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INFLUENCE OF VIRTUAL REALITY TOOLS ON HUMAN ANATOMY LEARNING

Abstract. The paper considers virtual reality (VR) as an effective way of teaching and learning. It discusses the possibilities of modern educational information technologies implementation, the educational advantages and drawbacks of 3D technologies and highlights VR features which enable dynamic forms of learning by creating artifacts in virtual environment with activities triggered by learners' interaction. The effective role of the means of VR in education is determined and theoretically substantiated. Approaches aimed at increasing the theoretical and practical readiness of learners for educational activity using VR tools are considered.
The research participants were exposed to two learning modes: traditional (textbook style) and VR. The experiment was based on Human Anatomy VR Complete Edition by Virtual Medicine software which provided interaction with virtual models of human anatomy. Anatomy knowledge test and Students' Engagement in School Four-dimensional Scale were used to compare learning outcomes and the levels of student cognitive engagement between the two groups on the basis of ANOVA test.
Participants in the VR mode improved learning performance (i.e. recollecting and reconstituting) and engagement scores (cognitive and agency subscales) compared to those in the traditional learning mode. Emotional self-ratings before and after the learning phase in the VR mode showed an increase in positive emotions and a decrease in negative emotions. Overall, participants in the VR mode displayed an improved learning experience when compared to traditional learning methods. The combination of visualization and interactivity makes VR learning mode advantageous for effective education. The directions of further research such as organizational and psycho-pedagogical conditions of VR implementation in education and teacher training are defined.

Keywords: VR; virtual reality; education; collaborative virtual environments; perception; engagement.

1. INTRODUCTION

Statement of the problem. Our country's educational policy contributes to the development of digital learning and the provision of high quality electronic educational resources in schooling. The digitalization of the educational space of Ukraine is both a technology and a new approach in the creation and use of digital resources, which aims to provide high-quality and continuous formal, non-formal, informal education in various forms. There is a need to update the methodology of teaching and psychological basis in the context of digitization, understanding the necessity to change the approach to teaching. According to V. Bykov, M. Leshchenko and L. Tymchuk, today needs the development of digital humanistic pedagogy, which would cause the emergence of a new educational paradigm, as well as a rapidly expanding scientific field that develops and motivates the occurrence of the advanced pedagogical thinking [1, p. 2]. Noureddine Elmqaddem stated that VR can finally be adopted in all domains, including education. “The nature of AR and VR and their recent enhancement thanks to various technological advancements allows a new type of learning that better meets the needs of the 21st century learner who wants entertainment, interactivity, participation and manipulation of objects” [2, p.235].

Embodied cognition proves that both human mind and body are working together to make the meaning of our experiences. Many studies acknowledge that embodied cognition is promising for learning. Embodied insight rose up out of the field of theory as an unmistakable difference to the surviving considerations set forth by Descartes. Descartes proposed a mind–body dualism dichotomy as a superior thinking ability. He explained realities from life experiences as the result of the way this duality operates.

Specialists from the University of Chicago [3] discovered that basic pantomiming in elementary pupils shows skills not found in discourse and can conceivably differentiate and enhance their insight.

Virtual Reality enables a client to associate with a PC produced three-dimensional model or virtual condition. These surroundings are well-known to us as plainly visible scale. It is realistic as it gives the opportunity to see the physical world. Fundamentally, VR is connected to various fields of training including engineering disciplines, medicine, archeology, history, design and many more. The benefit of VR over ordinary strategies is that the schoolchildren are allowed the chance to experience phenomena that would be difficult to represent or depict with traditional techniques. We contend here that this experiential nature of VR together with its other key element, intuitiveness, gives an important guide to regular learning ideal models.

Present day instruction frequently requires schoolchildren to fathom unpredictable or conceptual ideas or acknowledge situations and circumstances that previously never existed. Regular components for learning abstract concepts are the application of allegory and similarity. By utilizing similarity, we depict an occasion or dynamic idea of observable reality. The experience gives the material to the development of a psychological model of the idea, which thus prompts the establishment of learning [4]. Virtual reality is an innovation that replaces sensory input received from this present reality with tangible information made by PC recreation. In this regard, VR may demonstrate to be an amazing asset that can help in educating by giving a domain that enables the pupils to encounter situations and circumstances as opposed to envisioning them. The experiential idea of VR frameworks derives from three sources: engagement, synergy and multi-tactile response. Engagement means presence in the environment. The advantage of engagement is that it guarantees a feeling of essence or the inclination that one is truly in the delineated world [5].

