Application of Immersive Solutions in the Formation of Professional Competencies of Future Teachers

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Abstract

Immersive technologies are becoming a powerful tool for the transformation of teacher education, creating unprecedented opportunities for the formation of professional competencies of future teachers through immersion in virtual educational environments. This study examines various immersive learning technologies including virtual educational reality, augmented educational reality, mixed educational reality, and explores educational platforms as a means of creating an immersive educational environment. The introduction of these technologies is

especially relevant in the context of digitalization of education and difficulties in teaching due to war, which stimulate the search for innovative forms of teacher training. The purpose of to study the use of modern online animation technologies in the training of higher education specialists. The methodology is based on an empirical study that included a survey of 60 students of pedagogical specialties. The study found that immersive technologies are perceived as the most effective for developing digital competence (average score of 4.6 on a 5-point scale, 85% of positive ratings) and mastering modern educational technologies (4.5 points, 82%). Significant differences in the availability of immersive technologies between the capital's (83% of students had experience with VR) and regional educational institutions (35%) were found. The three most effective models for integrating immersive technologies have been identified: modeling real professional situations (efficiency 4.8 points), combined use of different types of technologies (4.6 points), and involvement of students in the development of immersive educational products (4.5 points). The results of the study are of practical value for the development of strategies for the technological modernization of teacher education in Ukraine.

INTRODUCTION

The system for training future teachers is undergoing intensive transformation under the influence of the digitalization of the educational space and changes in the requirements for the professional competencies of teachers. In this context, immersive technologies are forming a separate direction in the development of teacher education, as they enable the simulation of educational and professional situations that are difficult or impossible to recreate in a traditional educational environment. Analytical forecasts indicate rapid growth in the market for immersive technologies in education and their systematic integration into teacher training programs (Maulidah & Christyodetaputri, 2025). This necessitates a scientifically sound analysis of their didactic potential specifically within the context of higher teacher education.

Current research demonstrates the effectiveness of immersive environments in developing motivation, cognitive activity, and practical skills in students majoring in education. In particular, Tene et al. (2024) emphasize the effectiveness of combining immersive technologies with STEM education, while Van der Want and Visscher (2024) prove the feasibility of using virtual reality to practice complex pedagogical scenarios. Lowell (2024) considers augmented reality as a tool for authentic learning, and Yaremchuk (2022) emphasizes its importance for distance teacher training in domestic conditions.

At the same time, the available scientific literature provides only fragmentary coverage of the issue of the differentiated impact of immersive technologies on the training of teachers of various disciplines. In particular, there is insufficient research on how these technologies function in the training of future language teachers compared to representatives of the natural and social sciences, despite the fact that the educational programs of pedagogical institutions are formed on an interdisciplinary basis. It is this circumstance that determines the expediency of involving a sample of students from different pedagogical specialties with a subsequent analytical focus on language training as a separate subject area.

The purpose of this research article is to study the use of modern online animation technologies in the training of higher education specialists. The article is aimed at analyzing the impact of online technologies on the quality of education, improving student motivation and increasing their activity in the learning process.

LITERATURE REVIEW

Modern research on immersive technologies in education demonstrates their transformative potential. Ali (2022) proves that immersive technologies increase the learning of complex material by 27% compared to traditional methods. Bermejo et al. (2023) found that AR/VR promotes spatial thinking and increases motivation to learn. Buragohain et al. (2024) empirically confirmed that teachers trained using immersive technologies demonstrate a higher level of methodological competence in their own practice. The researchers also note that this effect persists for at least three years of professional activity, demonstrating the sustainability of the acquired competencies.

Guo et al. (2021) found that the integration of XR technologies creates a "learning by doing" environment that activates cognitive processes. Lowell (2024) sees XR as an authentic learning tool for developing soft skills. Van der Want and Visscher (2024) have shown that virtual reality provides a safe environment for practicing challenging pedagogical situations and developing empathy in future teachers. They additionally emphasize that this approach allows for safe simulation of conflict and stressful situations that rarely occur during traditional pedagogical practice but have a significant impact on professional activities.

In the Ukrainian context, Kulyk (2024) explores the potential of immersive technologies in teaching Ukrainian through the creation of an authentic language environment. Yaremchuk (2022) emphasizes their importance for providing a practical component of distance learning for primary school teachers. Osypova et al. (2021) propose a comprehensive methodology for integrating VR/AR into the educational process of pedagogical institutions. The authors emphasize the importance of taking into account the regional characteristics and technical capabilities of educational institutions when developing strategies for the implementation of these technologies in the Ukrainian educational environment.

