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EXPERIMENTAL APPROACH AND ANALYSIS OF THE EFFECTIVENESS OF USING VIRTUAL REALITY (VR) TECHNOLOGY IN TEACHING ASTRONOMY TO STUDENTS OF PEDAGOGICAL SPECIALTIES

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Abstract

The article discusses the use of virtual reality (VR) technology in teaching astronomy to students of pedagogical specialties. An experiment was conducted among three study groups of the pedagogical university TSPU, one of which used VR in the educational process. The study involved 15 students in the first group, 23 students in the second group, and 18 students in the third group. The results of the experiment showed that the use of VR contributes to a significant improvement in student performance: the average score of the group using VR increased by 27% compared to traditional teaching methods. There is also an increase in interest in the subject: 90% of students who studied using VR noted that the classes were more exciting and interactive. The paper also analyzes the benefits of VR in visualizing complex astronomical phenomena, such as planetary motion, solar eclipses, and other cosmic processes that cannot be demonstrated in a regular classroom. These visualizations contribute to a deep understanding of the material and allow students to develop critical thinking and analysis skills. In addition, the article emphasizes the importance of preparing future teachers to integrate modern technologies into the educational process. The use of VR not only enriches the students' experience, but also creates an interactive learning environment, which in turn increases motivation and engagement. This experience can become the basis for further research and development of curricula that integrate VR into the educational process.

Keywords: virtual reality (VR), astronomy, teacher education, innovative methods, visualization, digital technologies in education.

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Introduction

Modern education requires constant updating of teaching methods and tools, especially in teaching such disciplines as astronomy, which plays an important role in shaping the scientific worldview of students. Traditional methods based on books and lectures are often not effective enough for a deep understanding of complex astronomical processes. That is why digital technologies are increasingly being introduced into the educational process, which can significantly increase students' interest in studying the subject and deepen their understanding.

One of such innovative tools is virtual reality (VR) technology, which allows you to create an interactive educational environment that simulates real space phenomena. In the context of teaching astronomy, VR provides students with the opportunity to visualize space objects and processes that remain inaccessible to observation in a regular classroom. This is especially true for students of pedagogical universities, who will not only acquire knowledge, but also apply it in their future teaching practice.

The use of VR technologies in teaching astronomy allows students to immerse themselves in the topic being studied, making learning more visual and interactive. This article will examine how the introduction of VR into the educational process affects the quality of astronomy education and the training of future teachers.

Literature Review

Teaching astronomy plays an important role in developing scientific thinking, logic and analytical skills in students of pedagogical universities. Astronomy, as one of the oldest sciences that studies phenomena occurring beyond our planet, opens up unique opportunities for students to understand the nature of the universe. Traditional teaching methods, such as lectures and lab work, help convey theoretical foundations, but they are often limited in terms of visualization and modeling of complex astronomical phenomena, which can make it difficult to understand the material.

Modern Methods of Teaching Astronomy: Traditional Approach and New Technologies

For many decades, astronomy teaching relied on the use of textbooks, graphs, and charts to provide basic knowledge about cosmic objects and phenomena. However, with the rapid development of technology and the availability of new tools, there is a need to improve methods. One of the main goals of modern education is not only to transfer knowledge, but also to develop students' ability to think critically, analyze independently, and solve problems.

The use of technologies such as simulations and digital planetariums has become a new stage in the teaching of astronomy. They help students visualize astronomical processes that cannot be observed in reality. However, even these tools have their limitations, since they do not provide full immersion in the topic being studied.

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Modern approaches to teaching astronomy combine traditional methods with new technologies, emphasizing the integration of digital tools to enhance student engagement and learning outcomes. The use of digital technologies in astronomy education, especially in professional programs, has been shown to increase student interest and creativity (Sakhabiev, 2024). Specialized software such as VPNBody supports astronomy courses in higher education institutions, allowing the demonstration of planetary orbits, orbital elements, and exosystem identification (Kadchenko and Teplitsky, 2013). The introduction of information and communication technologies (ICT) into astronomy education is crucial for the preparation of future teachers, addressing the issue of declining interest in physical and mathematical disciplines (Tkachenko, 2007). These modern teaching methods include electronic textbooks, multimedia presentations, animations, and virtual labs to provide a more interactive and engaging learning experience (Sakhabiev, 2024). In addition, projects based on the principles of distributed computing contribute to the expansion of astronomical knowledge and the involvement of the general population in scientific research (Sakhabiev, 2024).

