Using Virtual Reality Technologies for Teaching Computer Science at Secondary School

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Abstract

The article reveals the problem of using virtual reality technologies for teaching computer science at secondary school as an innovative technology. Some ways of using virtual reality technologies for computer science education were analyzed and researched. Accordingly, we have developed virtual reality software for teaching students spreadsheets, algorithms and programming. Evaluation of the virtual reality tools use effectiveness for teaching computer science at secondary school and identifying ways to improve the components of the scientific and methodological system of teaching computer science were carried out using the methods of mathematical statistics. The innovative nature of the virtual reality technologies use is a methodological condition for increasing students' interest in learning, intensifying the learning process, revealing their cognitive, intellectual and personal potential, as well as the development of digital competencies, independence and more. The authors emphasize that the use of virtual reality technologies requires a thorough development of the virtual learning environment, detailed selection of learning content and its adaptation to specific groups of students. Based on the analysis of the obtained results, possible ways of effective system implementation of virtual reality technologies for teaching computer science at secondary school are identified, which includes selection of methods, digital tools, adaptation of theoretical material, development of individualized and creative tasks.

Keywords

Virtual reality, computer science, teaching computer science, methods (methodology) of teaching computer science, innovative pedagogy

1. Introduction

Global digitalization of the educational process: promotes the use of various digital technologies in schools and universities, among which are relatively new technologies of virtual and augmented reality (VR/AR), which significantly expand students' learning, cognitive and communicative capabilities, provide adaptability, manageability, interactivity, etc.; forms an ever-growing market for educational software. VR/AR technologies allow students, without leaving school classrooms or from home, to "immerse" themselves in the virtual worlds of robotics, physical and chemical processes, wildlife, outer space, museums of the world, didactic game environments, etc. This is especially important in the conditions of quarantine caused by COVID-19, which is reflected in the studies by O. Burov, A. Kiv, S. Semerikov, A. Striuk, L. Kolgatina et al. [1]. Accordingly, the requirements for professional competence of teachers increase, which includes the teacher's ability to intensify

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educational and cognitive activities of the "digital generation", keeping students' attention during the lesson, forming a lasting interest in the content of educational material and more.

Leading foreign and domestic scientists, such as O. Burov, A. Kiv, L. Kolgatina, H. Kravtsov, S. Semerikov, M. Shyshkina, A. Striuk, M. Striuk, T. Vakaliuk et al. studied the peculiarities of the AR/VR technologies application. Issues that reveal the importance of using AR/VR technologies in education as modern didactic tools are: features of education of "children of generation Z"; psychological and social specifics of adaptation to distance learning in the context of the COVID-19 pandemic (G. Toto and P. Limone) [2]; identification of ways to overcome obstacles to the development of the European Research Area (ERA) (M. Shyshkina, M. Marienko) [3]. In particular, M. Shyshkina, M. Marienko presented the "concept of the European cloud of open science" in the structure of which it is determined that augmented reality is a platform of open science in this structure [3]. The studies by M. Marienko, Y. Nosenko, M. Shyshkina, are relevant in this aspect which recommend the use of adaptive cloud systems with augmented reality in the process: teacher training as a way to adapt programs to individual needs of students, in group work, in inclusive education [4].

The research of scientists M. Shyshkina, M. Marienko is aimed at identifying ways to overcome obstacles to the development of the European Research Area (ERA) [3]. They "presented the concept of the European cloud of open science" and studied the structure of the cloud, in particular, determined that augmented reality is a platform for open science in this structure [3]. M. Marienko, Y. Nosenko, M. Shyshkina recommend the use of adaptive cloud systems with augmented reality in the process of teacher training and indicate the possibility of using them to adapt to individual needs of students, group work, inclusive learning [4].

V. Oleksiuk, O. Oleksiuk [5], point out the important role of the VR/AR technologies application in school computer science classes for: the formation of emotional and cognitive intelligence of students; visualization of algorithms and data processing processes; monitoring the operation of computer systems, modification of computer equipment.

Researchers L. Panchenko, T. Vakaliuk, K. Vlasenko reveal the ways of applying VR/AR technologies in accordance with innovative and child-centered directions of the concepts of the New Ukrainian School, in particular, the use of AR books [6], emphasizing the motivational aspect. H. Kravtsov, A. Pulinets use VR/AR technologies to visualize the educational content of school textbooks [7]. N. Osipova, H. Kravtsov et al., actualize the need to develop the Ukrainian-language educational software for training in VR/AR [8].

Based on the application of anthropological and holistic approaches in previous studies, we considered the application of VR/AR technology in teaching students to model and visualize biomechanical processes (Bernstein) and the use of the concept of Umwelt, value formation, images, semantic context and others [9].

Investigating the features of the augmented reality use in the educational process and taking into account the results of research on this problem by domestic and foreign scientists, we note the insufficient study of the VR/AR technologies use in secondary school to study computer science. Accordingly, we update the issue of studying the relevance of the virtual reality technologies use for teaching computer science at secondary school as an innovative technology.

Continuing the study of the use of augmented reality in the educational process, taking into account the results of research by domestic and foreign scientists, insufficient study of the use of VR/AR technologies in secondary school to study computer science, we identified the research topic "Using virtual reality technologies for teaching computer science at secondary school".

