Harnessing immersive technologies for enhancing mathematical logics education in secondary schools

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Abstract

The majority of information that individuals perceive throughout their lifetimes is received through the perception of visual images, a rule that applies to the performance of any activity. Consequently, failing to consider the visual presentation of new knowledge during the learning process, as well as its quality, can hinder new generations from receiving a quality education. Considering current realities and demands on knowledge, skills, and abilities acquired during training, the issue of using high-quality visual educational content is closely linked to the development and use of information and communication technologies. This work examines and analyses the current state of the use of immersive technologies in education and explores the possibilities and specifics of employing virtual worlds in the educational process. Practical results of approbating virtual tools in the educational process are provided. A pedagogical experiment aimed at determining the effectiveness of immersive technologies in the context of the Ukrainian education system has been initiated.

Keywords

mathematical logics, immersive technologies, learning tools, virtual worlds, gamification, secondary education

1. Introduction

The tendencies of modernisation in education are influenced by globalisation processes worldwide, labour market needs, and external factors such as the quarantine caused by COVID-19 [1]. In light of this, the digitalisation of the education system opens up numerous prospects for enhancing the quality of the educational process [2]. Consequently, under the conditions of the rapid development of information and communication technologies (ICT), the teaching methods in general education schools are evolving.

For many years, teachers have been utilising videos during classroom lessons to present the theoretical component of new material. Currently, the flipped classroom approach is gaining popularity, the implementation of which is not possible without the use of educational information based on video. However, an increase in the level of learning through electronic educational resources in the form of videos in the "Let's Plays" genre cannot be observed. It is worth noting that unlike previous generations of students who interacted with websites, blogs, and educational channels based on social media, the current generation learns more through YouTube Let's Plays and Twitch-based video streams [3]. The present younger generation does not use books, web pages, or any of the technologies traditionally employed by older individuals.

The formation of a new format of digital literacy is necessary for the participation of young people in these predominantly special educational environments [4]. Firstly, it involves the ability to record and edit videos, "capture" and broadcast gameplay and other on-screen activities, a high level of technical communication, and the capacity to inform and teach others by performing complex tasks. The so-called immersive technology, which integrates the virtual environment with the physical environment,

AREdu 2024: 7th International Workshop on Augmented Reality in Education, May 14, 2024, Kryvyi Rih, Ukraine
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becomes relevant, allowing users to naturally interact with mixed reality, encompassing two main types of reality: augmented (AR) and virtual (VR) [5, 6].

In today's rapidly evolving digital landscape, the integration of immersive technologies into the educational process holds immense potential for transforming the way we teach and learn [7, 8]. This is particularly true in the realm of mathematical logics, a subject that often poses challenges for students in secondary schools. By harnessing the power of virtual and augmented reality [9], educators can create engaging, interactive, and visually stimulating learning experiences that demystify abstract concepts and foster a deeper understanding of logical reasoning.

This research aims to explore the current state of immersive technologies in education, examine the possibilities and specifics of employing virtual worlds in the learning process, and present practical results of approbating virtual tools in the classroom. Furthermore, a pedagogical experiment has been initiated to determine the effectiveness of immersive technologies within the context of the Ukrainian education system.

2. Research methods

To address the objectives set forth in this work, a combination of theoretical and general scientific methods were employed. The analysis of psychological and pedagogical resources on the research problem was conducted to understand the state of development of using immersive technology in the study of mathematical logics in secondary schools, identify research areas, and establish principles and approaches to the use of immersive technology in teaching. A summary of national and international experience in the use of immersive technology in secondary schools was performed to identify development tendencies, clarify the basic conceptual and terminological framework, and establish the conceptual foundations of the study. Theoretical analysis and systematic analysis were also utilised.

To solve the set tasks, empirical research methods were employed, including an experimental study of the use of immersive technologies in the study of mathematical logics in secondary school, expert evaluation of survey results, and observation of initial activities with the use of immersive technologies in educational activities.

3. Literature review

The problem of immersive technologies in education has been addressed by researchers such as Babkin et al. [10], Burov and Pinchuk [11], Klochko and Fedorets [12], Kovalchuk et al. [13], Mintii [14], Mintii and Soloviev [15], Mintii et al. [16], Papadakis et al. [17], Palamar et al. [18], Semerikov and Striuk [19], Semerikov et al. [20, 21, 22, 23], Shepiliev et al. [24]. The concept of immersive technologies is interpreted differently; for example, Sokolyuk [25] defines it as a complex of people's sensations located in an artificially created three-dimensional world, in which they can change their viewpoint, zoom in and out of objects, and so on.