The analysis of recent studies and publications. The experiential idea of VR underpins a constructivist way to deal with learning [6]. Constructivism is defined as theory of knowledge acquisition. Schoolchildren construct their knowledge by learning from their own experiences. This theory states that pupils attempt to adopt new experiences within their already fixed world model. On the off chance that pupils cannot effectively absorb a new detail, they change their reality view to suit the new experience. When we expect that the world acts depending on our world model, but it does not, we have to adapt to the new experience by changing our model of the way the world works. We study from our experience. VR gives a situation to this dynamic theory testing and subsequently gives an amazing medium to studying. As proposed by Bruner, the pupils who effectively draw in with new material are bound to hold this material and review it at a later level [7]. Dr. Mirza Viquar Ahmed argues that VR improves the capacity of human mind by improving memory, stating that memory improvement focuses supremely on retaining the learned facts for a longer period of time [8, p.53].

VR advancements enable the client to see and associate with virtual conditions and items. Present day VR is conveyed through a headset, which enables the client to see – and now and again, hear – the 3D condition. This way the pupils are fully immersed in the virtual condition, as it replaces the existing environment around them. Submersion and commitment can be considered naturally connected in virtual conditions [9]. Mount et al. examined the connection between absorption, attendance and commitment [10].

Over the past two decades, the educational systems of different countries have been getting more interested in engagement, even though there is considerable disunity in understanding of this phenomenon. Early investigations characterized student commitment by detectable practices, for example, cooperation and time on undertaking [11]. Specialists have additionally fused passionate or full of feeling perspectives into their conceptualization of commitment [12], [13].

These definitions incorporate sentiments of having a place, delight, and connection. Not long ago, scientists examined parts of intellectual commitment, for example, students' interest in learning, persistence notwithstanding difficulties, and utilization of profound as opposed to shallow methodologies [14]. Some have likewise included self-guideline (the degree to which schoolchildren show command over their learning activities) as a part of psychological engagement on cognitive level [15], [16]. Scientists have proposed hypothetical models recommending that engagement of the schoolchildren ensue educational achievement. The earliest theory of engagement was the model of participation and identification [13]. This hypothesis characterizes engagement in school as "having both a behavioural component, termed participation, and an emotional component, termed identification" [13, p. 249].

Connell and his associates (Connell 1990; Connell and Wellborn 1991; Skinner and Belmont 1993) distinguish the continuum which has got engagement on one side and disaffected action on another. The students who are engaged show behavioural involvement in learning. They persevere the challenge and are full of positive emotions [12], [17]. Disengaged students differ. They are passive and bored, give up easily, do not try hard. Such negative emotions as anger, blame, and denial are displayed by them [18].

Reviewing students' engagement, Fredricks, Blumenfeld, and Paris [14] recommended dividing it into three aspects: behavioural, emotional, and cognitive. The main idea of behavioural engagement is to include involvement in social, academic and extracurricular activities. It is considered as determination for achieving positive academic outcomes and preventing dropping out [12], [13].

The focus of emotional engagement is on the extent of positive and negative reactions of both teachers and schoolchildren. Positive emotional engagement is supposed to create schoolchildren' ties to the institution. It influences their willingness to work [12], [13].

Cognitive engagement is characterized as the student's degree of investment in learning. It contains attention and responsibility in the approach to school tasks. The students are willing to exert the effort needed to master difficult knowledge and skills, to understand complex thoughts [14].

We accept that VR learning technique has got capacity to improve each of the three elements of school engagement and make an immense beneficial impact on the instructive improvement.

VR can display different highlights that could be valuable for students. It presents 3D format of environment. It is interactive, as it gives audio, visual and even haptic feedback. Showing learning materials in 3D can be particularly advantageous for teaching subjects where it is essential to envision the learning materials (for example in chemistry, biology, and medicine). Although imagining is one of the clearest advantages of VR, this could likewise be practiced with straightforward video. Nevertheless, recordings are passive learning objects, while VR offers an immediate association with the surroundings.