Aim of the research: to find out the potential possibilities of using virtual reality technologies for teaching computer science at secondary school as an innovative technology.

2. Selection of methods and diagnostics

The following methods were used: literature analysis, pedagogical observation, questionnaires, diagnostic methods, pedagogical research; statistical processing of research results and qualitative and quantitative analysis of results based on methods of mathematical statistics; design, programming, 3D modeling, etc.

We have developed *Questionnaire 1*, aimed at determining the interest of students in the use of didactic VR software in computer science lessons in secondary school:

1. Are you interested in using didactic software of virtual reality in computer science lessons?
2. Do you have experience in using didactic software of virtual reality in computer science lessons?
3. Please familiarize yourself with the software "Excel on a forest glade" (you can also use the tool in a browser without virtual reality glasses). Are you interested in using such a tool in the process of learning computer science?
4. Please familiarize yourself with "Tower of Hanoi" software (you can also use the tool in a browser without virtual reality glasses). Are you interested in using such a tool in the process of learning computer science?
5. Would you like to independently develop virtual reality software in computer science lessons?
6. Are you interested in the use of virtual reality software in the extracurricular time in the process of doing homework in computer science?
7. Are you interested in using virtual reality software to solve your own problems?

In order to estimate the required number of respondents (students) N, who have to answer the questionnaire, we used the formula (1).

$$N = \frac{t^2 \cdot w \cdot (1-w) \cdot n}{\Delta^2 \cdot n + t^2 \cdot w \cdot (1-w)}, \quad (1)$$

where n – amount of the statistical population; w – indicator of the share of the studied trait; Δ – permissible margin of error; t – confidence coefficient.

We have developed didactic software for virtual reality "Excel on a forest glade" [10] and "Tower of Hanoi" [11]. The tools are created in an interactive environment for the development of 3D objects of augmented and virtual reality [12].

The software VR tool "Excel on a forest glade" [10] is designed for the use in computer science lessons in 7th grade of secondary school while studying the chapter "Tabular Data Processing" to 3D-visualization of the theoretical basic aspects of working with Microsoft Office Excel, respectively to the curriculum [13]. The VR software "Tower of Hanoi" [11] is intended for use in computer science lessons in 8th grade of secondary school while studying the chapter "Algorithms and Programs", for 3D-visualization of the theoretical foundations of algorithmization and programming, according to the curriculum [13].

The possibility of using the developed VR didactic software in the process of teaching computer science was studied in 7-8th grades of the Regional Scientific Lyceum-Boarding School of the Municipal Institution of Higher Education "Vinnitsa Humanitarian Pedagogical College". The state of the researched problem was studied, the purposes and tasks of the research were substantiated, the ways of their solution were defined. The number of students involved in the study in 7th grade was 20 people. The students were divided into control and experimental subgroups of 10 people each. The number of students involved in the study in 8th grade was 27 people. The students were divided into control and experimental subgroups of 14 and 13 people in each group, respectively. The grade point average (GPA) of students in computer science at the beginning of the chapters study "Tabular Data Processing" and "Algorithms and Programs" was determined.

In order to clarify the organizational conditions for studying the chapters "Tabular Data Processing" and "Algorithms and Programs" using VR tools in secondary school, a survey was conducted. 5 teachers of schools of Vinnytsia region, masters and bachelors of subject specialty 014.09 Secondary Education (Informatics) (6 people), teachers of Vinnytsia Mykhailo Kotsiubynsky State Pedagogical University (2 people) took part in the survey. The significance of organizational conditions was assessed in points from 1 to 10 without repeating the points for a separate chapter: 1 – the least important condition, 10 – the most important condition. The following organizational conditions were assessed: the availability of the necessary technical support for viewing virtual reality applications, the availability of the necessary software for the development and use of virtual reality, the use of effective forms and methods of forming students' necessary skills, availability of the necessary methodological support for conducting lessons on the study of the chapter, the formation of students' positive motivation to study the chapter.

The efficiency of the VR didactic software tools developed by us for computer science teaching at secondary school were assessed. To confirm the statistical significance of the difference in GPA of students in computer science before and after the experiment, we used Wilcoxon's T-test [14]. Wilcoxon's T-test is used to compare the indicators of the same sample in two different conditions. A "typical" shift is considered to be a shift towards increasing the value of GPA in computer science.

Hypotheses:

H_0: The values of the GPA in computer science after the experiment exceeds the values of the GPA in computer science before the experiment at the level of significance $p<\psi$.

H_1: The values of the GPA in computer science after the experiment are less than the values of the GPA in computer science before the experiment at the level of significance $p<\psi$.

The calculation of the sum of the ranks of "atypical" shifts T_{emp} is carried out according to the formula

$$T_{emp} = \sum_{i=1}^{k} r_i \,, \tag{2}$$

where k is a number of "atypical" shifts, r_i is the ranks of "atypical" shifts ($i=1...k$).

T_{cr} is found in the table for a given n (number of indicators) according to the level of significance ψ. ψ is determined in accordance with the problem *0,05* or *0,01*, ie $p<0,05$ or $p<0,01$.

