

DIGITAL ENVIRONMENTS FOR LEARNING IN MATHEMATICS AND INFORMATICS TEACHER EDUCATION

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Absztrakt

DIGITÁLIS KÖRNYEZETEK

A LEENDŐ MATEMATIKA- ÉS INFORMATIKA TANÁROK KÉPZÉSÉBEN

A digitális technológiák egyre fontosabb szerepet töltenek be a matematika és az informatika oktatásában. A tanulmány a digitális környezetek alkalmazási lehetőségeit vizsgálja e tantárgyakban, valamint pedagógiai jelentőségüket a leendő tanárok képzésében. Az elemzés rámutat, hogy a digitális eszközök megfelelő didaktikai integrációja támogatja az aktív és reflektív tanulást, valamint hozzájárul a problémamegoldó gondolkodás és a pedagógiai kompetenciák fejlődéséhez.

Kulcsszavak: digitális technológiák, matematikaoktatás, informatikaoktatás, tanárképzés

Diszciplína: pedagógia

Abstract

Digital technologies are becoming an integral part of contemporary educational environments, and their importance is gradually increasing in mathematics and informatics education as well. This paper aims to analyse the possibilities of using digital environments in these subjects and to highlight their pedagogical potential in the education of future teachers.

Keywords: digital technologies, mathematics education, informatics education, teacher education

Discipline: pedagogy

Digital technologies have become an integral part of the educational process at all levels of education. In the education of future teachers, digital environments play an important role not only as tools for delivering content but also as the means for developing pedagogical, didactic, and technological competencies. Teacher education at universities should enable students to experience digital environments not only from the perspective of users but also from the perspective of future creators and evaluators of digital learning materials (Bocconi et al., 2016; Pšenáková, 2018).

This paper aims to analyse the role of digital environments in mathematics and informatics education and to highlight their importance in the education of future teachers, particularly about supporting active learning, problem solving, and reflection on the learning process.

Based on our pedagogical experience, it can be observed that the use of digital environments in the education of mathematics and informatics teachers has its specific characteristics. While in

mathematics digital environments are often used for the visualization of abstract concepts, supporting problem solving and providing feedback, in informatics they are naturally associated with algorithmic thinking, simulation, and the creation of digital artefacts. Despite these differences, several common didactic principles can be identified, such as an emphasis on student activity, systematic work with tasks, and reflection on the learning process (see: Pokorný, 2015).

Our pedagogical experience also indicates that digital environments provide the greatest benefits when they are integrated into teaching based on carefully designed didactic strategies. The use of digital tools without a clear pedagogical purpose leads only to a formal change in the organisation of teaching without a significant impact on the quality of learning. This conclusion corresponds with research findings that emphasize the need for methodological grounding of digital environments in teacher education (Pokorný, 2013; Pšenáková, 2021).

Defining the Concept of a Digital Environment in the Context of Teacher Education

The concept of a *digital environment* is used in scholarly literature in various ways, and its interpretation depends on the context in which it is applied. In a broader sense, a digital environment is often understood as a set of digital technologies, tools, and platforms that mediate educational content and support communication, interaction, and learning. In a pedagogical context, however, it does not refer only to technical infrastructure but primarily to a didactically designed space in which educational activities are carried out about learning objectives, content, and the needs of learners.

In the education of future teachers, the concept of a digital environment acquires a particular significance. Future teachers do not act in digital environments only as pupils or students, but also as potential creators, evaluators, and facilitators of digitally supported learning. Several studies indicate that the quality of students' experience with digital environments during their university studies significantly influences their later attitudes towards the use of technologies in pedagogical practice (Bocconi et al., 2016).

From a didactic perspective, it is therefore necessary to distinguish between the simple use of digital tools and the purposeful integration of digital environments into teaching. As Pokorný (2015) points out, the presence of digital technologies in teaching does not in itself guarantee higher

quality or effectiveness. The decisive factor is the way in which these technologies are integrated into teaching, what types of tasks they support, what level of activity and reflection they require from students.