The outstanding visual-sound-related kinaesthetic learning style model suggests three kinds of learning styles: visual, sound-related and kinaesthetic. VR headsets support complex visualisation, audio and movement tracking. VR allows all the three mentioned learning styles to be centred in one application. Other learning style models point out the importance of different perceptual modalities in learning. Many of them can be supported with the help of VR. It has been proposed that having an assortment of learning strategies is profitable; Gaytan and McEwen inferred that it is gainful to utilize an assortment of instructional techniques to speak to students' learning inclinations [19]. VR exercises could be intended to incorporate various learning techniques, so students can connect with the learning materials in the way that interests them most, as they have an inclination for different methods of data introduction [20].

Elliot Hu-Au and Joey J. Lee discussed that VR is especially useful for increasing student engagement, providing constructivist, authentic experiences to impact student identity; allowing for new perspective taking and empathy; and supporting creativity and the ability to visualise difficult models [21, p.222].

The scientists insist that educators must embrace and leverage better methods to deliver the most effective learning experiences for students who are taught in the experience age [19, 22].

Recent research has been critical of learning style approaches [22]. It is stated that there is little empirical proof of engagement for learning styles despite many theories. However, it is important to research varying sensory modalities and learning approaches as students have different learning preferences and habits.

Creating VR educational applications is an arduous and expensive undertaking. It is essential to examine whether these applications are valuable for learning or not. Along these lines, explorative research can help answer whether the advancement of instructive applications for this sort of equipment is worth seeking after.

The purpose of the article is to highlight the idea why learning might be encouraged by interactive VR systems and to prove the positive influence of VR tools on students' learning and engagement. The tasks were to provide the samples of the use of VR in educational contexts and to compare the participants' performance after the VR learning experiment.

2. THE RESEARCH METHODS

The research was done in the framework of the research project "Psychological determinants of professional personality formation" at Mukachevo State University, Ukraine.

Theoretical and empirical methods were used in the research. Systematization and comparison of scientific provisions were used for analysis of VR technologies that are being offered for Ukrainian students to determine their use. Empirical part contained observations and questionnaires for determining the effectiveness of student engagement and learning outcomes.

Participants were 48 (28 females, 20 males) students from schools in Mukachevo City, Ukraine. They were learning Anatomy. Participation was voluntary, and scores were confidential and anonymous. The students were divided into two learning modes: ordinary (reading material style) and VR. All members detailed typical or rectified to-ordinary vision.

The representativeness of the sample was obtained with a non-probability sampling method. All parents permitted their children to participate in the experiment. All participants' parents were aware of their right to refuse at any time and gave informed written consent. We also tutored and instructed the teachers who participated in the experiment. Control and experimental groups of students were formed.

The students of the experimental classes were learning with the help of VR setups and the students of the control group – with paper textbooks.

Eight sets of Oculus Go all-in-one VR were used for the VR condition. Each headset weighs 468g and demonstrates a 3D environment via two OLED displays (1280 x 1440 pixels for each eye) and supports visual and audio type of feedback. The screen's refresh rate can vary between 60 and 72 Hz relying upon the application or game. We used Human Anatomy VR Complete Edition by Virtual Medicine software, s.r.o. https://www.medicinevirtual.com/.

The procedure was the same for each student, beginning with a pre-test, followed by the learning stage. For the learning stage the participants were told to learn as much as they could from the learning materials. The same amount of time was given to the both modes. Participants completed a post-test after the learning phase. It included the same questions as the pre-test. The students were asked the question for qualitative feedback check. The improvement from pre-test to post-test was used as the basic scale of learning performance. This method was used in order to consider for any students with prior knowledge of Anatomy subject. Questions used for the test were either sourced directly from teacher's Anatomy test or were in a similar style as those questions. We measured the dimensions of engagements in this research work using 20-items scale, entitled Students' Engagement in School Four-dimensional Scale, SES-4DS, English version. A split-plot ANOVA (a mixed-design analysis of variance model) was used to test the contrast between the two groups.

3. THE RESULTS AND DISCUSSION

3.1 Justification of software approbation

The 22 anatomy knowledge questions were marked as correct or incorrect and used in the calculation of an overall percentage correct, separately for each participant. The top half of Table 1 demonstrates the average knowledge scores in the pre-test and in the post-test, together with the distinction scores, as a marker for learning. The relating normal scores of the SES-4DS appraisals are given in the bottom of the table.