If $T_{emp} \leq T_{cr}$ at the level of significance $p<\psi$, the shift in the "atypical" direction in intensity with high probability prevails, we accept hypothesis H_0. If $T_{emp}>T_{cr}$, with an intensity with high probability is dominated by a shift in the "atypical" direction, we accept hypothesis H_1 at the level of significance $p<\psi$.

3. Results and Discussion

VR/AR technologies have significant educational, epistemological, innovative and competency potential. This reveals the possibilities of implementation in the educational process of visual learning at a new quality level, simulation of objects and events, actualization of interactivity and educational-cognitive, innovative and activity actions of students, motivating them to learn. VR/AR technologies open up opportunities for teachers to create informative, realistic and personality-oriented didactic resources that help to conceptualize, illustrate and visualize theoretical aspects of learning and creatively, practically reveal the connection between theory and reality. The use of virtual reality technologies in education involves the appropriate restructuring of the educational process [9, 15].

Virtual reality can be used in the implementation of various forms of education. Virtual reality in education at a new high-quality technological level opens up opportunities: to conduct virtual lessons, teleconferences, videoconferences; creation of 3D electronic educational resources; development of presentation and information materials; creation of museums, laboratories, planetariums; visualization of complex objects, physical phenomena, etc. Effective forms of lessons using virtual reality technologies are: interactive classes, flash surveys, group work, Flipped Learning, project-based learning, independent work, creating didactic play environments, extracurricular education programs and others.

Let's present some of the organizational forms of teaching computer science with the help of virtual reality technologies in secondary school:

Virtual tour of the Museum of Informatics. This form differs from a real tour by a virtual display of real objects (for example, mechanical computers, a loom with software control, computer generation, figures of prominent computer scientists, diagrams, etc.). A virtual tour is used to develop students' skills of self-observation of certain objects, collecting and understanding the importance of the necessary facts for the development of computer science. Virtual rooms with exhibits can be organized using panoramic photos. A tourist can be offered an exhibition plan, virtual guide services, as well as voice and video accompaniment of the tour, additional explanations and materials, contact panel, etc.

Flipped Learning. Currently, several organizational forms of Flipped Learning implementation have been developed. We consider Flipped Learning in more detail in “The Use of Digital Technologies for Flipped Learning Implementation” [15]. For example, students are given homework

to master the theoretical learning material using didactic VR software for the next lesson, for example, using applications "Excel on a forest glade" or "Tower of Hanoi" [10, 11]. In the lesson, students interactively discuss issues that have arisen during the independent study of this material, analyze the possibilities of applying the acquired theoretical knowledge, perform practical tasks on this topic.

One of the organizational forms of Flipped Learning implementation is group work. The class is divided into groups and the groups are provided with study material presented in the form of virtual reality software. At the end of the time allocated for the development of this material, students of groups participate in a questionnaire or discussion on this material.

Another, interesting, creative option of group work for students can be a joint work of the group on the development of VR software, project work on the task using virtual reality technologies.

VR-technologies have significant advantages over other information technologies (Freina L. and Ott M.) [16]: visibility, security, interactivity, focus, involvement. However, despite the obvious advantages of using virtual reality technologies in education, today there are many potential problems of technological and professional-personal (in the sense of competence) nature.

The development of educational resources based on VR-technologies requires: specialized software, special technical equipment; a teacher must have skills in working with hardware and software; a school must have sets of equipment for the classes in which lessons will be held.

As an example, we considered and tested the possibilities of an interactive environment for the development of 3D objects with the subsequent possibility of their use in augmented and virtual reality modes CoSpaces Edu [12]. The choice of CoSpaces Edu environment was preceded by the analysis of a number of foreign and domestic experience studies in the use of VR/AR technologies in the educational process [12]. Including the integration of these technologies into the educational process of secondary school. CoSpaces is used in many subject areas – from STEM, STEAM, STREAM, from mathematics, computer science to social sciences, languages, art and creative spaces.

In order to conduct research, we have developed the didactic software "Excel on a forest glade" [10, 12] and "Tower of Hanoi" [11, 12] based on an interactive environment for the development of 3D objects of augmented and virtual reality CoSpaces Edu for 3D visualization of the basics of working with Microsoft Office Excel and algorithmization and programming.

“Excel on a forest glade” application we created consists of three action scenes, each of which contains objects and elements that allow students to learn the features of working with spreadsheets in Microsoft Office Excel in the form of a game in virtual reality (Fig. 1) [10, 12].

Virtual reality scene № 1 has the form of a "forest glade" on which a canvas with cells of a Microsoft Office Excel spreadsheet on which animals are placed is deployed (Fig. 1: 1, 2, 3). Working with this scene, students learn the concepts of a worksheet table, cells, range of cells and their addresses; study the rules of access to the cell and the range of cells at the address. For example, Fig. 1 (1, 2) an element of Scene № 1 is shown, in which students need to indicate the correct range of cells on which the bear lies, as well as the cell on which the hare sits Fig. 1 (3). In addition, scene № 1 is the main scene of the developed virtual reality environment, moving through this scene, the student gets to the virtual house (Fig. 1: 4), Scene № 2 (Fig. 1: 5), inside which is an exposition of slides of the educational presentation, which allows students to master the theoretical material of tables and data in Microsoft Office Excel program.

