The role of virtual reality in improving the quality of professional training of natural science teachers

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Abstract
The use of information technologies, in particular virtual reality, is becoming a topical issue in the professional training of natural science teachers. The study aims to assess the effectiveness of a professional development program that utilizes virtual reality as an educational tool to enhance the quality of training for natural science teachers. The obtained results testify to the positive impact of the virtual reality use on various aspects of teachers' professional training. The study found that the attitude towards technology improved significantly after the virtual reality introduction (from 65% to 72%). The percentage of positive responses regarding the feasibility of using STEM (Science, Technology, Engineering and Mathematics) technologies in education increased by 25%. Student feedback emphasizes the importance of integrating new technologies into STEM education. Further research should examine the training needs of STEM teachers in different educational contexts, explore effective technology integration strategies, and assess their impact on student outcomes.

Keywords
information technology; professional training; teachers; training programme; personal-oriented training.

O papel da realidade virtual na melhoria da qualidade da formação profissional dos professores de ciências naturais

Resumo
O uso de tecnologias da informação, em particular a realidade virtual (RV), está se tornando uma questão atual no treinamento profissional de professores de ciências naturais. O estudo visa a avaliar a eficácia de um programa de desenvolvimento profissional que utiliza a realidade virtual como uma ferramenta educacional para

melhorar a qualidade do treinamento para professores de ciências naturais. Os resultados obtidos atestam o impacto positivo do uso da realidade virtual em vários aspectos do treinamento profissional de professores. O estudo descobriu que a atitude em relação à tecnologia melhorou significativamente após a introdução da realidade virtual (de 65% para 72%). A porcentagem de respostas positivas sobre a viabilidade do uso de tecnologias STEM (Ciência, Tecnologia, Engenharia e Matemática) na educação aumentou em 25%. O *feedback* dos alunos enfatiza a importância de integrar novas tecnologias na educação STEM. Pesquisas futuras devem examinar as necessidades de treinamento de professores STEM em diferentes contextos educacionais, explorar estratégias eficazes de integração de tecnologia e avaliar seu impacto nos resultados dos alunos.

Palavras-chave
tecnologia da informação; formação profissional; professores; programa de formação; formação orientada para as pessoas.

El papel de la realidad virtual en la mejora de la calidad de la formación profesional de los profesores de ciencias naturales

Resumen
El uso de las tecnologías de la información, en particular la realidad virtual, se está convirtiendo en un tema de actualidad en la formación profesional de los profesores de ciencias naturales. El estudio tiene como objetivo evaluar la eficacia de un programa de desarrollo profesional que utiliza la realidad virtual como herramienta educativa para mejorar la calidad de la formación de los profesores de ciencias naturales. Los resultados obtenidos dan testimonio del impacto positivo del uso de la realidad virtual en varios aspectos de la formación profesional de los profesores. El estudio encontró que la actitud hacia la tecnología mejoró significativamente después de la introducción de la realidad virtual (del 65% al 72%). El porcentaje de respuestas positivas con respecto a la viabilidad del uso de tecnologías STEM (ciencia, tecnología, ingeniería y matemáticas) en la educación aumentó un 25%. La retroalimentación de los estudiantes enfatiza la importancia de integrar nuevas tecnologías en la educación STEM. La investigación futura debe examinar las necesidades de capacitación de los profesores STEM en diferentes contextos educativos, explorar estrategias efectivas de integración de tecnología y evaluar su impacto en los resultados de los estudiantes.

Palabras clave
tecnologías de la información; formación profesional; profesores; programa de formación; formación orientada a las personas.

1 Introduction

Modern professional development programmes for higher school teachers should ensure the acquisition of the necessary professional skills (Sheremet *et al.*, 2021; Horban *et al.*, 2021). Developing teachers' digital competencies is important, especially for quality STEM education. It is important that they not only get acquainted with new technologies

but also get practical experience in their use. Recognizing this need is key to successfully integrating technology into education (Gorman *et al.*, 2023; Horban *et al.*, 2022).

The introduction of new technologies in the field of student training creates some difficulties and obstacles, especially for teachers. Many educators feel underprepared or lack the necessary skills to effectively use technology tools in the classroom. The discrepancy between the growing demand for technology in education and the teachers' willingness to use it is becoming a serious problem (Dayal, 2023).