Table 1.

Indicators of knowledge scores (percentage correct) and engagement scales in the pre-test and post-test

Scale	Learning	N	Pre-test	Post-test	Difference
Knowledge scores	Virtual	24	30.1%	55.9%	+25.8%
	Textbook	24	29.8%	46.2%	+16.4%
Engagement scores					
Cognitive	Virtual	24	17.92	20.29	+2.37
	Textbook	24	17.80	18.87	+1.07
Affective	Virtual	24	23.04	23.78	+0.74
	Textbook	24	23.88	24.08	+0.20
Behavioral	Virtual	24	26.17	26.27	+0.10
	Textbook	24	25.87	25.74	–0.13
Agency	Virtual	24	16.14	18.88	+2.74
	Textbook	24	16.99	17.11	+0.12
Total engagement	Virtual	24	83.27	89.22	+5.95
	Textbook	24	84.54	85.80	+1.26

Notes. (*N*) - Number of participants

The data from knowledge questionnaires was additionally analysed by parting the inquiries into two classifications based on Bloom's taxonomy (Bloom et al. 1956). The first group (10 questions) identified with the recalling of data, while the second part (8 questions) was increasingly concerned about the reconstituting of data.

A 3 × 2-way ANOVA on the remembering and reconstituting scores demonstrated a critical test × condition interaction, $F(2,96) = 6.28$, $p = 0.022$, $\eta 2p = 0.116$ and $F(2,96) = 3.15$, $p = 0.037$, $\eta 2p = 0.062$ for reconstituting score. ANOVAs and LSD tests revealed that in the post-test participants scored significantly higher in the VR than in the textbook mode ($p = 0.008$ and $p = 0.041$, respectively). The corresponding analysis of the understanding scores also revealed a significant interaction. In summary, participants in the VR group showed better remembering and reconstituting than participants in the textbook one.

Concerning SES-4DS ratings – three separate one-way ANOVAs revealed a significant effect of condition for each of the two subscales (cognitive and agency). Both cognitive and agency ratings were significantly higher in the VR than in the textbook mode ($p = 0.015$ and $p= 0.021$, respectively). For other scales there was no difference between the VR and the textbook mode ($p>0.05$).

Qualitative data was also gathered. The participants were asked as part of their online questionnaire: “What did you think of the format of the learning materials/the equipment used?” The question was optional, and about half of the participants gave some written feedback.

The students characterized the reading material style learning materials as "fundamental", "exhausting" and "flat". There were disparities in reports, with certain participants saying the materials were "clear" and "simple to gain from", yet others stating that the materials were "misty" and the models "weren't useful". On the other hand, the participants found that the VR was "troublesome" to utilize, regularly explaining "at first", but saw it more "engaging", with two participants saying that it "made learning process more exciting" and another commenting that it was "helpful, powerful and vivid".

The feedback suggests that there is some difficulty using the equipment “at first”. It is supposed that future studies can benefit from giving VR participants a test period with the equipment first, to familiarize themselves with hardware and software.

3.2 Application in Schooling

VR applications in schools fall into two sub-classes, those in which educators use pre-created applications (Cell Biology, Virtual Gorilla Exhibit, MaxwellWorld, Atom World, Newton World, Greek Villa), and those in which schoolchildren themselves assemble virtual universes so as to test speculations (Virtual Stage, Wetland Ecology). Pre-created applications consist of a virtual environment, supporting hardware and software in which students perform needed tasks. The most engaging items for teaching and learning are those which are managed, empowering teachers to centre and guide students’ experiences. It means that the students do not need to look for the information. The content is quickly uploaded individually and easily delivered to students. Virtual reality implementation is neither cheap nor simple yet, “but they are definitely important tools in the learning and development toolkit” [23, p.30].

At the same time, VR as an educational tool has some drawbacks. Here we consider some of the key problems. We have distinguished the following three general and possibly serious disadvantages that have limited the general use of VR in schools:

1. Potentially high budgetary expenses of acquiring a system.
2. Lack of authenticity/constancy/skill transfer issues.
3. Physical influences on end-users.