Based on our pedagogical experience and an analysis of relevant literature, this paper understands a digital environment in the education of future mathematics and informatics teachers as a comprehensive learning space that includes a didactically designed set of digital tools, platforms, and learning materials supporting learning, interaction, and reflection.

A digital environment defined in this way includes not only learning management systems (e.g. LMS), but also interactive learning materials, visualization tools, simulations, and other digital resources that enable students to work actively with content. An important component of a digital environment is also feedback, whether in the form of automated assessment, interaction with the teacher, or discussions among students.

From the perspective of mathematics and informatics, digital environments can be seen as spaces that make it possible to connect abstract concepts with concrete representations and procedures. In mathematics, digital environments are often used to visualize relationships, support problem solving, and verify procedures, while in informatics they enable the simulation of algorithms, work with data, and the creation of digital

artefacts. However, digital environments in both disciplines share a common goal - to support systematic and active learning (Pokorný, 2013; Pšenáková, 2018).

Digital Environments in Mathematics and Informatics Education

In the context of mathematics and informatics education, digital environments can be understood as a broad spectrum of tools and platforms that differ in their functions, levels of interactivity, and didactic orientation. Their aim is not to replace traditional teaching but to expand the possibilities for working with subject matter and to support the active engagement of students in the learning process.

The use of digital environments in mathematics and informatics education is currently the subject of extensive scholarly discussion. Many authors agree that digital environments have the potential to support active learning, individualisation, and the development of higher cognitive processes; however, their pedagogical benefits are not automatic and depend on the way they are implemented in teaching (Bocconi et al., 2016; Kirkwood & Price, 2014). From this perspective, it is important to analyse not only the technological possibilities of digital environments but, above all, their didactic functions within specific subjects.

Digital environments can serve various roles in education – ranging from the

visualisation and presentation of subject matter, through supporting problem solving, to creating environments for experimentation and the development of students' own solutions. A specific group is represented by learning management systems (LMS), which enable the organisation of course content, assignment of tasks, communication among participants in the educational process, and the provision of feedback. In the preparation of future teachers, these environments are also important for the development of pedagogical and organisational competencies, as students learn the principles of planning and managing teaching in digital environments (Bocconi et al., 2016).

However, the specific forms and functions of digital environments differ depending on the nature of subjects. Universal solutions do not exist; what is essential is that digital environments support students' active work, enable feedback, and create opportunities for reflection on learning in both mathematical and informatics contexts.

Digital Environments in Mathematics Education

In mathematics education, digital environments are often associated with supporting the understanding of abstract concepts through visualisation, dynamic representations, and interactive tasks. Through digital tools, students can manipulate and experiment with mathematical objects, modify parameters, and

observe the consequences of these changes, which can contribute to a deeper conceptual understanding of the subject matter (Hoyles & Lagrange, 2010; Drijvers et al., 2016).

At the same time, several authors point out that digital tools may also lead to superficial learning if they are used merely to demonstrate completed solutions without actively engaging students in the process of problem solving (Kieran et al., 2014). In this context, the importance of tasks that encourage students to formulate their own strategies, verify solutions, and reflect on the problem-solving process is emphasised.

In pedagogical practice, various digital environments are used for this purpose, such as tools for creating interactive tasks and providing feedback (e.g. Kahoot, Quizizz), or environments enabling dynamic work with mathematical representations (e.g. GeoGebra). These environments allow students to engage actively with the content and provide immediate feedback, which is particularly important in the process of solving tasks.

Based on pedagogical experience, it appears that digital environments in mathematics are most beneficial when they are not used solely for the assessment of knowledge but rather when they support discussion about solution strategies and enable the comparison of different approaches to solving problems. Such use of digital environments corresponds with the recommendations of authors who emphasise the need to connect techno-

logical tools with the didactic objectives of mathematics education (see: Hoyles & Lagrange, 2010; Pokorný, 2015).

Digital Environments in Informatics Education

In informatics education, digital environments represent a natural component of teaching, as the content of the subject itself is closely connected with working in digital environments. Digital tools enable students to design, test, and analyse solutions to problems, thereby supporting the development of algorithmic and problem-solving thinking.