The growing emphasis on developing teachers' digital competence is reflected in the desire to gain a deep understanding and comprehensive skills in the use of technology, especially in the context of quality STEM education. This requires teachers not only to have a basic level of understanding but also to be able to actively create, develop and integrate innovative technological resources to improve their pedagogical strategies (Carabregu-Vokshi, 2024).

When integrating new technologies into the STEM educational process, it is critical to consider that initial teacher training remains relevant. However, this training should go beyond simple familiarization with the tools, it should also include strategies for solving the associated challenges (Agbo *et al.*, 2023). One promising direction is VR use.

VR not only captures students' attention by creating an immersive learning environment, but also enables teachers to demonstrate abstract or complex concepts through visual interactive scenarios (He *et al.*, 2024). For example, students can learn about the internal structure of a molecule or discover and explore historical events in an interactive format that enhances their understanding and engagement.

However, implementing VR in the educational process requires additional teacher training and support. They must not only know the technical aspects of using VR, but also develop adaptive curricula that meet their students' academic and pedagogical needs. This approach allows not only to involve students in learning, but also to prepare them for the challenges of the modern technological world (Rodrigues, 2022).

The aim of the study is to evaluate the developed professional development programme using VR as an educational tool to improve the quality of professional training of natural science teachers. The aim was achieved through the fulfilment of the following research objectives:

1. Develop a professional training course for teachers using VR;
2. Conduct an assessment before and after the delivery of the course on the skills of using VR in everyday life;
3. Determine students' personal attitude after the experiment.

2 Literature review

Modern challenges and innovations in natural science education require constant updating of knowledge by teachers to provide students with the most up-to-date and effective education. With the emergence of new technologies in a fast-changing world, teachers must follow innovations and be ready to integrate them into their pedagogical practice. Furthermore, recent studies emphasize the importance of introducing modern technologies, such as VR, into the educational process.

Digitization has significantly changed education as one of the most important spheres of the modern world. This has become an effective strategy in all aspects of the educational process, eliminating the difference between virtual and physical environments and introducing more scientific learning methods (Rosak-Szyrocka, 2024). Dalimunthe and Simanjuntak (2023) point out that knowledge transfer now goes beyond traditional lectures, as new technologies enable exponential expansion of access to information. Besides, digital technology is constantly evolving, encompassing video projectors, smart boards, mobile devices, e-books, downloadable music, seamless audio and video networks, and online social networks.

The growing use of technological devices as tools for education has significantly changed the educational landscape (Li; Li, 2024). Introducing new technologies has disrupted traditional teaching methods, creating a need for innovative approaches to knowledge transfer to meet modern technological advances. The theory of connectivism is the best framework for this study as it encompasses the concept of learning in the digital age (Kadmos; Taylor, 2024). It emphasizes the importance of interaction in networks as a key element for exchanging knowledge and developing technological skills (Rodrigues, 2022). Ideally, its prospects are important for understanding the challenges of digital learning in the 21st century and for bridging these gaps (Carabregu-Vokshi *et al.*, 2024; Zhylin *et al.*, 2023).

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Teachers also need access to professional development programmes in the field of new technologies. Without such opportunities, the use of technology to effectively transfer knowledge in the classroom will remain unrealized (Theodorio, 2024). Researchers emphasize that technology is constantly evolving; therefore, teachers need to keep their knowledge up to date through regular in-service training to keep their technology expertise current.

Internal factors that prevent teachers from using digital technologies in the classroom may include their attitudes and beliefs and resistance to technology implementation (Ratnawati *et al.*, 2023). It is believed that if teachers do not realize the usefulness and experience of digital technologies, they will persist in traditional teaching methods (Dayal, 2023).

Regardless of the level of education, digital skills have become necessary for effective communication with the global community, performing administrative and educational tasks, and developing creative and innovative abilities (Stofkova, 2022). Therefore, technologies play a key role in the learning process.

Research confirms that using modern technologies (VR, 3D modelling or simulation) enhances students' motivation and involvement in achieving higher academic performance (Carabregu-Vokshi, 2024). Therefore, teachers must have the necessary digital competencies and the skills to use modern technologies during classes and use them more effectively at work.