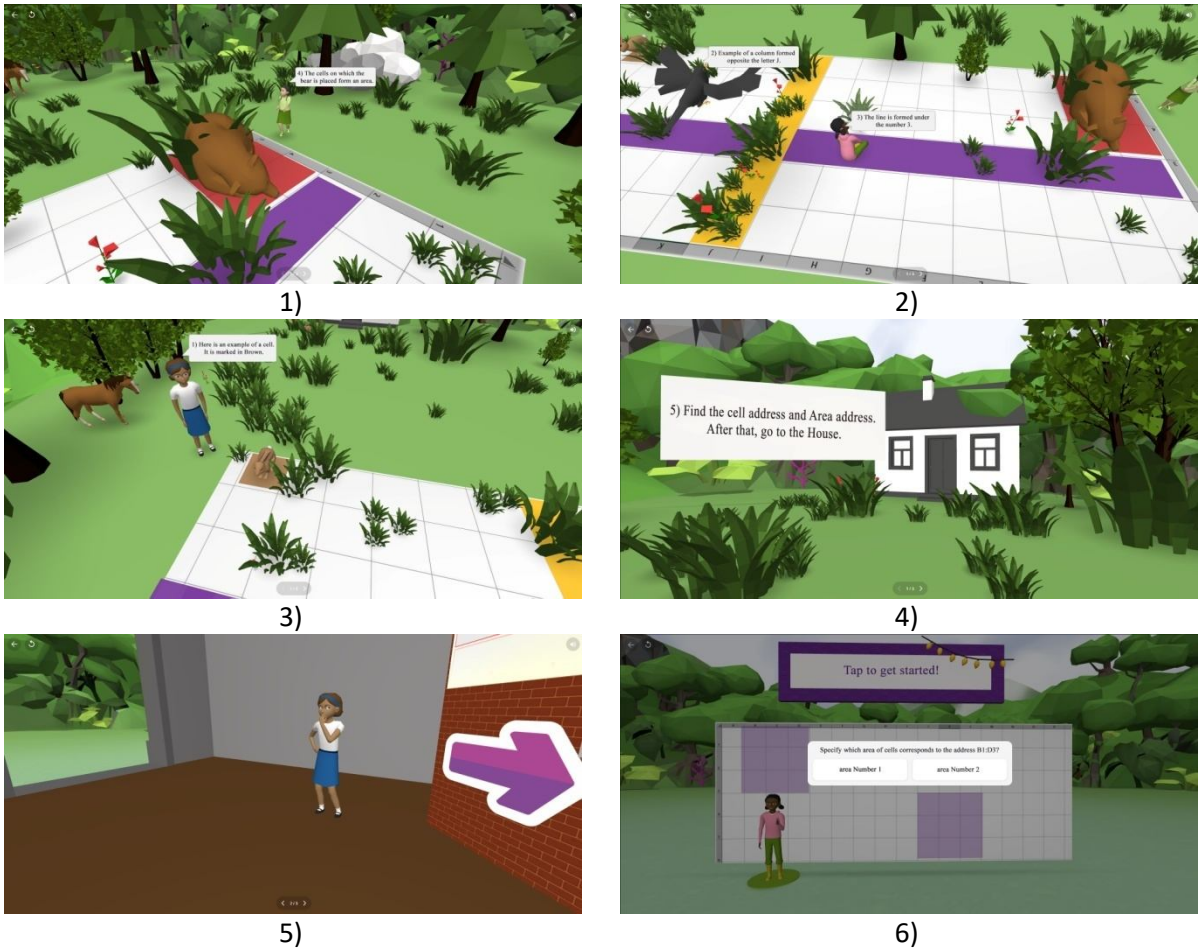
After mastering the theoretical material presented on the elements of Scene № 2, the student finds a link to testing on the materials of the topic, and goes to Scene № 3 (Fig. 1: 6).

Scene № 3 is an interactive blitz test that aims to test the effectiveness of the student's mastering of theoretical material presented in the environment (Fig. 1: 6). Answering the questions of the test, the student can understand whether he/she has sufficiently mastered the presented theoretical material, and if necessary, returning to the main stage, to process the theoretical block again.

Also, we have developed a didactic VR tool "Tower of Hanoi", which is designed to illustrate the basics of algorithmization and programming [11, 12]. The application created by us conditionally consists of two parts, each of which contains objects and elements that allow students to learn the features of “Tower of Hanoi” algorithm in VR mode (Fig. 2).

The scene is conditionally divided into two parts. In the first part there is a pyramid tower on a rod in the initial state, and two empty rods (Fig. 2: 1). On the right side there are instructions for performing actions. On the surface there are control arrows, which can be manipulated by the disks of

the tower up and down, left and right. The user is asked to transfer all the disks to another rod, folded in a monotonous descending order from the bottom to the top, following the rules specified in the instructions. The second part provides an example of demonstrating how to solve a game with fewer discs (Fig. 2: 2).



1) 2) 3) 4) 5) 6)

Figure 1: General view of the developed didactic resource "Excel on a forest glade" to study the basics of working in Microsoft Office Excel [10]: 1), 2), 3), 4) Scene № 1; 5) Scene № 2; 6) Scene № 3.

1) 2)

Figure 2: Didactic tool of virtual reality "Tower of Hanoi": the environment of independent implementation of the algorithm by the user [11]: 1) First part; 2) Second part.