Effective digital environments in informatics should provide space not only for creating functional solutions but also for reflecting on the process, identifying errors, and optimising procedures. This reflective dimension of work is considered crucial for the development of a deeper understanding of informatics concepts (Denning, 2017).

In pedagogical practice, various environments that support creation and experimentation are used, such as visual programming environments (e.g. Scratch) or online simulators and development environments (e.g. Tinkercad, repl.it). These environments provide opportunities for iterative problem solving, working with errors, and continuous reflection on the solution process.

However, in informatics education as well, the pedagogical benefits of digital environments depend on the way they are

integrated into teaching. The use of digital tools alone, without a clear didactic intention, does not automatically lead to a deeper understanding of the subject matter (Kirkwood & Price, 2014). Digital environments are most beneficial when students are guided not only towards obtaining the “correct result” but also towards analysing the chosen approach and its didactic implications, which is particularly important in the preparation of future informatics teachers.

Common Features and Differences in Approaches to Digital Environments

Despite the specific characteristics of mathematics and informatics, several common didactic principles can be identified in approaches to digital environments. Many authors emphasise the importance of active student engagement, working with tasks that support problem solving, and providing feedback that leads to reflection on learning (Kirkwood & Price, 2014; Bocconi et al., 2016).

The differences between the two disciplines are reflected mainly in the types of activities that digital environments support. While in mathematics the focus is primarily on supporting the understanding of abstract relationships and problem-solving strategies, in informatics the emphasis is placed on the process of designing, testing, and refining solutions. Nevertheless, digital environments in both

disciplines fulfil a similar role – they create conditions for systematic, active, and reflective learning (Pokorný, 2013; Pšenáková, 2018).

The Use of Digital Environments in the Education of Future Mathematics and Informatics Teachers

Digital environments also play a significant role in the education of future teachers, as students in teacher education programmes do not act in digital environments only as learners, but also as future creators and organisers of digitally supported teaching. Higher education therefore represents an important space for gaining experience with different types of digital tools and for developing the ability to critically evaluate their didactic potential.

In the pedagogical preparation of future mathematics and informatics teachers, digital environments are primarily used to support students’ active engagement with the content, the solving of problem-based tasks, and reflection on their own procedures. In this way, students become familiar not only with the subject matter itself, but also with ways in which digital tools can be effectively integrated into the teaching of subjects. Examples of such digital environments used in the preparation of future teachers are illustrated in Figure 1.

Digital Environments in the Teaching of Mathematics to Future Teachers

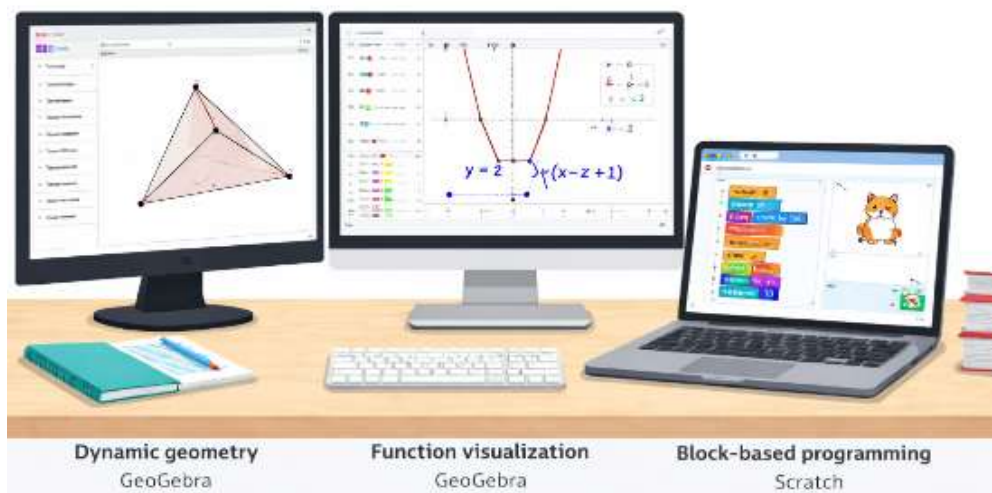
In mathematics teaching, digital environments are primarily used to support the visualisation of mathematical relationships and experimentation with mathematical objects. Students can work with dynamic representations, modify parameters, and observe the consequences of these changes, which supports a deeper understanding of mathematical concepts.