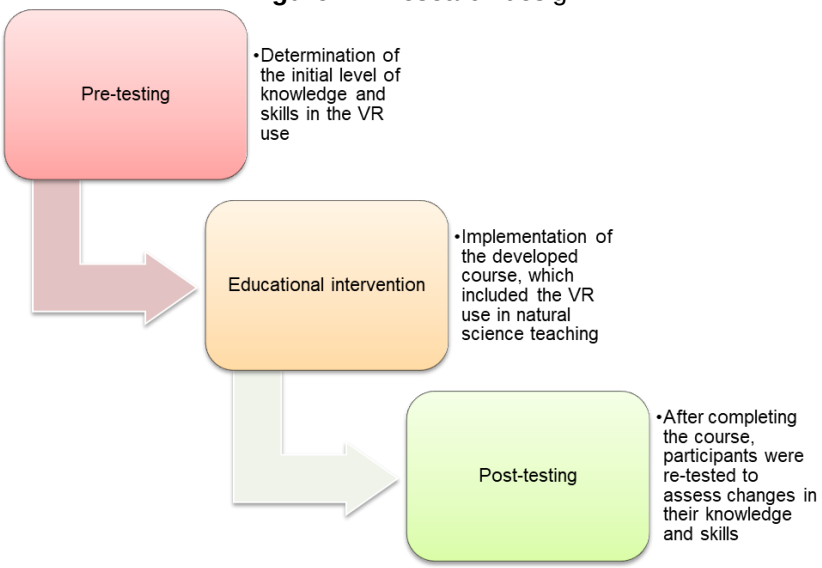
Al Breiki *et al.* (2023) emphasize the importance of examining teachers' attitudes toward VR. The researchers, however, determined that teachers are concerned about introducing VR into the classroom. Nevertheless, the teachers demonstrated better opportunities for introducing modern technologies, which contributed to a more effective educational process.

The studies of most researchers demonstrate that VR use has a high potential for more effective training (Hoai *et al.*, 2024; leBrasseur, 2023). The conducted literature analysis shows that many researchers study the use of innovative technologies to improve the educational process, which indicates the relevance and appropriateness of conducting a more in-depth study (Han, 2023; Marougkas *et al.*, 2023).

3 Methods

The research design is presented in Figure 1.

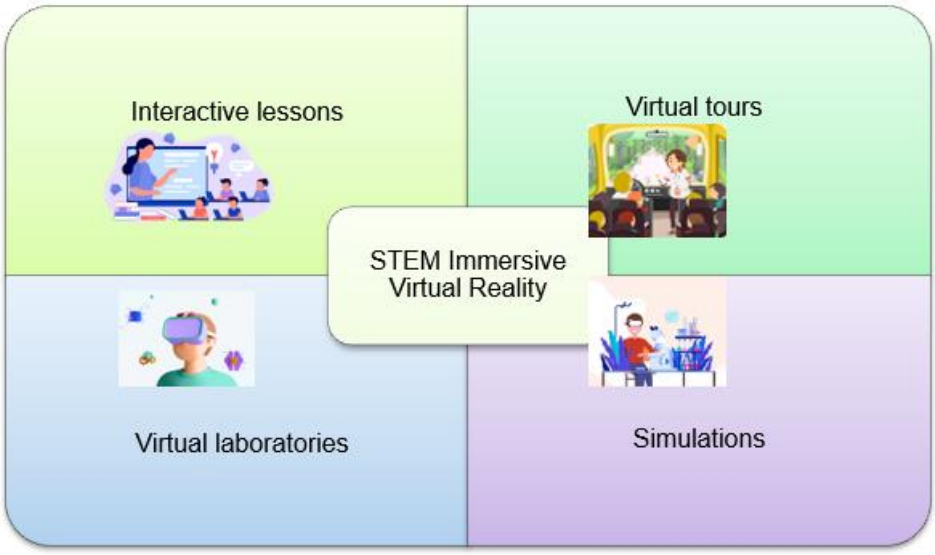
Figure 1 – Research design



Source: Own preparation (2024).

The developed STEM course was delivered to improve the professional competencies required for using several digital technologies (Figure 2). The developed course is created based on educational classes planned for 2023/2024. The duration of the course was 60 hours.

Figure 2 – Integrated STEM learning to improve professional competencies of natural science teachers



Source: Own preparation (2024).

The STEM Immersive Virtual Reality course combines active learning methods incorporating inquiry-based science education with STEM teaching strategies. This course was delivered in a hybrid format where the 60 hours of instruction were split evenly between in-person and virtual workshops. The in-person seminars lasted 30 hours and included theoretical and practical sessions, focusing on using the latest technologies, such as VR, simulations, and virtual laboratories. There was also specialized training on using the CoSpaces platform to create a 3D virtual learning environment that could be visualized using a VR headset.