According to Sergeev [26], the exposure of the subject to the learning environment, particularly the immersive environment, and orientation within it allows for the examination of the processes of including the subject in the "worlds" of learning, which can live according to their own laws and not necessarily correspond to the worlds of physical reality. The researcher specifies three types of exposure: exposure to the subjective world, exposure to the physical environment, and exposure to the virtual environment.

Among the investigators of the problem of edutainment, which is learning through play, in modern pedagogy, we can see scholars such as Buckingham [27], DeVary [28], Kazanci and Okan [29], Korniienko et al. [30], Riabko et al. [31], Tokarieva et al. [32], Varina et al. [33]. Addis [34], a professor at Bocconi University in Italy, points out that edutainment is a specific activity that is based on learning and satisfaction with one's own curiosity.

Semerikov et al. [35] analyse the approaches to the definition of "immersiveness", "immersive educational environment", "immersive approach in education", and "immersive educational resources"

(IER), which were used to identify the relationship between the virtual environment and the learning environment being implemented. The pedagogical aspects of learning in immersive environments are examined.

Video games for education form an essential segment of educational content today, with Digital Game-Based Learning (DGBL) becoming increasingly popular. A study by Tokac et al. [36] presents the effectiveness of video game-based mathematics training, claiming that video games contribute to the improvement of mathematical knowledge compared to traditional methods. Wouters et al. [37] have studied the influence of "serious games" on learning in detail, proving that those who learn through serious games have learned more compared to those who learned through conventional teaching methods. Scientists have different opinions on the use of games in teaching, with some stating that for the success of DGBL, it is necessary to have "correct" games for teaching, while others believe that teachers should take an active role in developing educational activities with the help of digital games [38, 39]. Teachers should adapt digital games as part of their teaching tools.

In the study by Chen et al. [40], the effect of competition in DGBL was analysed. According to the data obtained during the research, competition in DGBL was effective for mathematics, science, and language and was effective for students in schools and colleges. The highest effect was observed during task performance in puzzle games, strategy games, role-playing games, and modelling, but not in action games. As a result, it was discovered that competition in DGBL was equally effective for cognitive and non-cognitive results.

Similar results on the use of games in K-12 mathematics education were acquired by Byun and Joung [41]. This paper examines the current trend of DGBL by analysing research on DGBL for mathematics learning and achievements in mathematics learning. The authors also note future directions of DGBL research in the context of mathematics teaching. Out of 296 studies analysed, only 33 were identified as empirical and were systematically analysed to investigate current trends. Due to a lack of statistical data, only 17 out of the 33 selected studies were analysed to calculate the overall effect of digital games on mathematics education.

A related study was conducted by Clark et al. [42], who analysed the published results of research on the overall effect of digital games on learning outcomes from 2000 to 2012. Out of 1,040 papers considered, only 69 had information about the unique empirical research use of digital electronic games in education, involving a total of 6,869 respondents. The researchers concluded that games as a medium certainly provide new and powerful opportunities, but it is the active creative activity in the game environment that determines the effectiveness of the learning environment.

Gunter et al. [43] analysed the RETAIN model (Relevance, Transfer, Adaptation, Immersion, Naturalisation), which is based on the following positions: relevance represents the correspondence of the materials to the students' needs; concordance represents the necessity of presenting the academic content in accordance with the game plot; integration is based on the existing experience of students in other spheres, as well as the possibility of using the knowledge in real life; adaptation refers to a change of behaviour as a result of integration from the virtual into the real world; engagement represents intellectual involvement in the game process; and implementation of the skills acquired in the game and their use in real life.

Apart from the above-mentioned issues, the relationship between game, pedagogical, and realistic components in serious games is no less important. Harteveld [44] states that the attributes of serious games are pedagogy, low resource intensity, timeliness, harmony, experience, unambiguity, research, game elements, attributes, interactivity, involvement, learning goal, goal groups, organisation, reality, and challenge. Pedagogy declares the necessity of reflection, but the game, ideally, encourages it. The highest results are achieved by learning by doing, which means that students must not just read the text but live the learning process internally. The low level of informational intensity of resources allows children to form the ability to make self-evaluations and decisions.