In addition to visualisation tools, digital environments that enable task assignment and immediate feedback are also used in teaching. Such environments can support student activity during lessons while

simultaneously providing teachers with an overview of the level of students' understanding of the subject matter. However, an important aspect of their use is that digital tools should not serve only for the assessment of knowledge but should also support discussion about solution strategies and reflection on problem-solving processes.

As an illustration of the use of digital environments in the teaching of future mathematics teachers, one may consider the use of dynamic geometry software (e.g. GeoGebra, Cabri Geometry, Desmos Geometry, Cinderella, or C.a.R.). It is important that future mathematics teachers do not use these tools merely as a more

Figure 1: Examples of digital environments supporting learning in mathematics and informatics (dynamic geometry software, function visualization, and block-based programming). (Source: Authors' elaboration; visualization generated with the assistance of the generative AI tool ChatGPT.)



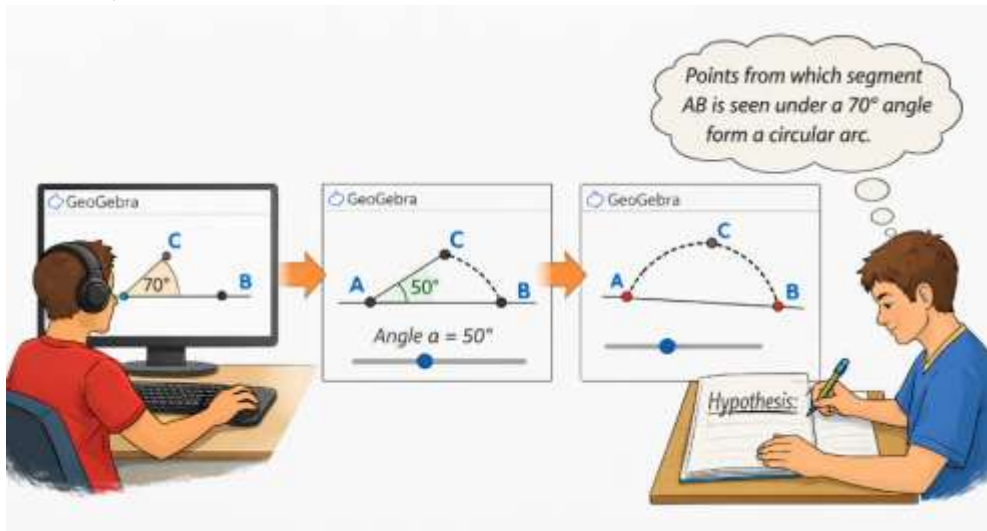
precise and convenient substitute for drawing on the board, but that they learn to construct geometric objects, modify their properties, and manipulate them dynamically.

The essence of working with these tools lies in the use of dynamic elements that allow students to discover mathematical relationships in an active and exploratory manner. For example, using the *Trace* tool in the GeoGebra environment, students can investigate the set of all points in the plane from which a given segment AB is seen under an angle of 70° . After constructing the segment AB and dynamically changing the angle using a slider, a set of points is generated whose

shape students can observe and analyse. In this way, they can formulate hypotheses about the properties of geometric objects, which they subsequently verify or prove using mathematical arguments. The process of discovering geometric properties through dynamic manipulation in the GeoGebra environment is illustrated in Figure 2.

Solving similar tasks leads students to understand that digital tools are particularly valuable when they support the exploratory nature of learning. Through dynamic manipulation, students can, for example, investigate the triangle inequality or the relationship between the distance of the centers of two circles, their radii, and

Figure 2. Schematic illustration of discovering geometric properties in the GeoGebra environment. (Source: Authors' elaboration; visualization generated with the assistance of the generative AI tool ChatGPT.)



the number of their intersection points. When solving construction problems, they can also analyse how the choice of given elements influences the number of possible solutions.