3.1 Sample

The study involved 160 students (f = 90 women; m = 70) from the following departments: The Department of Natural Sciences and Teaching Methods of Hryhorii Skovoroda University in Pereiaslav; the Department of Biology, Human Health and Teaching Methods, who voluntarily participated in a course on the VR use in natural science teaching. The sample was selected randomly. The sample included students in the second and third years of the bachelor's programme.

3.2 Intervention

1) Pre-testing (Appendix A). Before the course, the participants filled out the STEM questionnaire, which contained 28 closed-ended items and 4 open-ended questions. The pre-testing aimed to determine the initial level of knowledge and skills in using VR. The STEM questionnaire included questions on a 5-point Likert scale to assess skills, confidence, and attitudes toward VR technologies. The omega coefficient for 28 points on the Likert scale showed acceptable reliability (ω = 0.752). Besides, five open-ended questions described participants' views on aspects related to new technologies in STEM education.

2) Educational intervention. The participants participated in a specially designed training course that included lectures, hands-on activities, and group projects that used VR to teach natural science. The course lasted 8 weeks, with classes twice a week. The course used VR headset, special educational programmes and simulations covering topics in biology, chemistry, physics and earth sciences.

3) Post-testing. After completing the course, participants completed the STEM questionnaire again to assess changes in their knowledge and skills following the educational intervention.

4) Interview. Upon completing the course, semi-structured interviews were conducted with a sample of participants to collect qualitative data on their experiences and attitudes towards VR use in education. The interview questions sought to elicit participants' experiences of using VR, the challenges they encountered, and their views on VR's effectiveness in enhancing natural science learning. Interviews were estimated to last between 15 and 20 minutes each.

3.3 Instruments

Quantitative analysis. Quantitative data from the questionnaires were analyzed using descriptive statistics (means, standard deviations) and inferential statistics (t-tests) to test the significance of changes between pre-test and post-test. SPSS was used for data analysis.

Qualitative analysis. Qualitative data from the interviews were analyzed using thematic analysis to identify major themes regarding the use of VR in science education. NVivo was used for qualitative data analysis.

Table 1 – Categories of closed-ended elements of the STEM questionnaire

Categories	Interpretation
A. Attitude towards technologies (1-7)	Studying people's skills and attitudes towards modern technologies. The category assesses the level of interest in technology, personal use of technology, and technological competencies for educational purposes. The questions also make it possible to assess the ability to think critically about digital content, particularly the ability to assess the quality and reliability of information on social networks and the Internet.
B. Frequency of using VR for educational purposes (8-14)	Examining the frequency and personal purpose of using VR for personal entertainment or learning. It aims to determine the extent to which participants incorporate technological tools and devices into their daily routines.
C. The possibility of using VR for STEM education (15-21)	Studying the appropriateness of using technologies such as virtual labs, immersive VR, and sensors to collect data in a laboratory setting. The main emphasis is on assessing the potential practicality and ease of integration of these technologies into education
D. The VR potential as a resource for STEM learning (22-28)	This category focuses on exploring the possibilities of using various technologies in the teaching and learning of STEM subjects

Source: Own preparation (2024).

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4 Results

The results of the quantitative analysis that were obtained are grouped and presented in Table 2. The descriptive analysis before the test shows the students' initial ideas regarding various aspects of the use of modern technologies in education.

Table 2 – Results of the statistical analysis of the STEM questionnaire categories (A;C;D)

Categories	Yes answers, %		Mo		Wilcoxon signed-rank test		ES
	Before	After	Before	After	Sig.	Z	d
A. Attitude towards technologies	65	72	2	3	0.007 **	−2.687	1.125
B. Frequency of using VR for educational purposes	30	70	15	7	0.186	-1.298	0.555
C. The appropriateness of using STEM learning technologies in education	55	80	9	7	0.193	−1.311	0.542
D. The VR potential as a resource for STEM learning in elementary education	45	55	1	3	0.263	−1.123	0.510

Note: Mo is the standard deviation; D - effect size based on Cohen's d;
** statistically significant*
Source: Own preparation (2024).

The obtained results indicate the positive impact of VR on various aspects of teacher training. The table shows that the attitude towards technology has improved significantly after the introduction of VR. The percentage of positive responses increased from (p=7%), which is statistically significant (p=0.007) and accompanied by a large effect size (d = 1.125). The frequency of using VR for educational purposes also increased (p=40%), although this result is not statistically significant (p = 0.186). Despite this, the size effect is moderate (d = 0.555). The appropriateness of using STEM learning technologies in education improved by 25%, but this indicator also did not reach statistical significance (p = 0.193), although the effect size remains moderate (d = 0.542). Finally, the potential of technology as a resource for STEM learning increased by 10%. So, VR positively affects attitudes towards technology and certain aspects of use in the educational process, although not all changes are statistically significant.