Maulidah and Christyodetaputri (2025) consider immersive technologies as tools for inclusive education that take into account diverse educational needs. Tene et al. (2024) prove the effectiveness of virtual laboratories for STEM education, especially for experiments that are dangerous or expensive in a real environment. MacDowell et al. (2022) developed a methodology for designing AR/VR learning experiences for different educational levels, and Bakhmat

et al. (2022) consider immersive technologies as a tool for bridging the gap between theory and practice in teacher education. They also emphasize the importance of integrating immersive technologies into all stages of teacher education, starting from the first years of study, to develop a systematic understanding of their potential and gain confidence in their use.

Alqahtani and Alnajdi (2024) identified key barriers to the introduction of immersive technologies: high cost of equipment, limited availability of quality content, and insufficient teacher training. Leshchenko et al. (2022) and Makedon et. al. (2025a) emphasize the need for a systematic approach to integrating these technologies into the educational environment, which involves the transformation of educational programs and teaching methods. The researchers note that overcoming the identified barriers requires coordinated efforts at the level of individual educational institutions, national educational systems, and international partnerships.

Despite considerable research interest, the following issues remain unresolved: the gap between theory and practice of implementation; insufficient study of methodological aspects of the formation of specific competencies; conflicting data on long-term effectiveness; lack of research on economic feasibility; insufficient attention to the adaptation of immersive technologies to the specific conditions of Ukrainian education in the context of military challenges. These gaps determine the need for our study of the model of implementation of immersive technologies in the training of pedagogical specialists, especially language teachers. Of particular importance is the analysis of methods for adapting immersive technologies to the specific needs of different pedagogical specialties, given the differences in educational tasks and subject methods.

MATERIALS AND METHODS

The study is based on a quantitative survey of students pursuing a degree in education. The survey aims to assess the perception of the effectiveness of immersive technologies in shaping the professional competencies of future teachers. Data collection took place in 2024 at higher education institutions in Ukraine. The sample was formed according to the principle of accessibility, with interdisciplinary representation. The sample size is 60 respondents from

pedagogical specialties in the language, natural sciences, and social sciences. The sample was formed according to the principle of proportional representation of different courses of study (3rd year – 38%, 4th year – 35%, Master's degree – 27%) and specialties (philology specialties made up the largest share of the sample (68%, 41 people), natural sciences specialties (18%, 11 people), social sciences and humanities (14%, 8 people).

Data collection was carried out using a structured questionnaire consisting of three sections. The first section covers questions about the respondents' level of digital competence. The assessment is carried out using a four-level ordinal scale through self-assessment. The second section measures the effectiveness of immersive technologies in five professional aspects: development of training materials, management of the learning process, assessment of learning outcomes, teaching load, and inclusive interaction. Respondents rate each aspect on a five-point scale. The third block records experience working with specific immersive platforms in education.

Data analysis includes descriptive and inferential statistics. Mean values and standard deviations are calculated for each aspect. The integral index of perception of the effectiveness of immersive technologies is formed as the arithmetic mean of five indicators. The ordinal nature of the variables and the absence of guarantees of normal data distribution determined the choice of Spearman's correlation coefficient to test the relationships. The statistical significance of the results was assessed at $p < 0.05$. Data processing was performed in electronic computing environments..

RESULTS

Immersive technologies are a key innovative direction in the development of modern education, providing deep immersion of students in the learning process through the stimulation of various sensory modalities. The term "immersiveness", borrowed from the English language (from "immersion"), implies the creation of the effect of presence and full inclusion in an alternative context. According to Kuznetsov (2025), the modern educational thesaurus is actively enriched with new concepts: "immersive environment", "virtual", "augmented", "mixed" and "augmented reality", which are combined into the lexical and semantic field of temporal reality and reflect various aspects of

technological immersion in the educational process.

The theoretical gap requires the interpretation of immersive technologies in teacher training through the prism of pedagogical theories that treat learning as a cognitively mediated interaction between the subject and the educational environment. Immersive environments should be viewed as a form of pedagogical mediation. They transform the linear model of teaching into a nonlinear, situational process of knowledge and professional skill formation. This approach is consistent with contemporary interpretations of learning, where the emphasis shifts from content transfer to creating conditions for active knowledge construction.