An important issue is also the efficiency of DGBL. There is a variety of methods for evaluating DGBL, which leads to controversy in determining the reliability and validity of certain methods. All et al. [45] investigated various methods of assessing teaching effectiveness, which were developed by experts in the field of psychology and pedagogy through structured meetings to identify the most

important methods for conducting DGBL effectiveness studies. The suggested improvements in the methodology of determining the level of efficacy relate to the implementation of the intervention in both the experimental and control groups. The participants of the experiment themselves determine which elements should be omitted during the exercise (e.g., the instructor's supervision, additional elements consisting of essential information) and which elements will be important (e.g., procedural support, training). The investigators determined the parameters for which the similarity between the experimental and control conditions (e.g., time of influence on the workout, instructor, day of the day) can be achieved. Regarding the testing of methods, the suggested improvements concern the exposition of participants to the conditions (e.g., parameters to be taken into account when using blocked randomised design), the general design (e.g., the need for an initial test and a control group), test development (e.g., developing and running parallel tests), and testing (e.g., next steps after at least 2 weeks of training).

Gamification is the use of certain elements of games in non-gaming practices. Salen and Zimmerman [46] define a game as a system in which players are involved in an artificial conflict, defined by rules and expressed in a quantitative result. Gamification is distinguished from other game formats by the fact that its participants are focused on the purpose of their real activity, not on the game as such. Game elements are integrated into real situations to motivate specific forms of behaviour under given conditions.

4. Research results

Recent research shows that the market value of educational software in 2018 was $2.3 billion, and by 2025, this number is expected to double. This assumption indicates the active implementation and use of software in all spheres of education and culture, including immersive technologies, i.e., technologies of full or partial inclusion in the virtual world, as well as different kinds of virtual and mixed reality. However, it is first necessary to find out what kinds of technologies allow for the creation of modern content and the differences between them.

- Real Reality (RR) – the objective reality in which we exist and perceive through our senses.
- Augmented Reality (AR) – a visualisation technology associated with the combination of real-world objects and information, combined through the use of computers, capable of projecting digital information behind device screens and connecting virtual objects to the real environment. PokemonGO, which has been popular for a few years, is a great example of AR technology.
- Virtual Reality (VR) – a technology that transports people into an artificial world where the natural environment is completely altered. In general, virtual reality means the creation of an imitation of real-world experience, which people can enter at any time with the help of technology.
- Mixed Reality (MR) – the latest development in virtual reality technology, which can cause a variety of sensations. Mixed reality occurs not only in the physical or virtual world but is a mixture of the reality of our world and virtual reality, which can be seen as a supplement to reality and a supplement to virtual reality.
- 360-photos, video – content consisting of one 360° or several stitched photos and videos. This is the process of creating photos of a certain object, which are taken from different sides and combined into one package. Viewing 360-photo gives you the opportunity to see many more details, so to say, to feel them at the physical level.

The use of immersive technologies opens up numerous new possibilities in teaching and education, which are quite complicated, time-consuming or costly for traditional approaches. They outline nine facts in favour of immersive technologies, such as clearness, concentration, maximum involvement, safety and effectiveness. With the help of AR and VR, learning a subject is a much more effective way than standard teaching. The majority of publications on this problem indicate the possibility of using VR and AR technologies in the educational sphere for the purpose of visual modelling of educational

material, supplementing it with more knowledge, developing children's spatial ideas, skills of research and experimentation, extensive projecting, which saves time on learning information, accelerates learning and makes this process fun and active.

It is known that various natural and social sciences, which usually act simultaneously as consumers and providers of scientific and practical results for the field under consideration – physics, mathematics, linguistics, biology, psychology, etc. – belong to the number of calculating sciences. An important place among computational sciences is occupied by the relevant part of mathematics, which has various names: theoretical informatics, mathematical theory of calculations, cybernetics, etc.

The part of mathematics, which is a numbering science, is also not homogeneous. It includes branches of mathematical physics, the theory of numerical methods of differential equations, the theory of mass maintenance, which is used for creating operational systems, in the theory of games and so on. However, the central place in this field of mathematics, which is connected to the computational sciences, belongs to mathematical logics and algorithm theory. Often these two disciplines are combined under the joint name "mathematical logics", considering algorithm theory to be a part of mathematical logics in the broad sense of the word.

Since among mathematical disciplines, mathematical logics is the only discipline that studies the relationship between texts and their meaning, the mathematical description of this relationship is of primary importance when texts are transformed from a means of communication between people into a means of interaction with a computer.

Nowadays, mathematical logics is becoming more and more important; it is a theoretical basis for informatics, which middle school students study in grades 10-11, so it is very useful to develop and refine the concepts of mathematical logics at an early school age. It is necessary to introduce it to students as early as possible, using it in practice. We therefore propose to introduce mathematical logical elements in the school mathematics course. This approach can be closely connected with the program of developmental teaching, which is now being implemented in many schools.