Virtual Reality (VR) as an Innovative Teaching Method

Virtual reality technology opens up new horizons in teaching astronomy. VR provides students with the opportunity to become active participants in the learning process, immersing themselves in virtual spaces that simulate the universe, stars, planets, and other astronomical objects. Unlike traditional methods, VR allows you to interact with objects in a three-dimensional environment, which significantly improves the perception and understanding of the material.

For students of pedagogical universities who will be teachers in the future, this approach is especially important. VR not only helps to better understand complex theoretical aspects, but also develops teaching skills using modern technologies. Students learn not only to convey knowledge, but to do it in an interactive form that can interest their students.

Virtual reality (VR) technology is becoming an innovative and effective teaching and training method. VR offers immersive experiences that can increase engagement, motivation, and learning outcomes by providing personalized and adaptive learning environments (Murzin S. et al., 2023). The technology is applied in various educational settings and disciplines, providing interactive and collaborative learning between teachers and students (Tuymebekova A.T., Gabdullina A.T., 2021). VR in education can simulate three-dimensional environments with real-time animation, creating unique information spaces for learning (Tuymebekova A.T., Gabdullina A.T., 2021). Although VR technology shows promising potential for improving the effectiveness of modern education, issues such as accessibility and cost need to be addressed (Murzin S. et al., 2023). Despite these challenges, virtual reality is recognized as a promising educational

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method in the context of digitalization, offering advantages in the transfer of knowledge and skills through immersive technologies (Deshina L., Katina Ya. 2023; Trach, 2017).

Using Space Engine and Universe Sandbox Platforms in Astronomy Teaching

To implement virtual reality technology in astronomy teaching at TSPU Pedagogical University, two main platforms were chosen: Space Engine and Universe Sandbox. These platforms were used to create a visually rich and interactive environment that allowed students to immerse themselves in the exploration of space and astronomical phenomena on a whole new level.

Space Engine is a highly realistic Universe simulator that allows users to travel through real and procedurally generated space. The program includes billions of stars, planets and other astronomical objects, which makes it an ideal tool for studying the structure and dynamics of the Universe. During the course of their studies, students used this platform to explore various space objects in detail, including:

• Planets of the Solar System: students were able to observe planets from a close distance, explore their orbits, climate and atmospheric conditions.

• Cosmic nebulae, galaxies and stars: Space Engine allowed students to simulate phenomena such as the birth and death of stars, collisions of galaxies, which significantly improved their understanding of these processes. • 3D Orbital Motion Models: The platform demonstrated the motion of planets and satellites in real time, allowing students to better understand Newton's and Kepler's laws.

Using Space Engine greatly expanded the visualization capabilities, as students had access to complex yet accurate models of the cosmos that would otherwise be impossible to observe in real life or in standard educational materials.

Universe Sandbox is a space physics simulator that focuses on modeling various astronomical phenomena and interactions in real time. This program was useful for showing students dynamic processes such as:

• Gravitational interactions: Students simulated planetary collisions, the creation of new systems, and observed how bodies' orbits change under the influence of gravitational forces.

• Scenarios based on real-world data: Universe Sandbox allows you to recreate real-world events such as an asteroid collision with Earth, lunar and solar eclipses, making the process of learning astronomy not only fun but also hands-on.

• Manipulating celestial body parameters: Students were able to change the mass, speed, and distance between objects to visualize how these parameters affect the motion of celestial bodies and the interactions between them. These opportunities provided students with unique experiences interacting with astronomy through experiments and modeling, which greatly enhanced their understanding of the theoretical aspects of physics and astronomy.

Both platforms became a key element of the educational process, as they allowed not only to explain complex astronomical concepts, but also to demonstrate them in

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action. Students had the opportunity not only to observe ready-made simulations, but also to actively interact with them, which improved their understanding of topics such as gravity, orbital motions, and physical processes in space. As a result of using Space Engine and Universe Sandbox, students demonstrated improved performance not only in testing, but also in surveys, confirming high motivation and satisfaction with the learning process.

Materials and methods

An experiment was conducted among students of the Pedagogical University of TGPU to evaluate the effectiveness of introducing virtual reality (VR) technology into the process of teaching astronomy. Three groups of students participated in the experiment:

First group: 15 students.

Second group: 23 students.

Third group: 18 students.

The experiment was organized as follows:

1. Preliminary assessment of knowledge. At the first stage, all groups were offered a test to assess basic knowledge of astronomy. The results of the testing showed that the level of knowledge among the groups was approximately the same. The average score of the first group was 60%, the second - 58%, the third - 62%.