The theory of technology-mediated learning defines immersive technologies as a cognitive interface between learning tasks and professional experience. They bridge the gap between theoretical ideas and practical actions. This explains the variability in the effectiveness of immersive technologies depending on students' digital competence and subject specialization. The results of the study go beyond applied analysis. They are integrated into the scientific discourse on the role of immersive environments as a structural component of modern models of learning and teaching. This is confirmed by generalised studies in the field of educational technologies (Suh and Prophet, 2018).

A comprehensive analysis of immersive technologies allows us to identify several main types of reality used in the educational environment. Virtual reality (VR) provides complete immersion in an artificially created digital world using special devices (helmets, glasses, gloves); augmented reality (AR) overlays digital elements on the real world through mobile device cameras; mixed reality (MR) provides real-time interaction between real and virtual objects; augmented reality (XR) combines all of the above types and creates a comprehensive immersive experience. As Kuznetsov (2025) rightly notes, these technologies contribute to the formation of new content in the educational space, stimulate the search for innovative approaches to learning, and expand opportunities for people with special educational needs, as they rely on a complex system of perception, activating various senses.

The assessment of the immersive technologies market in education needs to be refined, taking into account current dynamics rather than just forecast values. According to generalized industry reviews, by 2024, the educational segment of immersive technologies will have already formed as an independent direction with a multi-billion dollar volume, concentrated mainly in higher

education, corporate training, and professional training of teachers. Maulidah & Christyodetaputri's (2025) forecast of reaching $58.5 billion by 2028 reflects the inertial continuation of this trend, but actual growth is determined by uneven access to technology, regional constraints, and the institutional readiness of education systems.

The study involved 60 students of pedagogical specialties from Ukrainian higher education institutions. Among them, 68% are students of philology, and 32% are students of other pedagogical specialties. Distribution of respondents by year of study: 3rd year – 38%, 4th year – 35%, Master's degree – 27%.

The analysis of the study results allowed us to identify the main types of immersive technologies used in the training of future teachers and to assess the frequency of their use in the educational process. Table 1 presents the classification and characteristics of immersive technologies used in teacher education according to the study and the analysis of curricula.

The results of the survey on the experience of using immersive technologies in the educational process showed that AR applications are the most common (67% of respondents had experience using them), and mixed reality technologies are the least common (only 12% of respondents). It is important to note that the availability of technologies differs significantly depending on the educational institution: 83% of students from the capital's higher education institutions had experience with VR equipment, while among students from regional institutions this figure is only 35%.

Table 1. Immersive technologies in the training of pedagogical education specialists

Type of technology	Characteristics	Examples of platforms	Educational objectives
Virtual reality (VR)	Complete immersion of the user in a virtual educational environment using VR devices	Google Expeditions, EngageVR, NeosVR, Rumii	Simulation of pedagogical situations, virtual classes, development of methodological skills
Augmented reality (AR)	Overlaying digital objects onto the real educational environment via mobile devices	Merge Cube, Quiver, ARTranslate, Assemblr EDU	Visualization of educational material, language practice, formation of subject concepts

Type of technology	Characteristics	Examples of platforms	Educational objectives
Mixed reality (MR)	Combining real and virtual objects with the ability to interact in real time	zSpace, ClassVR	Interactive lab work, collaborative learning activities, project-based learning
360° video	Panoramic video footage with the ability to view the educational environment	YouTube 360, HistoryMaker VR, The Body VR	Lesson observation, analysis of pedagogical situations, virtual tours
Immersive learning platforms	Comprehensive platforms for immersive interaction, communication, and learning	Labster, InMind 2, Anyland	Formation of professional competencies, development of digital literacy, practice-oriented learning

Source: compiled by the author based on the analysis of Billingsley et al. (2019), Mariukhnich (2024), Parasynchuk (2025)

The study results also indicate that educational platforms serve as a powerful means of creating an immersive educational environment, allowing students to engage with realistic scenarios and collaborate in virtual spaces regardless of their physical location, which is particularly important in the context of unequal access to specialized equipment.

An analysis of respondents' answers to the question about the effectiveness of different types of immersive technologies in shaping the professional competencies of future language teachers revealed that 78% of respondents consider such technologies effective for the development of methodological competence, 85% – for the formation of digital competence, and 64% – for the development of communicative competence. At the same time, virtual reality technologies for simulating pedagogical situations (average score of 4.7 on a 5-point scale) and AR applications for language learning (average score of 4.5) received the highest efficiency scores.

Table 2 presents the results of the students' survey on the effectiveness of using immersive technologies for various aspects of their professional training. The evaluation was conducted on a 5-point scale, where 1 is "not at all effective" and 5 is "extremely effective".