Digital environments are also used when exploring the properties of functions. Using sliders that allow them to modify parameter values, students can analyse the relationships between the graphs of functions $f(x)$ and $f(x)+a$, $f(x)$ and $f(x+a)$, $f(x)$ and $-f(x)$, $f(x)$ and $a \cdot f(x)$, or $f(x)$ and $f(a \cdot x)$. In this process, students formulate hypotheses, subsequently verify them, and discuss their validity.

The importance of digital environments is also evident when solving stereometric problems, where they enable dynamic manipulation of spatial objects and an easy change of perspective on a construction, which is often very difficult to achieve when drawing on a board or paper using traditional methods.

As another illustration of the use of digital environments in the teaching of future teachers, one may consider our own interactive applications implemented in the LMS Moodle environment. In the course *Combinatorics and Data Handling*, in addition to video lectures and textual learning materials, interactive applications designed for practicing the solution of combinatorial problems are also available. For example, students are required to find all possible solutions to a specific problem (e.g. all possible ways in which the sum of 13 can appear when three different dice are rolled).

Within these applications, students experiment, actively search for solutions, and gradually correct their previous mistakes based on the feedback provided by the application. Such an environment supports active learning and enables students to acquire new knowledge through their own activity.

Digital environments also play an important role in the assessment of students' knowledge. The experience with online testing gained during university studies can later be used by future teachers in their pedagogical practice, for example when implementing distance learning or conducting online examinations. The COVID-19 pandemic showed that many teachers were not sufficiently prepared for this form of teaching, partly because they had not encountered it during their own studies.

An example is the examination from the course *Combinatorics and Data Handling* (Pokorný, 2026), which was conducted in the Moodle environment. The test was automatically generated from a large database of questions, minimizing the probability that two students would receive the same test. At the same time, students were connected via Microsoft Teams with their cameras turned on during the entire testing period, allowing the instructor to monitor the course of the examination. A statistical comparison of the results of students who completed the test online and those who took it in person did not reveal a significant difference in performance, suggesting

that this form of assessment can largely eliminate opportunities for cheating.

For future teachers, it is important to gain experience with such forms of assessment, as they can serve as inspiration for their future pedagogical practice.

Digital Environments in the Teaching of Informatics to Future Teachers

In informatics education, digital environments occupy a specific position, as the very nature of the subject is closely connected with working in digital environments. Students use environments that enable the design of algorithms, program development, or the simulation of technical solutions, thereby acquiring not only technical skills but also the ability to analyse and optimise solution procedures.

Such environments allow students to experiment with different circuit configurations without the need for physical hardware while immediately observing the consequences of their solutions. Students design solutions, test their functionality, identify errors, and gradually modify and optimise their solutions. This iterative process supports the development of algorithmic thinking while also enabling the connection between theoretical knowledge and practical application and leading students to reflect on their own problem-solving procedures.

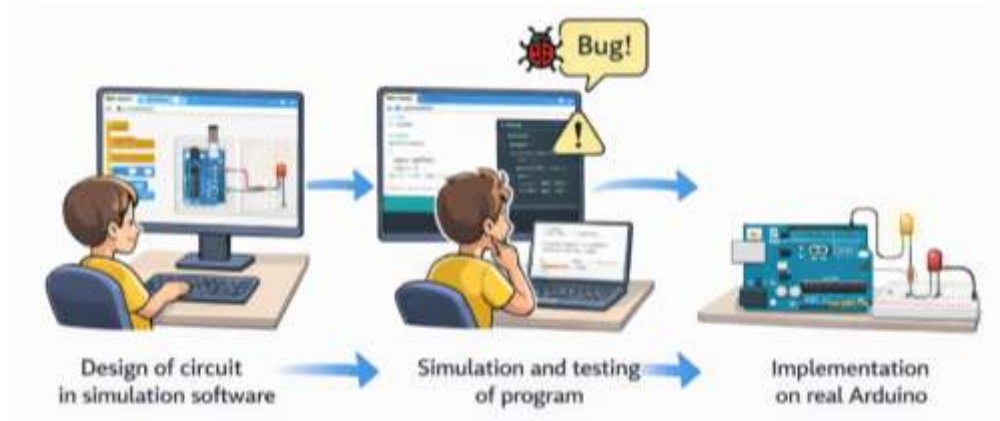
As an illustration of the use of digital environments in the teaching of future