To find out the potential possibilities of using VR didactic software "Excel on a forest glade" and "Tower of Hanoi", we tested it on the basis of the Regional Scientific Lyceum-Boarding School of Vinnitsa Humanitarian Pedagogical College.

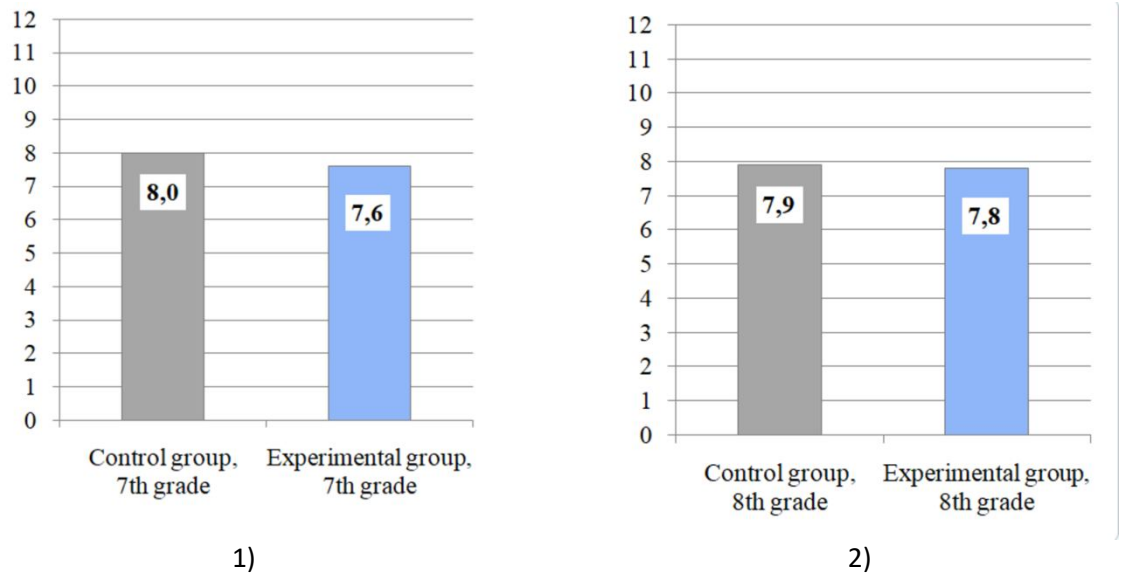
At the beginning of the study in the chapter "Tabular Data Processing" the GPA in computer science for 7th grade students in the control and experimental groups was relatively homogeneous and was *8,0* and *7,6* points, respectively (Table 1, Fig. 3: 1).

At the beginning of the study, the chapter "Algorithms and Programs" in the control and experimental groups was relatively homogeneous and was *7,9* and *7,8* points, respectively (Table 1, Fig. 3: 2).

Table 1

Number of students and the GPA of 7th and 8th grade students in computer science at the beginning of the study of the chapters "Tabular Data Processing" and "Algorithms and Programs", respectively.

Student groups	Number of students	GPA in computer science
Control group, 7th grade	10	8,0
Experimental group, 7th grade	10	7,6
Control group, 8th grade	14	7,9
Experimental group, 8th grade	13	7,8



1) 2)

Figure 3: The GPA of students of 7th and 8th grades in computer science at the beginning of the study of the chapters "Tabular Data Processing" and "Algorithms and Programs", respectively (Table 1: 1) 7th grade; 2) 8th grade.

Based on the obtained questionnaire data, we analyzed the organizational conditions for studying the chapters of computer science "Tabular Data Processing" and "Algorithms and Programs" using VR tools in secondary school (Table 2, Fig. 4).

As can be seen from the Table 2 and the Figure 4, the highest number of points as a result of the survey of the above respondents, gained such organizational conditions that can be applied in the study of “Tabular Data Processing” and “Algorithms and Programs” using VR tools in secondary school: the availability of the necessary technical support for viewing virtual reality applications, the availability of the necessary software for the development and use of virtual reality tools, the use of effective forms and methods of forming students' necessary skills; formation of students' positive motivation to study chapters. Organizational conditions scored a slightly lower number of points: the availability of the necessary methodological support for conducting lessons on the study of chapters.

In our opinion, this result is due to the fact that in comparison with the first four conditions, which scored the highest number of points, these conditions are important, but not decisive. Because, even if there is the necessary methodological support for lessons in the chapter, but in the absence of students’ motivation to study the chapters using VR tools, without using effective forms and methods

of teaching students, appropriate hardware and software, high results of students to achieve this chapter are practically impossible.

Table 2

Questionnaire for assessing the organizational conditions for studying the chapters "Tabular Data Processing" and "Algorithms and Programs" using VR tools in secondary school.