However, many children find it difficult to learn mathematics at school, and one of the reasons is the loss of motivation for learning or the subject itself. To address this problem, elements of mathematical logic should be introduced in primary and secondary schools through educational games. In the process of games, children memorise different logical tasks, which form certain logical operations without noticing. Thus, the basis for learning the number of words, one of the sections of mathematical logics, is laid.

Game techniques have always been used in school education. Tests and examinations, passing from one class to another, final tests – all of these have elements of the game, but they are not always valid. The problem is that classical educational methods often ignore the simple but important fact that learning should bring joy and satisfaction and should be entertaining. It is known that the human brain is set up for the positive, that is, when instead of struggling with boredom there is a drive and positive emotions, information is absorbed more easily.

The main reason for play-based methods is to focus on mistakes. Teachers at school always focus on mistakes but rarely praise for correct answers or solutions. The fixation on mistakes causes students to concentrate more on grades than on knowledge. In computer games, on the other hand, faults are accepted and are the main tool for achieving success. Let's take the game Angry Birds, which at least once played all modern children. It vividly demonstrates how with each failure the player tries new variants of successful achievement of the goal – to kill the pigs. By playing, we know that there is nothing wrong with failure – the sooner we do something wrong, the sooner we can find a good solution. Game is one of the ways of motivation, the development of logical thinking, but not a universal peremptory mean. Gamification without high-quality educational content will not work.

In order for the learning process to be called gamifiable, it must contain the 4 characteristics that McGonigal [47] revealed in her TED talk:

- clearly defined goals that provide motivation to participate in the game;
- logical and step-by-step rules that set the limits and framework for achieving the goals;

- a stable communication system ensuring that the objectives can be achieved and the players comply with the rules;
- a voluntary agreement to participate in the game and follow the rules for achieving the goal.

Werbach and Hunter [48] emphasise the motivational function of gamification. They believe that gamification allows for the activation of people's learning activity. Moreover, gamification allows not only the creation of new games but also the use of their components for motivation. According to them, any game component can be used behind the game format to shape people's attitudes toward a certain environment.

Among the many applications of digital learning, Lifeliqe's main product, the Digital Science Curriculum, deserves special attention. This project (https://www.lifeliqe.com/products/lifeliqe-app) focuses on the K-12 science curriculum, involving students in an open-ended interaction with STEM subjects. This interaction is enabled by interactive 3D models, more than 1,500 available in AR/VR, and a large number of animated videos. Thanks to this, users can use more than 1,000 prepared and ready-to-use activities with great efficiency. An important factor of handy use is that the available digital content is fully compatible with the main natural science textbooks used in the U.S. educational system.

One of the games that has become very popular among children and teachers is Minecraft (https://minecraft.net). Minecraft is a virtual community where players can wander and interact with the world from blocks. Since its release in 2011, the game has become a cultural phenomenon. Over 200 million units were sold worldwide (data as of August 2020) [49]. Due to this success, a special version of Minecraft: Education Edition (Minecraft EDU, https://education.minecraft.net/) was released.

The Minecraft EDU educational game process is structured as follows: the teacher controls the virtual map where students play; the teacher can integrate lessons and assignments into this map. To prevent teachers from doing too much extra work, the game offers a rich library of previously created "worlds" as well as a collection of previously created lessons. The Minecraft EDU learning environment provides you with a wide range of options. For example, finding the perimeter of that particular area or distinguishing dinosaur remains from other digs. The teacher gives each student access to the buildings and places on the virtual map, thus coordinating his or her activities. This makes it possible to teach many people at the same time individually [50].

Due to its flexibility, the game is easily adaptable to different educational subjects. For those who have decided to try Minecraft EDU in their classes, you may want to consider these suggestions:

1. Before the game, discuss together with students the rules of behaviour in the virtual world. No one will be pleased if a classmate destroys a copy of the Arc de Triomphe you've been working on for a couple of sessions.
2. Confirm that your world is set up for the task of the lesson, before the start of his students. For those teachers who are too busy, Minecraft EDU offers a ready-to-use starter kit of core school subjects (https://education.minecraft.net/class-resources/lessons/).
3. Make a paper copy of the instructions, assignments, questions, or suggestions for your students. This will help them concentrate on the task.
4. Allow time for an introductory lesson to show children the basics of the game: click on the menu, perform the main actions. It is better to combine beginners players with experienced, to facilitate learning. It's important to remember that this is just a game that helps us accomplish a certain task. Combine the secondary educational environment – books, textbooks with the Minecraft environment.
5. Take a break every 30 minutes. At this time, ask students to share their accomplishments or difficulties, as well as their feelings with the class.