informatics teachers, one may consider the use of the online simulation environment Tinkercad, which enables the design and simulation of electronic circuits and the programming of Arduino microcontrollers. Within a course focused on the practical applications of microcontrollers, students work in this environment with virtual models of electronic components and microcontrollers, which they can connect into circuits, test, modify, and simulate directly within the environment without the need for immediate work with physical hardware. Such an environment enables experimentation and provides a safe space for identifying and correcting errors before implementing the solution in a real circuit.

During practical exercises, students, for example, design a simple circuit to light a light-emitting diode (LED) using an Arduino microcontroller, employing a breadboard, a resistor, and basic program code controlling the behaviour of an output pin. The Tinkercad environment allows students first to simulate the circuit and verify the functionality of the program before transferring the solution to a real device.

The didactic procedure followed by students—from designing a solution in the simulation environment to implementing it in real hardware—is illustrated in Figure 3. Students first design the circuit and program in the simulation environment, where they can test and modify the solution. After verifying the functionality

Figure 3: The process of students' work when solving tasks with microcontrollers using a simulation environment. (Source: Authors' elaboration; visualization generated with the assistance of the generative AI tool ChatGPT.)



through simulation, the same circuit can be implemented using real hardware, i.e. an Arduino microcontroller and electronic components.

Such a procedure supports the iterative nature of problem solving, in which students gradually design the electronic circuit in a simulation environment, where they modify it, test its functionality, identify errors, and adjust the program or the circuit configuration. Only after verifying the functionality through simulation is the solution implemented in real Arduino hardware, which significantly reduces the risk of damaging the hardware, which may be financially demanding.

In the pedagogical preparation of future teachers, the use of simulation environments has an additional benefit - students gain experience with tools that they may later use in their own teaching practice

when explaining the principles of microcontroller operation or when implementing project-based learning.

Pedagogical Benefits of Digital Environments in Teacher Education

Based on pedagogical experience, it can be concluded that digital environments have significant potential in the preparation of future teachers, particularly in three areas: supporting active learning, developing problem-solving thinking, and creating space for reflection on one's own learning. At the same time, their effectiveness depends on the way they are integrated into teaching and on the didactic intentions with which they are used.

For future teachers, it is important not only to acquire skills in working with specific digital tools, but above all to understand how these tools can support students' learning in mathematics and informatics.

Conclusion

Digital environments represent an important component of the contemporary educational landscape, and their significance is gradually increasing in both mathematics and informatics education. As shown by the analysis of the relevant literature and the pedagogical experience of the authors, digital tools have the potential to support active learning, experimentation, and reflection on problem-solving processes. However, their presence in teaching does not automatically guarantee a higher quality of education. The decisive factor is the way in which digital environments are didactically integrated into teaching and the types of learning activities they support.

A comparison of the use of digital environments in mathematics and informatics shows that although these disciplines have different characteristics, digital tools fulfil a similar pedagogical function in both. In mathematics, they primarily support visualization and the understanding of abstract concepts, while in informatics they create space for designing, testing, and iteratively improving solutions. In both cases, however, digital environments contribute to the development of active and reflective learning.

The use of digital environments is particularly important in the preparation of future teachers. Students in teacher education programmes should acquire not only technical skills in working with digital tools but also the ability to critically evaluate their didactic potential and integrate them appropriately into teaching. From this perspective, it is important that digital environments in teacher education are not used merely as technological support for instruction, but as a means of developing pedagogical thinking and reflection on one's own teaching practice.

The findings suggest that further research could focus particularly on analysing specific ways of integrating digital environments into the teaching of mathematics and informatics and on examining their impact on the development of the professional competences of future teachers.

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