N	Name of organizational conditions	Assessment for chapters "Tabular Data Processing"	Assessment for chapters "Algorithms and Programs"
1	Availability of the necessary technical support for viewing virtual reality applications	121	124
2	Availability of the necessary software for the development and use of virtual reality	116	118
3	Application of effective forms and methods of forming students' necessary skills	118	119
4	Formation of students' positive motivation to study the chapter	114	111
5	Availability of the necessary methodological support for conducting lessons on the study of the chapter	84	98

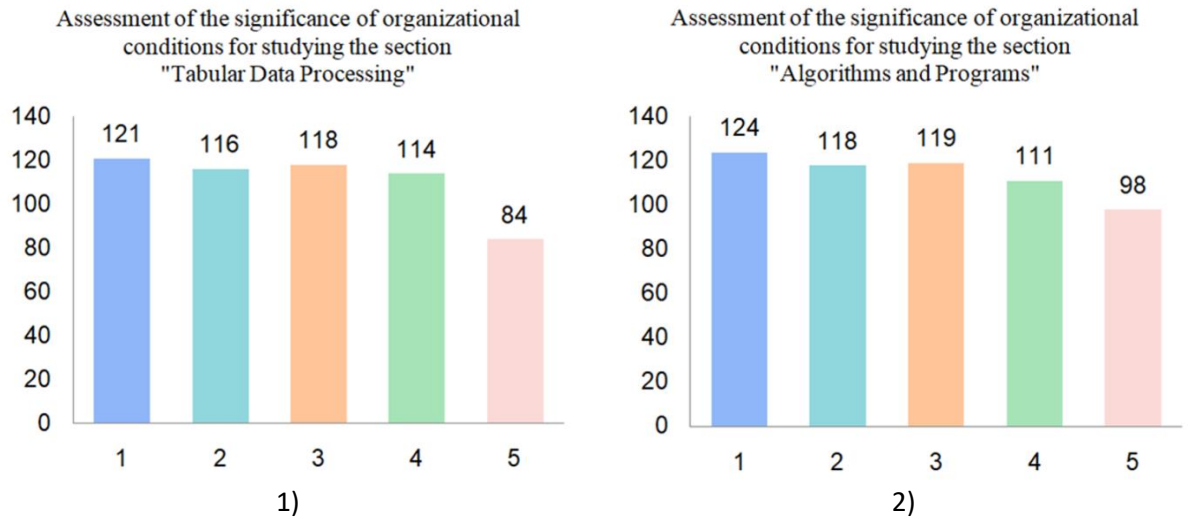


Figure 4: Diagrams of the respondents' assessment results of the organizational conditions necessary for the successful education of students using VR tools in the secondary school chapters (Table 2): 1) "Tabular Data Processing"; 2) "Algorithms and Programs".

The students training of control and experimental groups in the chapters "Tabular Data Processing" and "Algorithms and Programs" using VR tools in 7th and 8th grades, respectively, was organized as follows: training in control groups was conducted according to traditional methods, and in experimental groups – using these VR tools.

According to the results of the study, it was found that the GPA of students in the experimental groups for the study of "Tabular Data Processing" and "Algorithms and Programs" (in 7th grade – *8,3*, in 8th grade – *7,9*) is higher than the corresponding GPA in computer science before the study of these chapters (in 7th grade – *7,6*, in 8th grade – *7,8*), as well as the GPA in the relevant experimental

groups after studying these chapters is higher than in the control groups (in 7th grades – *7,4*, in 8th grades – *6,8*) (Table 1, Table 3, Fig. 3, Fig. 5). In the control groups, we observe lower values of the GPA for the study of "Tabular Data Processing" and "Algorithms and Programs" (in 7th grade – *7,4*, in 8th grade – *6,8*) compared to the corresponding values of the GPA with computer science to the study of these chapters (in 7th grade – *8,0*, in 8th grade – *7,9*) (Table 1, Table 3, Fig. 3, Fig. 5).

Table 3

Number of students and the GPA of 7th and 8th grade students in computer science based on the results of studying the chapters "Tabular Data Processing" and "Algorithms and Programs", respectively.

Student groups	Number of students	GPA in computer science
Control group, 7th grade	10	7,4
Experimental group, 7th grade	10	8,3
Control group, 8th grade	14	6,8
Experimental group, 8th grade	13	7,9