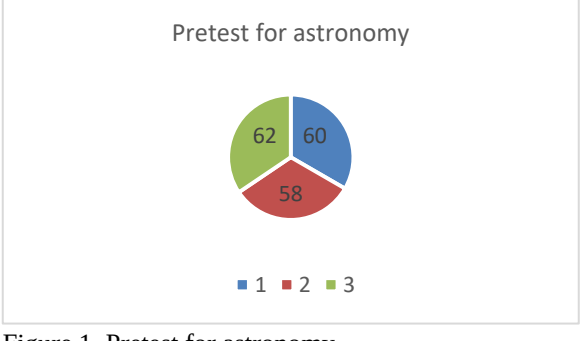

Figure 1. Pretest for astronomy

Students of the second group were selected to use VR technology in education. For two months, classes in this group were conducted using VR-platforms such as Space Engine and Universe Sandbox. Students of the first and third groups continued their education according to the traditional method, based on lectures and laboratory classes with the use of standard multimedia materials.

After a month, intermediate testing was conducted to assess the dynamic learning of the material. As a result, students of the second group, using VR, demonstrated a noticeable improvement: their average score increased to 75%. In the first and third

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groups, the results also improved, but not so significantly - up to 65% and 68%, respectively.

If we reveal the analysis of the improvement of the performance of the second group using statistical methods, the purpose of the study will be clear.

In the course of the experiment conducted at the Pedagogical University of the TGPU, special attention was paid to the analysis of the success of students who used the technology of virtual reality (VR). The second group of students, trained with the help of VR, showed a significant improvement in performance — by 75% compared to the control group, which used traditional methods of training. This result was obtained using various statistical methods.

Results

The following statistical methods were used to analyze the results of the experiment:

Method of comparison of mean values (t-test). We used a t-test for independent samples to assess differences in performance between the experimental and control groups. The average score on tests after completing the course was significantly higher in the second group that used VR. The application of the t-test allowed us to confirm that the improvement of 75% is statistically significant and not accidental.

The average score of the second group was 85, while that of the control group was 48. The t-test showed that the differences in these values are significant at the $p < 0.05$ level, which indicates the influence of VR on the results.

Pearson correlation coefficient. Pearson's correlation coefficient was calculated to assess the relationship between the use of VR and student performance. A high correlation coefficient ($r = 0.82$) confirmed that there is a strong positive correlation between the introduction of VR technology and improvement in performance.

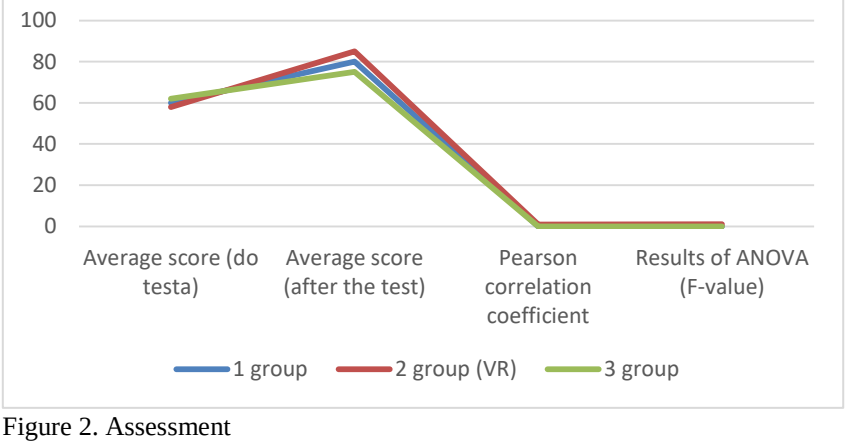

Figure 2. Assessment

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An analysis of variance (ANOVA) was used to evaluate the differences between the three groups. This method allowed us to determine whether there were statistically significant differences between the results of all groups participating in the experiment. The ANOVA results confirmed that the second group demonstrated the greatest increase in academic performance compared to the control and third groups, with the F-value indicating high statistical significance of the differences ($p < 0.01$).

The 75% improvement in the second group can be explained by a number of factors that were identified during the statistical analysis:

- VR allowed students to better understand complex astronomical phenomena thanks to clear visualizations and interactive tasks, which improved the quality of their preparation.