Let's look at a few already existing Minecraft EDU worlds that can be used by teachers of various school subjects. The first world is called Tutorial-world and is a guide to the Minecraft world. In fact, it is necessary for those teachers and students who are not familiar with Minecraft, or for those who need to update their memory about the basics of the game and the means of controlling their actions, for

example, in the creation of objects. To use this guide you only need to download the file .mcworld and import it into Minecraft: Education Edition. During the course of the course you will be accompanied by two guides – Jessica and Stephen. However, you should not forget that to get the best results, you should get the maximum amount of information, which you can get from the special knowledge base.

Fantastic-mr-fox's world is Mr. Fox's fantastic world, which gave us the idea of creating a fantastic world of our own. The use of this world in the teaching process has the following goals: to learn to recognise the meanings of individual words and whole phrases; to learn how to describe characters and events and to write stories based on the text, using the details found in the text itself. As one of the variants for the development of the teaching process itself, you can use the previous viewing of the final of the animated film "Fantastic Mr. Fox" with the subsequent analysis of the events and attempts to invent a continuation of the story. That is, students are encouraged to invent their own history of how the stars will live in the future, what kind of resources they will need, what kind of housing and its modifications they will need. "Practical" activity with the world of Minecraft Fantastic Mr. Fox is in the creation of housing for the own character in the underground zone of the virtual construction. In addition, the students are encouraged to use these coordinates, create tunnels to three farms. A separate task is to write an article for the newspaper or a story about a day in the life of the inhabitants of the underground city.

The geography teacher will enjoy worlds with such biomes as the savannah, mountains, taiga, and the ocean, for example, the world of secret-reef. This world is dedicated to learning about coral reefs, their possible structure, the most varied forms, sizes and colours. A coral reef is composed of several assemblages of coral blocks. Each of these assemblages has a certain type. For example, dead corals. Moreover, these assemblages can be realised with different forms. But there is no rule that necessarily some structure must be composed of one type of corals. More often for everything on one reef there are several types of corals. Depending on the edition, there may be different types of assemblages.

The world of project-storytelling offers its own variant of teaching, which will be useful for teachers of literature and Ukrainian language. Its purpose is to encourage the development of creative skills in writing texts. In this world, where the "Tree of Souls" is located, you will find yourself in a rural area with stores and houses. The temples of the 4 elements (Fire, Water, Air and Earth), 11 theme factories and buildings, 35 vacant lots for students to create their own buildings or businesses, 6 mini islands with unique possessions – so many opportunities encourage each of the students to create their own story.

For biology teachers there is a lesson on elephant life and protection called watr-humans-and-elephants. Interesting lesson lesson-hub-volume-i, where the author wrote that in this world there is a collection of educational activities you can engage in learning fractions or study the history of the United States in the mid-20th century. Physics teachers will find it interesting to study the properties of Redstone in the redstone-breakout and redstone-lodge worlds. In this educational virtual world you can create traps, automated crop farms, and much more. World-of-chemistry and lessons in chemistry-lessons will be of use to chemistry teachers. In these worlds there is a great table of chemistry elements of Mendeleev. Children are happy to learn the process of creation of air balloons. Teachers of informatics are interested in the program lessons/code-builder-for-minecraft-education-edition. In this course, it is necessary to use Code connection and be able to work with Scratch, CodeMake, Tynker, which also deals with 3D modelling and allows you to move the created objects in the Minecraft world.

The most interesting thing in Minecraft is the Redstone resource, which can be used to create logical schemes. Thus, the player can make their buildings interactive. The chains created with Redstone transmit energy from one unit to another, like electric chains, and the torch is needed to supply energy to the chain. If you install pins, buttons and other control elements and use them, the grader will be able to switch the lance from one position to another.

Minecraft allows players to create logical valves that perform simple logical operations. For example, by using two shafts, you can create an "AND" valve that lets "energy" through only when both levers are active, or an "OR" valve that lets "energy" through if either of the two levers are active. This system has a device of real electronics and Boolean logic, which allows to create complex mechanisms. Thanks to this feature the game can serve as a virtual constructor for programmers and engineers. The teacher

can use not only ready-made lessons, but also create their own.