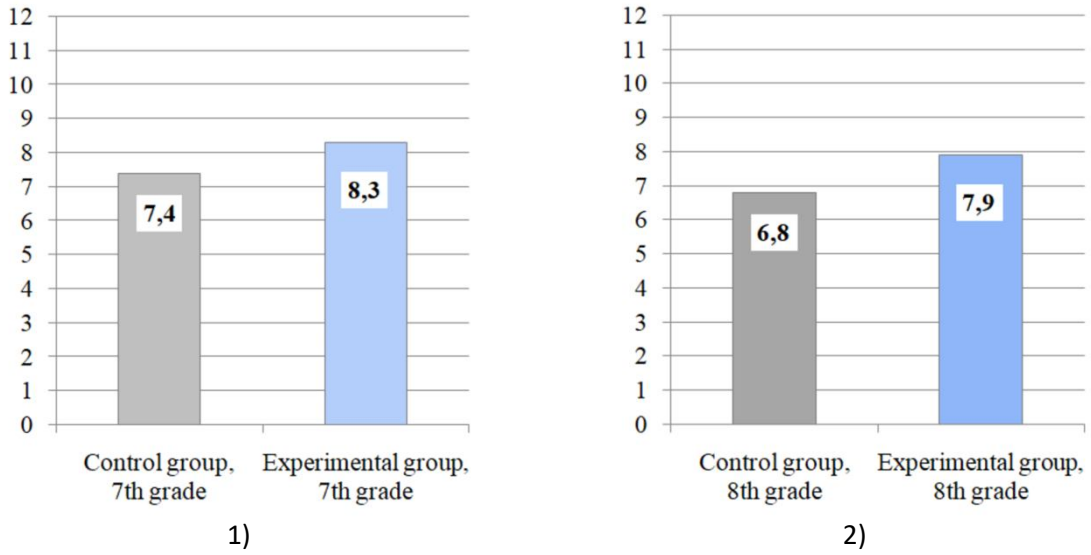


Figure 5: The GPA of students of 7th and 8th grades in computer science based on the results of studying the chapters "Tabular Data Processing" and "Algorithms and Programs" are respectively (Table 3: 1) 7th grade; 2) 8th grade.

We confirm the statistical significance of exceeding the values of the GPA in computer science 7th and 8th grade students after the experiment over the values of the corresponding indicators before the experiment using Wilcoxon's T-test [14]. The obtained absolute values of the differences in the indicators of the GPA in computer science before and after the experiment are arranged in ascending order and ranked in ascending order of absolute differences using average ranks. Calculated T_{emp} by formula (2) for the GPA in computer science of 7th grade students by studying the section "Tabular Data Processing" (formula (3)).

$$T_{emp} = \sum_{i=1}^{k} r_i = 8\,, \tag{3}$$

Find the critical value for the Wilcoxon's T-test for $n=10$, using the data in statistical tables [14]: for $p<0,05$ the $T_{cr}=10$, for $p<0,01$ the $T_{cr}=5$. The empirical value $T_{emp}<T_{cr}$ $(8<10)$ at the significance level $p<0,05$. Hypothesis H_0 is accepted. The values of the GPA in computer science of 7th grade students by studying the section "Tabular Data Processing" after the experiment exceeds the values of the GPA in computer science before the experiment at the level of significance $p<0,05$.

Calculated T_{emp} by formula (2) for the GPA in computer science of 8th grade students by studying the section "Algorithms and Programs" (formula (4)).

$$T_{emp} = \sum_{i=1}^{k} r_i = 11{,}05\,, \tag{4}$$

Find the critical value for the Wilcoxon's T-test for $n=13$, using the data in statistical tables [14]: for $p<0{,}05$ the $T_{cr}=21$, for $p<0{,}01$ the $T_{cr}=12$. The empirical value $T_{emp}<T_{cr}=12$ $(11{,}5<12)$ at the significance level $p<0{,}01$. Hypothesis H_0 is accepted. The values of the GPA in computer science of 8th grade students by studying the section "Algorithms and Programs" after the experiment exceeds the values of the GPA in computer science before the experiment at the level of significance $p<0{,}01$.

To determine the interest of students in the use of didactic VR software in computer science lessons in secondary school, we conducted a questionnaire of students using *Questionnaire 1*.

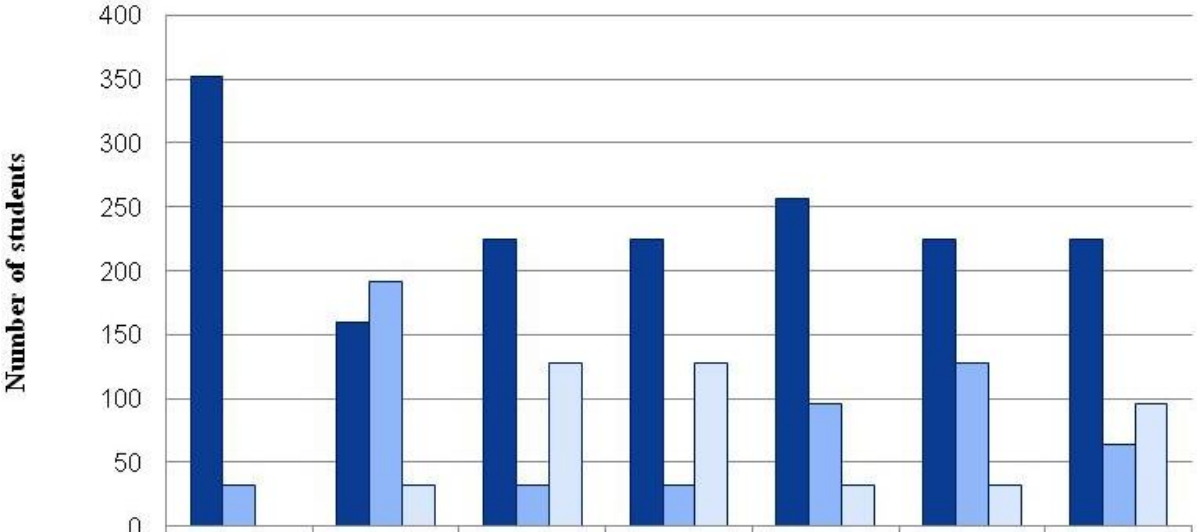
The required number of respondents (students) N, who has to answer the questionnaire, is estimated. For this purpose, the volume of the general population is determined. According to the statistics, the number of students in secondary school in the 2020-2021 academic year in Ukraine was *4211* thousand students, so in 7-8th grades there were approximately *842,2* thousand people, $n=842200$ [17]. Choose the maximum value of the product $w*(1-w)=0{,}25$ to obtain more reliable results, which is achieved at $w=0{,}5$. The confidence coefficient for the forecast with an accuracy of *95%* is chosen from the tabular value of the Student's coefficient, at $\alpha=0{,}05$ it is equal to $t=1{,}96$. Note the allowable margin of error $\Delta=0{,}05$. According to the formula (1) we calculate the required number of respondents (students) $N=383{,}98\approx384$ students. *387* secondary school students of Ukraine took part in the questionnaire to determine the interest of students in the use of VR didactic software in computer science lessons.