The first relates to the high costs involved in developing and/or buying a VR. As we have seen, VR frameworks comprise programming for the control of the representation, PCs for running the software and innovation for presentation and interaction. The increasing use of VR brings the economies of large-scale manufacturing and reduces costs of both hardware and software. Additionally, off-the-shelf educational systems exist, and such frameworks are faster option of VR classes deployment. While the innovation is moderately new, in any case, it will stay generally costly in contrast to traditional teaching methods.

3.3. VR and perceptions

Realism can increase the engagement of the viewer in visualization. It can both reduce perceptual double meaning and provide redundancy of sensory information. As a result, experience becomes richer. Much progress was accomplished in the realism obtainable in graphical simulations. This is because of the expanding popularity of PC games. The PC games industry has turned out to be very productive and this has created innovative work in illustrations algorithms and devoted hardware for rendering designs and simulating dynamics. This has profited VR simulations and VR systems. While VR systems once required high-end PC support, it is possible to see rendering, dynamics and interaction control on a single desktop machine. Where extra processing power is required (or the addition of haptics and 3D sound for instance) clusters (connected groups) of PC workstations might be utilized. Interactivity is balancing with realism in many aspects.

The use of VR innovations permits better perception supporting demonstration and encouraging improvement of students' creativity and engagement. The plausibility of dynamic communication with VR is near empirical handling in physical world and gives the "learning by doing" effect. These variables are essentially adding to the appreciation of showed content, which quickens the learning procedure accordingly. The use of traditional learning methods containing static text and pictures for the understanding of some processes and procedures, especially in such science as anatomy, is insufficient. This makes space for implementation of digital technologies with 3D visualization. They will allow virtual manipulation with unnatural objects, providing features of gamification to support curiosity and playfully leading to creative solutions. As a result, the students feel satisfied and their motivation to get new knowledge increases.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

There is proof that active learning is helpful to students. The advantages found for VR are basically the advantages of active learning, however, they may also be a consequence of different psychological reasons.

The goal of this research work was to consider the impacts of utilizing VR headsets for learning. Summing up the results of our study, we can conclude that the participants in the VR mode demonstrated advantages in learning over the participants in the textbook mode. Further breakdown of the learning engagement demonstrated that participants in the VR mode were better at "remembering" and "reconstituting" than those in the traditional mode and furthermore indicated better cognitive engagement.

VR was found to have an exceptionally positive effect on mood. Participants of the VR group stated increase in positive feelings and a general decrease in negative ones during the experiment. On the other hand, reading material mode participants demonstrated a decrease in positive feelings. In sum, the utilization of VR headsets positively affects the learning background.

The significance of student's engagement is already generally recognized. The SES-4 DS Scale additionally demonstrates that engagement can be expanded using VR. Participants in the VR mode evaluated their study higher, showing that they had better adopted the content.

The beneficial outcomes on feeling and engagement in VR are significant advantages for both inside and outside homeroom learning. This learning is usually disregarded, with the attention being on different results, for example, test scores. In any case, it was exhibited that students' feelings, engagement and inspiration are profoundly connected with one another.

Respondents see traditional formal and informal instructive strategies as dull, stretched, tedious and lacking expressiveness, prompting inadequate or wrong comprehension of learned content. It makes the learning boring and demotivates students from acquisition of new information and self-advancement. Computer generated reality makes close computerized representation of the objects and environments that are hardly observable in the real world. It permits intuitive control with modes where the activity of the student triggers occasions and gains from observational experience and virtual action. The significance of computer-generated reality in learning is expanding because of its characteristics and highlights. Its application may cultivate imaginative and sidelong reasoning, quicken the learning procedure and persuade both teachers and pupils to supportable self-improvement and advancement of abilities fundamental for progress and development of associations. This examination has exhibited how VR can improve or supplement ordinary learning methods. It is critical to think about how VR innovation can benefit learning beyond the classroom, self-study in particular.