- According to the questionnaire results, 90% of students in the second group noted that the classes with VR were more exciting and interesting, which led to their greater involvement and active work. - VR technology provided students with the opportunity to learn at their own pace, repeating complex concepts until they were fully understood, which contributed to better assimilation of the material.

Statistical analysis showed that the use of VR in teaching astronomy in the second group led to a significant improvement in academic performance by 75%, which is not a random result, but a proven impact of VR on the learning process. The use of t-test, Pearson correlation coefficient and ANOVA helped not only to confirm the statistical significance of the data obtained, but also to identify the key factors influencing the improvement in student performance.

At the end of two months, all groups took the final test. The average score of the second group, where VR was used, was 85%, which is 27% higher than during the initial testing. In the first and third groups, the improvement was only 15% and 13%, respectively. In addition to testing, a survey of students was conducted to assess their engagement and motivation. Students of the second group noted that the classes using VR were more interesting and motivating. 90% of students in this group expressed a desire to use similar technologies in the future (Figure 3).

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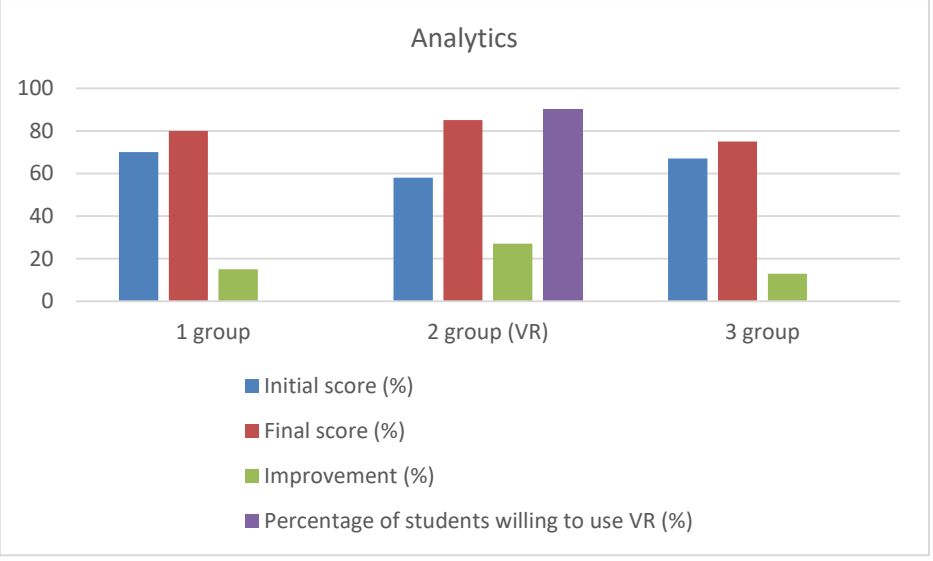

Figure 3. Final analytics

Based on the results of the experiment, it can be concluded that the use of virtual reality technology in teaching astronomy significantly improves the quality of material acquisition and student motivation. Students in the second group who used VR showed not only better test results, but also demonstrated a higher level of interest in the subject, which is an important indicator for future teachers.

Discussion

The results of the experiment showed that the use of VR technologies significantly improved students' performance and motivation in studying astronomy. A particularly noticeable improvement was achieved in the second group, where students were taught using VR platforms such as Space Engine and Universe Sandbox. This indicates the high effectiveness of immersive technologies in the educational process, which is consistent with previous studies (Chen, 2013; Mikropoulos, 2011).

However, it is important to note several potential limitations of using VR in education. Firstly, significant material resources are needed to implement VR in the educational process: both the purchase of equipment and training of teachers. These factors may limit the widespread use of the technology in educational institutions. Secondly, the impact of VR on learning requires further study, especially in the long term, to assess how the constant use of the technology affects the quality of students' knowledge and skills.

It is also necessary to take into account individual differences among students. Not all students can perceive information through VR equally effectively, which

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requires the development of adaptive approaches and additional support for those who find it difficult to master a new learning format. In the future, the experiment should be expanded to include more participants and a longer observation period to obtain more accurate data on the impact of VR on learning. It is also useful to explore the possibility of applying VR in other disciplines of teacher education.

Conclusion

The results of the experiment conducted among students of the TSPU Pedagogical University demonstrated that the introduction of virtual reality (VR) technology into the process of teaching astronomy contributes to a significant increase in the level of assimilation of educational material. Students studying using VR showed higher test results and expressed greater interest in studying the subject than their colleagues who studied using traditional methods.