According to the results of the questionnaire, the following results were obtained (Table 4, Fig. 6). The questionnaire of students showed that students are generally interested in the use of didactic VR software in computer science lessons, the percentage of answers "Yes" to all questions of the questionnaire was *61,9%*, which is more than the answers "No" (*21,4%*) and "Undefined" (*16,7%*), as well as more than their total volume – 38,1\%. The students gave the most positive answers to questions № 1 and № 5, respectively confirming their interest in using didactic VR software in computer science lessons (*91,7%*) and the desire to independently develop virtual reality software in computer science lessons (*66,7%*). The majority of students positively evaluated and expressed interest in using didactic VR software tools "Excel on a forest glade" (*58,3%*) and "Tower of Hanoi" (*58,3%*) in computer science lessons. Also, the results of the questionnaire show that many students have no experience of using didactic software of virtual reality in computer science lessons (*50,0%*). *58,3%* of students are interested in the use of virtual reality software in the extracurricular time and *58,3%* – in the process of homework in computer science.

Table 4

The results of the students' questionnaire to determine their interest in the use of didactic VR software in computer science lessons using Questionnaire 1.

Questions	Yes (number)	No (number)	Undefined (number)	Yes (%)	No (%)	Undefined (%)
1	352	32	0	91,7	8,3	0,0
2	160	192	32	41,7	50,0	8,3
3	224	32	128	58,3	8,3	33,3
4	224	32	128	58,3	8,3	33,3
5	256	96	32	66,7	25,0	8,3
6	224	128	32	58,3	33,3	8,3
7	224	64	96	58,3	16,7	25,0
Total number	1664	576	448	61,9	21,4	16,7



	1	2	3	4	5	6	7
Yes	352	160	224	224	256	224	224
No	32	192	32	32	96	128	64
Undefined	0	32	128	128	32	32	96

Figure 6: Graphical representation of the results of students' questionnaires to determine their interest in the use of didactic VR software in computer science lessons using Questionnaire 1.

4. Conclusion

Based on the analysis of the ways of using virtual reality didactic software "Excel on a forest glade" and "Tower of Hanoi" and determination of students' interest in these digital products, the study reveals the potential possibilities of using virtual reality technologies for teaching informatics in secondary schools. The use of VR/AR technology opens up opportunities for an innovative transformation of the educational process.

The methodological bases of designing, development and use of didactic software of virtual reality "Tower of Hanoi" and "Excel on a forest glade" with the use of CoSpaces Edu service in computer science lessons in secondary school were developed and researched.

Pedagogical organizational conditions for the use of virtual reality tools for studying the chapters "Tabular Data Processing" and "Algorithms and Programs" in computer science lessons in secondary school are identified: the availability of the necessary technical support for viewing virtual reality applications and the necessary software for the development and use of virtual reality, effective forms and methods of forming students' necessary skills, the development of students' motivation to study these chapters.

It was found that the GPA of students in experimental groups that studied the chapters "Tabular Data Processing" and "Algorithms and Programs" is higher than the corresponding GPA in computer science that studied these chapters, respectively, in 7th grade – *8,3* (GPA in computer science – *7,6*), in 8th grades – *7,9* (GPA in computer science – *7,8*). Also, this GPA is higher than in the control groups, respectively, in 7th grade – *7,4*, in 8th grade – *6,8*. Such a positive dynamics of the GPA in the control groups was not observed. Using Wilcoxon's T-test it was proved that the value of the GPA of 7th and 8th grade students in the study of "Tabular Data Processing" and "Algorithms and Programs" using virtual reality tools "Tower of Hanoi" and "Excel on a forest glade" is statistically higher than the corresponding GPA with a significance level of $p<0,05$ and $p<0,01$, respectively.

The study, through theoretical understanding and analysis of students' attitudes based on questionnaires, reveals the possibilities of further use of didactic software of virtual reality "Excel on a forest glade" and "Tower of Hanoi" as software products that can increase the effectiveness of

computer science teaching in secondary school. *61,9%* of students are generally interested in using didactic VR software in computer science lessons. *91,7%* of students are interested in using didactic VR software in computer science lessons. *66,7%* – independently develop virtual reality software in computer science lessons. Also, *58,3%* and *58,3%* of students, respectively, positively evaluated and expressed interest in using didactic VR software "Excel on a forest glade" and "Tower of Hanoi" in computer science lessons. However, half of the surveyed students – *50,0%* have no experience of using didactic software of virtual reality in computer science lessons.

Theoretical and practical results, conclusions, proposals and recommendations formulated in the study can be used: for further research in this area; in the process of designing and using didactic tools based on virtual/augmented reality technologies.

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