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ВПЛИВ ЗАСОБІВ ВІРТУАЛЬНОЇ РЕАЛЬНОСТІ НА ВИВЧЕННЯ АНАТОМІЇ ЛЮДИНИ

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Анотація. Стаття присвячена проблемі віртуальної реальності (VR) як ефективного способу навчання. Обговорено можливості впровадження сучасних освітніх інформаційних технологій, переваги та недоліки використання 3D-технологій в освіті та підкреслено властивості VR, які забезпечують динамічні форми навчання, створюючи артефакти у віртуальному середовищі в поєднанні з діяльністю, ініційованою інтерактивною взаємодією учня. Визначена та теоретично обґрунтована ефективна роль засобів VR в освіті. Розглянуто методичні підходи, спрямовані на підвищення теоретичної та практичної готовності учнів до навчальної діяльності в закладах шкільної освіти з використанням засобів VR.

Респондентам, які взяли участь у дослідженні, було створено два варіанти умов навчання: традиційні умови (використовуючи підручник) та навчання з використанням VR. Експеримент базувався на додатку Human Anatomy VR Complete Edition від Virtual Medicine, який дозволяє взаємодіяти з віртуальними моделями анатомії людини. Порівняння результатів навчання та рівнів когнітивної залученості учнів двох груп було здійснено з використанням дисперсійного аналізу ANOVA за допомогою тесту знань з анатомії та чотиривимірної шкали шкільної залученості.

Учасники в умовах VR покращили якість навчання (а саме: запам’ятовування та відтворення) та показники залученості (когнітивна та суб’єктна субшкали) порівняно з тими, які перебували в традиційних умовах. Самозвіт учнів щодо загального емоційного стану до та після фази навчання з використанням VR продемонстрував збільшення позитивних та зменшення негативних емоцій. У цілому, використання VR в освітньому процесі продемонструвало покращення результатів навчання порівняно з традиційними методами. Поєднання візуалізації та інтерактивності роблять метод навчання за допомогою VR ефективним. Визначено напрями подальшого дослідження: організаційні та психолого-педагогічні умови запровадження VR у закладах шкільної освіти та підготовки вчителів до їх використання.

Ключові слова: VR; віртуальна реальність; освіта; віртуальне середовище; сприйняття, залученість.

ВЛИЯНИЕ СРЕДСТВ ВИРТУАЛЬНОЙ РЕАЛЬНОСТИ НА ИЗУЧЕНИЕ АНАТОМИИ ЧЕЛОВЕКА

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Аннотация. Статья посвящена проблеме виртуальной реальности (VR) как эффективного способа обучения. В статье обсуждаются возможности внедрения современных образовательных информационных технологий, преимущества и недостатки использования 3D-технологий в образовании и выделяются свойства VR, которые обеспечивают динамические формы обучения, создавая артефакты в виртуальной среде в сочетании с деятельностью, инициированной интерактивным взаимодействием ученика. Определена и теоретически обоснована эффективная роль средств VR в образовании. Рассмотрены методические подходы, направленные на повышение теоретической и практической готовности учащихся к учебной деятельности в учреждениях школьного образования с использованием средств VR.

Респондентам, которые приняли участие в исследовании, было создано два варианта условий обучения: традиционные условия (используя учебник) и обучение с использованием VR. Эксперимент основывался на приложении Human Anatomy VR Complete Edition от Virtual Medicine, которое позволяет взаимодействовать с виртуальными моделями анатомии человека. Сравнение результатов обучения и уровней когнитивной вовлеченности учащихся двух групп было произведено при помощи дисперсионного анализа ANOVA с использованием теста знаний по анатомии и четырехмерной шкалы школьной вовлеченности учеников.

Участники в условиях VR улучшили качество обучения (а именно: запоминание и воспроизведение) и показатели вовлеченности (когнитивная и субъектная субшкалы) по сравнению с теми, которые находились в традиционных условиях. Самоотчет учеников относительно общего эмоционального состояния до и после фазы обучения с использованием VR продемонстрировал увеличение положительных и уменьшение отрицательных эмоций. В целом, использование VR в образовательном процессе продемонстрировало улучшение результатов обучения по сравнению с традиционными методами. Сочетание визуализации и интерактивности делают метод обучения с помощью VR эффективным. Определены направления дальнейшего исследования: организационные и психолого-педагогические условия внедрения VR в учреждениях школьного образования и подготовки учителей к их использованию.

Ключевые слова: VR; виртуальная реальность; образование; виртуальная среда; восприятие; вовлеченность.