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Table 3 shows the results of a student survey on the VR use. The responses were collected before and after the delivery of the STEM course to assess their impact on different aspects of learning.

Table 3 – Results of statistical analysis of dichotomous elements of the STEM (B) questionnaire category

Questions	f before		f after	
	Yes, %	No, %	Yes, %	No, %
8. Do you use VR in your learning?	31	65	55	44
9. Do you use VR for laboratory work or experiments?	39	62	80	46
10. Do you use VR to learn complex concepts or topics?	33	74	84	55
11. Do you use VR to participate in virtual tours or field research?	40	71	59	17
12. Do you participate in classes using VR headsets for educational simulations?	32	75	69	16
13. Do you use VR for practical tasks or training?	18	64	65	21
14. Do you use VR to visualize educational material, for example, to view 3D models?	20	61	79	49
Category B ∑	30,4	67,4	70,1	35,4

Note: f - frequency.
Source: Own preparation (2024).

The table shows that before the VR introduction, only a small part of students used them in their educational classes, laboratory works or experiments to study complex concepts or topics, participate in virtual excursions or field studies, educational simulations, perform practical tasks or trainings, and also for visualization of educational material. However, after the introduction of VR, these indicators have increased significantly, which indicates the high efficiency and usefulness of these technologies in the educational process.

The overall rate of VR use among students increased from 30.4% to 70.1%, while the proportion of those who did not use VR decreased from 67.4% to 35.4%. This indicates a significant increase in the implementation of VR technologies in the educational process after their integration.

It is interesting to note the scale of changes in students' answers. For example, the use of VR for laboratory work or experiments achieved the maximum growth from 39% to 80%, a significant increase of 41 percentage points. The use of VR to learn complex concepts or topics also showed a significant increase, from 33% to 84%, a 51

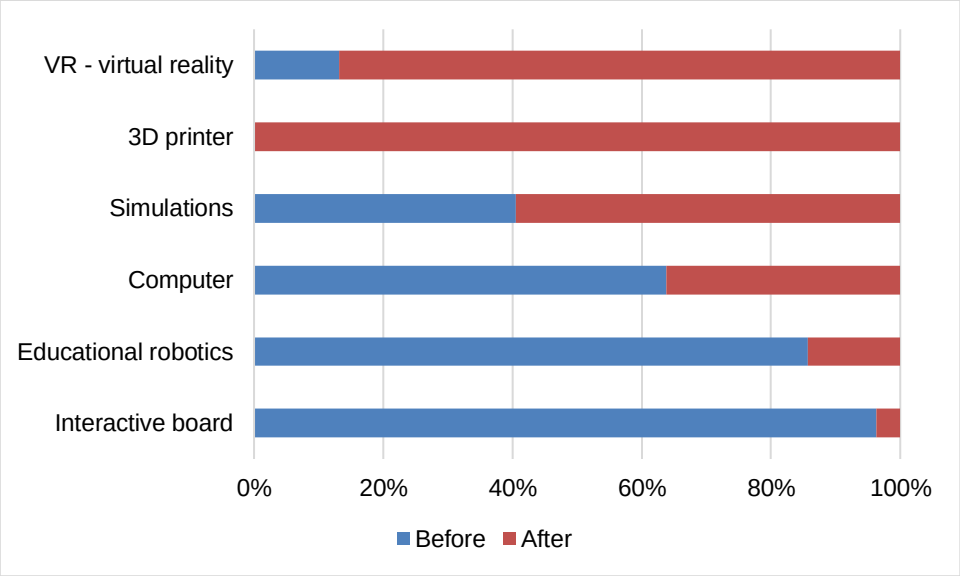
percentage point increase. This emphasizes a significant role of VR in improving students' understanding of complex topics.

In addition, the use of VR to visualize educational material increased from 20% to 79%, a 59 percentage point increase. This confirms that VR is a powerful tool for creating visual and interactive materials that help students learn information better.

In general, the survey results show that the introduction of VR has significantly improved the quality of the educational process, increasing not only the number of students using these technologies but also their effectiveness in various aspects of learning.

The qualitative analysis of the STE" section gives grounds to draw several interesting conclusions (Figure 3).