Table 2. Evaluation of the effectiveness of immersive technologies in the formation of professional competencies of future teachers (n=60)

The aspect of professional training	Average efficiency score (1-5)	Percentage of respondents who rated the effectiveness at 4-5 points	Percentage of respondents who rated the effectiveness by 1-2 points
Methodological training	4,2	78%	8%
Building digital competence	4,6	85%	5%
Development of communication skills	3,9	64%	15%
Mastering modern educational technologies	4,5	82%	6%
Preparing for distance learning	4,3	79%	7%
Developing skills in developing educational materials	4,1	76%	9%
Gaining experience in classroom management	3,7	58%	18%
Developing student assessment skills	3,5	52%	22%
Adapting to inclusive education	4,2	77%	9%
Overcoming pedagogical stress	3,6	55%	19%

Source: compiled by the author

The study revealed significant differences in the perception of the effectiveness of immersive technologies depending on the students' specialty. For example, philology students rated the effectiveness of AR applications for language learning higher (mean score 4.7), while science students preferred virtual laboratories (mean score 4.8). There was also a correlation between the level of digital competence of students and their assessment of the effectiveness of immersive technologies: students with a high level of digital literacy showed a more positive attitude towards the use of such technologies in the educational process.

Among the most promising areas of application of immersive technologies in the training of language teachers, respondents noted: the creation of virtual language environments for practicing communication skills (82% of respondents), modeling of pedagogical situations to practice methodological skills (79%), development of interactive teaching materials using AR technologies (76%), virtual excursions to cultural and historical sites related to the study of language and literature (74%).

The study of the experience of introducing immersive technologies in higher education institutions has helped to identify the most effective models of their integration into the educational process. The highest performance indicators were demonstrated by: 1) integration of immersive technologies into the practical training of students through modeling real professional situations (efficiency was rated at 4.8 points out of 5 possible); 2) combined use of different types of immersive technologies within one course (4.6 points); 3) involvement of students in the development of immersive educational products as part of project work (4.5 points).

In the modern educational environment, competency-based education is becoming a key mechanism for transitioning to an innovative economy as it promotes the development of social capital as a leading factor in the fourth industrial revolution (Yuldashev et al., 2022). Yuldashev and colleagues emphasize that the organizational and legal model of such education should be aimed at consolidating not the actual, but the desired, designed organization, and should be sufficient for its implementation in practice. A significant number of studies also confirm that in the preparation of future teachers, the effectiveness of immersive technologies in the formation of digital competencies received the highest rating (average score of 4.6 on a 5-point scale), which indicates their potential in developing the necessary professional skills for modern education (Bakhov et al., 2021).

The analysis of answers to the question about the most effective immersive technologies for teacher training in different specialties revealed clear subject-oriented preferences. The content analysis of the responses allowed us to identify the main categories of technologies that respondents consider the most effective for their areas of specialization and to establish the percentage distribution of their popularity within each specialty (Figure 1).

The presented data demonstrate a clear specialization of preferences for immersive technologies depending on the subject area. Students majoring in phi-

lology prefer technologies that provide language immersion and communication practice, including AR applications for language learning (42%) and VR simulations of pedagogical communication (36%). For natural science majors, virtual laboratories (65%) dominate the list, allowing them to simulate experiments in a safe environment. Representatives of social sciences and humanities prefer historical visualization technologies: 360° video reconstructions (48%) and VR tours (41%). This distribution clearly reflects the functional relevance of different types of immersive technologies to the specific educational objectives of each subject area.

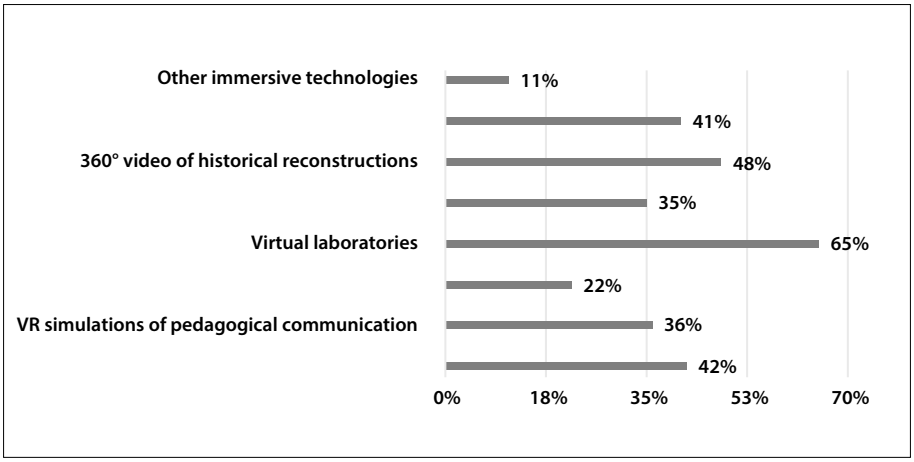

Figure 1 The most effective immersive technologies for training teachers of different specialties (according to respondents, %)
Source: compiled by the author

