaustible, but simultaneously, it places the responsibility on teachers to stay abreast of technological advancements. The use of digital technology, therefore, demands continuous self-education from instructors, but based on our experiences, the incorporation of these supplementary tools motivates students and supports them in the learning process.

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