One of the most widespread and popular types of games are constructors, because they allow you to learn through the gameplay and discover the basics of technical skills. A variety of programs and web resources that allow you to look at the process of creating new devices or appliances are also the essence of the designers, if you look at them for the impact on the development of skills. The online resource Tinkercad (https://www.tinkercad.com) is a web tool that allows you to model objects of any complexity, which in the future can be built on a 3D printer. Tinkercad does not have any restrictions in the professional context. In particular, it is possible to create electronic circuits and connect them to the Arduino virtual circuit board simulator. These powerful tools make it much easier to learn how to design and program new circuits for those who are just starting to use Arduino.

We investigated two virtual learning environments, one created with Minecraft EDU and the other created with Tinkercad and their practical use on the topic "Logical operators".

According to the curriculum, the subject "Logic operators" is studied during the study of the subject "Informatics" (8th grade) and is related to such issues as the basics of algorithmisation and programming, processing and storage of information. For a better understanding of the educational material is needed not only sources of information, but also working digital models. To implement these models on the basis of real mechanics or electromagnetic devices is quite difficult and ineffective, because the students, for the most part, will not be able to understand the existing analogues. In this case, it is better to use the virtual learning environment for everything, which is in fact a virtual world where most of today's children feel "at home".

Despite the large number of researches on gamification, this educational trend has not become popular in the Ukrainian education system, as evidenced by the survey conducted as part of the MoPED [51]. Only 7.5% of lecturers, 18.6% of students, and 15% of teachers considered gamification as one of the three most important educational trends. The reasons for this result lie in the weak technical base of universities, partial awareness of the teaching staff in the information and communication sphere, the use of English language in most Internet platforms, the lack of methodological methods of using gamification, the lack of financial resources for paid subscriptions.

Partly this problem can be solved by training prospective teachers to use gamification technology in the educational process of the school within the framework of university educational programs. Training of future teachers for the use of serious games must be a process that is purposeful, planned, multilevel and multi-stage nature with the organised interaction of all participants in the educational process and aimed at mastering the knowledge and skills of using serious games in educational activities with constant monitoring of the achieved results. This makes it possible to assert the necessity to include in the vocational training of future teachers disciplines aimed at acquiring knowledge and skills in the field of gamification in the educational activities of schoolchildren.

Educational training programs for future teachers of mathematics, physics and informatics do not include educational components that form competencies for using serious games in professional activities. However, the elements of such training should be included in the educational components, taking into account the departmental spheres of professional training. The topic "Logical operators" is related to such educational components as mathematical logic, algorithm theory, discrete mathematics, programming, teaching methods, etc. The inclusion of elements of gamification in these educational components will form the basis for the further use of gamification in professional activities. For this purpose it is necessary to use every opportunity. Thus, in our opinion, such possibilities can include:

- visual materials for lectures (screenshots created in the game environment or in its background, product placement);
- practical tasks with elements of gamification (full or partial use of serious games);
- independent work performed in game environments (additional points for use in the process of playing games);
- laboratory works on teaching methods (results are aimed at creating educational content and taking into account students' desire to use games).

Special attention should be paid to the training of future teachers for the knowledge and skills of using serious digital games in teaching in the teaching discipline Methods of teaching by branches of knowledge. It is necessary not only in theory but also in practice to study the stages of organisation of educational activities on the basis of serious games, such as:

- to identify the target audience of the educational content;
- to set the instructional goal;
- to create the structure of the educational content;
- to identify the elements that can be gamified;
- to implement the selected elements through a digital game;
- to use the developed educational content;
- to perform monitoring of the educational process on the spot and at the end of the day;
- to analyse the results obtained.

During the training at the HEI, future teachers need to be prepared to use serious games based on the advantages and disadvantages of gamification. Advantages include: the ability to use distance learning (both individually and collectively); the ability to use a variety of multimedia tools and modern technology; strengthening the creative abilities of individuals, development of creative thinking, self-organisation, self-control and self-discipline; less academic pressure, increasing independence in learning and self-development; increasing interest in learning through an interesting presentation of the material, which increases the level of mastering the material. The disadvantages of gamification are: the presence of deficit of communication during the training; the possibility of the emergence of irrational judgments; increased number of hours that people spend at the computer; possible technical failures in the work; the need for special training of teachers and a certain amount of time for learning new technologies; a considerable amount of time for the development and implementation of game technologies; high financial and time costs.