Figure 3 – Distribution of respondents' answers before and after the experiment



Source: Own preparation (2024).

The figure above shows that at the beginning of the study, the participants mostly considered traditional technologies useful for STEM learning. However, the post-test revealed a significant shift towards more modern technologies such as VR, 3D printing and simulations, which have become more important. This shows a shift in perspective among participants who are beginning to recognize the potential of VR and other innovative technologies to enhance STEM learning.

Next, the participants of the experiment identified several advantages of using VR technologies. Disadvantages, such as the need for significant investment in technology and training, were also noted.

Additional observation, both before and after testing, focused on discussing the importance of teacher training and ongoing introduction to new technologies. Some participants expressed the need for ongoing in-depth workshops rather than short courses. The post-test responses emphasized the satisfaction and practicality of classes using new technologies.

The results of the qualitative analysis indicate a positive shift in the participants' understanding of the attitude towards new technologies in STEM education. The developed STEM course helped to improve their awareness of the potential benefits and challenges associated with these technologies, which is confirmed by quantitative data and emphasizes the importance of comprehensive training of teachers in digital competencies for the effective implementation of technologies in the educational process.

5 Discussion

The obtained results testify to the positive impact of VR use on various aspects of the professional training of natural science teachers. The study found that attitudes towards technology improved significantly after introducing VR technologies, with positive responses increasing from 65% to 72%. The percentage of positive responses regarding the feasibility of using STEM technologies in education increased by 25%.

The results of the student survey confirm that after the introduction of VR, its use has increased significantly in various aspects of the educational process. For example, the use of VR for laboratory work increased from 39% to 80%, and for learning complex concepts — from 33% to 84%. This demonstrates the high effectiveness of VR in education.

The results that were obtained correspond to the conclusions of other researchers in this field. For example, a study conducted by Chen and Syu (2024) showed that using VR in education significantly increases student engagement and improves learning outcomes. Similar conclusions were also drawn by Gorman *et al.* (2022), who noted that VR facilitates a better understanding of complex topics through interactive and visual elements.

However, some researchers, such as Agbo *et al.* (2023), emphasized the high costs and the need for specialized training to effectively use VR, which was also noted in our study. These findings emphasize the importance of investing in teacher training and infrastructure to maximize the VR potential in education.

In general, the obtained results are consistent with previous studies and emphasize the positive impact of VR on the educational process, as well as the high need for comprehensive training of teachers for the effective implementation of these technologies in educational programmes (Huang *et al.*, 2023; Romano *et al.*, 2023). There is an urgent need for such programmes because of the gap between the educational process and the rapid development of technology (Huo *et al.*, 2023; Rojas-Sánchez *et al.*, 2023). Teachers often lack the necessary skills and training to use technology in education effectively (Cukur, 2023; Raja *et al.*, 2023). This imbalance between the growing demand for technology in education and the teachers' readiness to do so has long been a concern (Weidlich; Kalz, 2023). Positive feedback from students demonstrates the success of the course and emphasizes the importance of such initiatives in the initial training of teachers. Instructors also noted positive aspects of the course, indicating potential demand for more specialized technology integration courses.

6 Final considerations

The conducted research confirmed that the need for additional professional training of future natural science teachers using modern technologies, such as VR, is still relevant. Students demonstrate a positive attitude towards technologies in education and recognize their potential for improving the educational process. However, it is determined that teachers need thorough training to implement these technologies in their pedagogical activities effectively.

The study revealed a gap between the perception of the potential of new technologies and their practical use during education. Training programmes should not only introduce these technologies but also provide practical experience and guidance on their effective application.

Participants' feedback emphasizes the importance of integrating new technologies into STEM education. Despite the enthusiasm and recognition of the

benefits, there is also an awareness of challenges, particularly regarding ease of use and implementation of technology in education.

In summary, the results of the study emphasize the importance of technology-oriented education, especially for future teachers. Special educational programmes are required that will be able to overcome the gap between technological potential and its practical application. The integration of modern technologies corresponds to modern pedagogical approaches, such as STEM education, supporting students' active participation and developing problem-solving skills. To maximize the potential of new technologies, it is important to provide educators with appropriate training and support.

It is also worth noting that the high potential of new technologies, particularly VR, contrasts with the difficulties in their use. Curriculum development involving these technologies can bridge the gap between technology and its effective use as a learning resource.

Further research should examine the training needs of STEM teachers in different educational contexts, explore effective technology integration strategies, and assess their impact on students' performance.

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