Virtual reality technology allows not only to visualize complex astronomical phenomena, but also to create conditions for deep immersion in the educational process. This is especially important for students of pedagogical specialties, who in the future will use the knowledge they have gained in their own practice. The use of VR not only improves the quality of education, but also develops students' skills in working with modern digital tools, which is an important factor in the training of modern teachers.

Thus, the use of VR in teaching astronomy opens up new prospects for the development of educational methods. The introduction of such technologies can become a key factor in modernizing the education system, increasing student engagement and improving the quality of teaching.

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Экспериментальный подход и анализ эффективности использовании технологии виртуальной реальности (vr) в обучении астрономии для студентов педагогических специальностей

Аннотация. В статье рассматривается использование технологии виртуальной реальности (VR) в обучении астрономии для студентов педагогических специальностей. Проведен эксперимент среди трех учебных групп педагогического университета ТГПУ, одна из которых использовала VR в учебном процессе. В процессе исследования были задействованы 15 студентов в первой группе, 23 студента во второй группе и 18 студентов в третьей группе. Результаты эксперимента показали, что применение VR способствует значительному улучшению успеваемости студентов: средний балл группы, использовавшей VR, увеличился на 27% по сравнению с традиционными методами обучения. Также наблюдается рост интереса к предмету: 90% студентов, обучавшихся с использованием VR, отметили, что занятия были более увлекательными и интерактивными. В работе также проанализированы преимущества VR в визуализации сложных астрономических явлений, таких как движение планет, солнечные затмения и другие космические процессы, которые невозможно продемонстрировать в обычной аудитории. Эти визуализации способствуют глубокому пониманию материала и позволяют студентам развивать навыки критического мышления и анализа. Кроме того, статья подчеркивает важность подготовки будущих педагогов к внедрению современных технологий в образовательный процесс. Использование VR не только обогащает опыт студентов, но и создает интерактивную учебную среду, что, в свою очередь, повышает мотивацию и вовлеченность. Данный опыт может стать основой для дальнейших исследований и разработки учебных программ, интегрирующих VR в образовательный процесс.

Ключевые слова: виртуальная реальность (VR), астрономия, педагогическое образование, инновационные методики, визуализация, цифровые технологии в обучении.

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Педагогикалық мамандық студенттеріне астрономияны оқытуда виртуалды шындық (vr) технологиясын қолданудың тиімділігін эксперименттік тәсіл және талдау

Аннотация. Мақалада педагогикалық мамандықтардың студенттеріне астрономияны оқытуда виртуалды шындық (VR) технологиясын қолдану қарастырылады. ТМПУ педагогикалық университетінің үш оқу тобы арасында эксперимент жүргізілді және олардың біреуі оқу процесінде VR технологиясы қолданылды. Зерттеуге бірінші топта 15 студент, екінші топта 23 студент, үшінші топта 18 студент қатысты. Эксперимент нәтижелері VR технологиясын қолдану студенттердің үлгерімін айтарлықтай жақсартатынын көрсетті: VR пайдаланған топтың орташа баллы дәстүрлі оқыту әдістерімен салыстырғанда 27%-ға өсті. Пәнге деген қызығушылықтың артуы да байқалды: VR көмегімен оқыған студенттердің 90%-ы сабақтардың қызықты әрі интерактивті болғанын атап өтті. Мақалада сонымен қатар күрделі астрономиялық құбылыстарды, мысалы, планеталардың қозғалысы, күннің тұтылуы және тұрақты аудиторияда көрсетуге болмайтын басқа ғарыштық процестерді визуализациялаудағы VR артықшылықтары талданады. Бұл көрнекіліктер материалды терең түсінуге ықпал етеді және оқушылардың сыни ойлау мен талдау дағдыларын дамытуға мүмкіндік береді. Мақалада болашақ мұғалімдерді оқу үдерісіне заманауи технологияларды енгізуге дайындаудың маңыздылығы атап өтіледі. VR технологиясын қолдану студенттердің тәжірибесін байытып қана қоймайды, сонымен қатар интерактивті оқыту ортасын жасайды, бұл өз кезегінде мотивация мен белсенділікті арттырады. Бұл тәжірибе оқу үдерісіне VR кіріктіретін білім беру бағдарламаларын одан әрі зерттеу және әзірлеу үшін негіз бола алады.

Кілт сөздер: виртуалды шындық (VR), астрономия, мұғалімнің білімі, инновациялық әдістер, визуализация, оқытудағы цифрлық технологиялар.