During our research we carried out an survey among the students of the State Higher Educational Institution "Donbas State Pedagogical University", who are studying on the educational programs of secondary education (mathematics), secondary education (physics), secondary education (informatics) or on their combination with other educational programs. Respondents were asked the following questions:

1. How do you feel about the use of any games in the educational process? (positive/negative)
2. Are you familiar with the concept of gamification? (yes/no)
3. How do you feel about limiting the use of mobile devices in educational institutions? (supportive/not supportive)
4. How do you feel about the increasing influence of mobile devices on children's education? (positively/negatively)
5. Do you support the teaching of children at school through computer games as a necessary element of the teaching process? (I do/I do not)
6. Do you support the training of adults through computer games as a necessary element for improving qualification and acquiring new knowledge and skills? (I approve/not approve)
7. Did you have your own experience of learning through the computer game? (yes/no)
8. Do you know someone who has had some experience with learning through a computer game? (yes/no)
9. Should the teaching of methods that use gamification in the teaching process be a necessary element of pedagogical education? (yes/no)
10. Are you ready to learn how to use games during your own professional activities? (yes/no)

A total of 102 students took part in the survey. The results of their responses are presented in table 1.

The results show that most of the students are familiar with the concept of "gamification", are ready to learn by playing and to teach others. Most of the respondents are ready to learn new methods and

Table 1
Results of answers during the survey.

Question	yes / positive / support	no / negative / do not support
Q1	85	17
Q2	76	26
Q3	22	80
Q4	63	39
Q5	74	28
Q6	55	47
Q7	19	83
Q8	24	78
Q9	63	39
Q10	69	33

support new forms and means of learning and do not understand the restrictions on the use of mobile devices that can be useful in educational activities. However, the number of those who have used or interacted with them is very small, although there is a tendency for the number of students who learn through games to grow.

As it was mentioned in the theoretical part of our research, we introduced elements of gamification into the educational disciplines of teaching methods. We have been offered the laboratory tasks of working out the educational scenarios of "Logical operators" in the Minecraft EDU environment (figure 1) and creating the educational project in the Tinkercad environment (figure 2). As a result of the group project, several teaching tasks were created and tested during the students' production practice at educational institutions.

Figure 1: Example of creating a logical operator in Minecraft EDU.

The aim of the educational project in the Tinkercad environment is to demonstrate the principles of algebraic logic and the construction of tables of truth, which the students studied as part of this subject. However, this material was theoretical for them, because it did not create an idea of how it could be implemented in real life. Therefore, the main condition for the effectiveness of the lessons was to create conditions for a clear demonstration of the work of logical elements. The most optimal

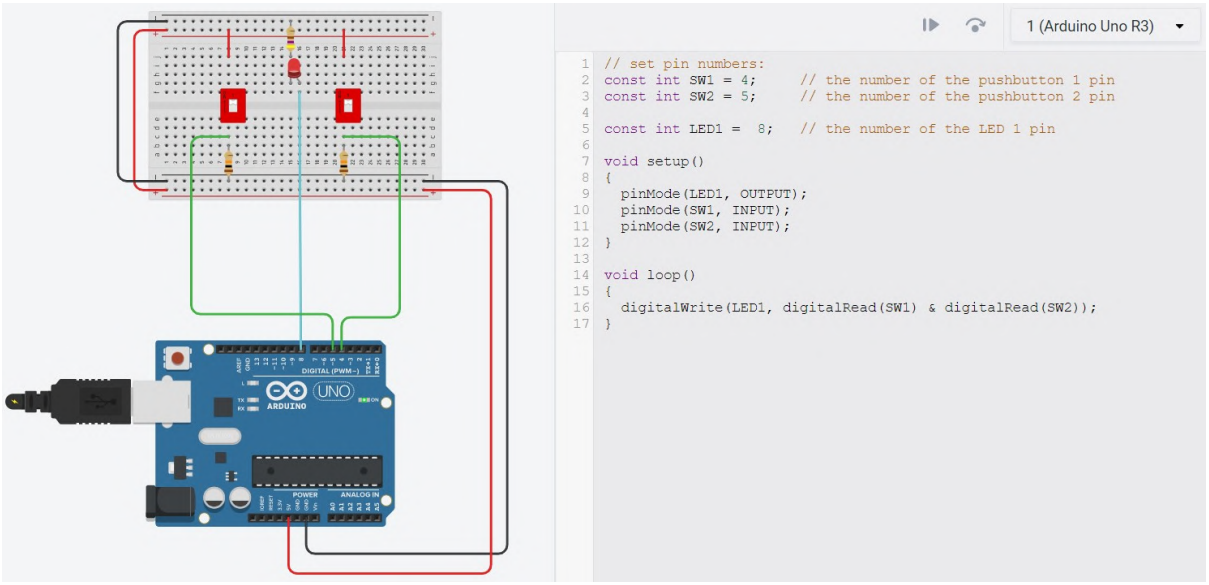

Figure 2: An example of creating a scheme for the logical operator “AND” in Tinkercad.

variant in this case is to conduct lessons with additional study of materials related to electronics and circuit engineering.

The students were given the task to independently create tables of truth for logical “AND” and “OR”, design an informational model of the circuit in the Tinkercad environment, test it on the basis of the principle circuit, and, in case of a successful result, build this circuit on the breadboard.

After the scheme was created, it should be tested and the results of the work should be compared with the results of the tables of truth. The result of this project is the creation of a physical object as a proof of the correctness of the truth tables for logical elements. This was successfully achieved due to the fact that all subject areas were taken into account in the necessary proportions with the successful implementation of the interdisciplinary approach. The goal was successfully achieved and the results of their work resulted in an electrical scheme, which fully corresponded to the results of their calculations and reflected the principles of logical “AND” and “OR” operation.

With the help of the Tinkercad environment you can introduce students to the concept of relay-contact circuits. We explain, under the contact we mean the physical body, which can exist in only two states – “on”, “off”, which we will denote as 1 and 0 accordingly. Connecting contacts in series corresponds to the operation “conjunction”, and connecting them in parallel corresponds to the operation “disjunction”. By opening contact we denote a contact that does not conduct current, which corresponds to the negation operation of the algebra of statements. In other words, we show that the algebra of relay-contact circuits, which is isomorphic to the algebra of statements, is created. The analogous equivalences of the algebra of statements correspond to equivalences of the algebra of relay-contact schemes. Using examples, it can be shown that each of the investigated schemes is described by the corresponding formula of the algebra of relay-contact schemes. Thus, the practical significance of mathematical formulas is explained.

The students’ reports on the internship and their own observations revealed a significant interest in the suggested tasks. Despite the fact that the topic “Logical Expressions. Changes of Logical Type. Logic operations” in the 8th grade belongs to the section “Programming” and is often difficult to understand, the material was studied at a high level. This is evidenced by the fact that further use of the knowledge gained during the study of the topic “Logical Expressions. Changes of Logical Type. Logic operations” in such topics as “Algorithms with branching” and “Cyclic algorithms” did not cause any difficulties in learning these new topics. Moreover, the homework assignment, which students often do without enthusiasm, was completed successfully and absolutely by all students without exception (boys and girls), indicating their interest in this educational tool. The survey of students showed that close to 18% of 8th grade students had active Minecraft accounts and participated in collaborative game sessions.

This difference did not have much effect on the results of the tasks. Children who already have Minecraft game accounts completed the tasks quicker than their peers. However, the virtual learning environment created by the Tinkercad tools has caused more interest among children who are engaged in robotics. This can be explained by the fact that robotics has a more realistic realisation than the imaginary world of Minecraft.

5. Conclusions

The development of computer technology and the general increase in digital literacy, coupled with the challenges posed by the COVID-19 pandemic, have necessitated the search for new, more effective ways and methods of learning. In addition to the use of electronic educational resources in the form of websites, blogs, and channels, there is a growing need to implement learning through technologies that provide a high level of visualisation combined with "interaction" with the physical environment. In other words, there is a pressing requirement for teaching using immersive technology that integrates the virtual environment with the physical environment, allowing users to naturally interact with mixed reality, which includes augmented (AR) and virtual (VR) realities.

The practical application of immersive technologies in the educational process is most effectively combined with gamification – the use of certain game elements in non-game practices. Game elements are integrated into real situations to motivate specific forms of behaviour under given conditions. The positive results of this synergy can be observed through examples such as Lifeliqe's Digital Science Curriculum, the special version of Minecraft: Education Edition, and the online resource Tinkercad, a web tool that enables the modelling of objects that can be built using a 3D printer.

During the practical part of the research, it was found that most students are familiar with the concept of "gamification" and are ready to learn and use this methodology in their educational activities. Furthermore, studying the topic "Logic Operators" in the Minecraft EDU environment and creating a teaching project in the Tinkercad environment showed a growing interest in mathematical logics and improved quality of work results among both students and educators.

Therefore, we can conclude that gamification of the educational process, a relatively new form for Ukraine, is a promising tool to enhance the quality of education for children, adolescents, and adults, deepening the level of acquired knowledge and enabling more effective use of skills and abilities. However, its successful implementation in the education system requires the establishment of a clear procedure and adherence to the key stages of creating a game mechanism. Reviewing methods of using digital game content, creating a library of digital electronic educational resources, and developing methods for teaching the use of gamification for further application are new topics for further scientific research and development.

Declaration on Generative AI: The authors have not employed any Generative AI tools.

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