The study revealed a range of barriers that prevent the widespread introduction of immersive technologies in teacher training in Ukraine. Respondents assessed the importance of various factors that limit the integration of these innovative tools into the educational process. The survey results allowed us to rank these obstacles by frequency of mention and determine their relative weight in the perception of future teachers (Figure 2).

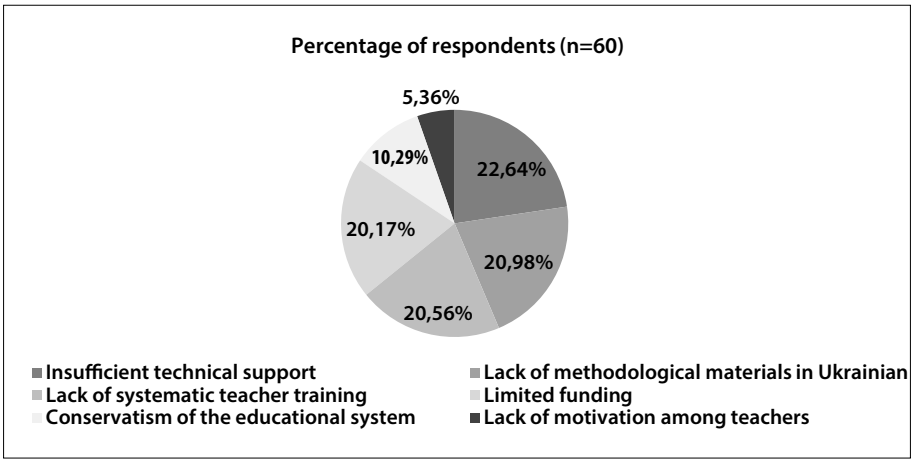

Figure 2. Main barriers to the introduction of immersive technologies in teacher training (% of respondents, n=60)
Source: compiled by the author

The analysis of the results shows that respondents consider logistical and methodological factors to be the most significant obstacles to the introduction of immersive technologies. The highest scores were given to "insufficient technical support" (91.7%) and "lack of methodological materials in Ukrainian" (85%). Somewhat lower, but also significant, scores were given to "lack of systematic teacher training" (83.3%) and "limited funding" (81.7%). It is noteworthy that institutional and motivational barriers – "conservatism of the educational system" (41.7%) and "lack of motivation among teachers" (21.7%) – are assessed as less critical. This distribution indicates that future teachers are primarily aware of the practical aspects of implementing innovations and points to potential areas of priority interventions to optimize this process.

Spearman's correlation analysis was used to test the hypothesis of a relationship between students' level of digital competence and their perception of the effectiveness of immersive technologies. This choice was determined by the ordinal scale of the digital competence variable and the rating nature of the effectiveness assessments on a scale of 1–5.

The level of digital competence was coded with numerical values: initial level – 1, average – 2, sufficient – 3, high – 4. For each respondent, the integral index of the perception of the effectiveness of immersive technologies was calculated as the arithmetic mean of the ratings for five aspects of professional training:

$$E_i = \frac{1}{5}\sum_{j=1}^{5} x_{ij}, (1)$$

where xij is the assessment of the effectiveness of immersive technologies in a particular aspect.

Spearman's correlation coefficient is calculated using the standard formula:

$$\rho_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)}. (2)$$

where di is the difference between the ranks of variables for the i-th respondent, n=60.

The results of the analysis showed a statistically significant positive correlation between the level of digital competence and the integral assessment of the effectiveness of immersive technologies: ρs =0.47, p<0.001. Verification of the significance of the coefficient using the t-test:

$$t = \rho_s \sqrt{\frac{n-2}{1-\rho_s^2}}. (3)$$

showed t(58)=4.06, confirming the rejection of the null hypothesis of no correlation. Additional analysis of individual components of the effectiveness index revealed that the strongest connection with digital competence is observed for the aspects of digital skills formation (ρs=0.52, p<0.001) and mastery of modern educational technologies (ρs=0.49, p<0.001).

The results show that students' digital readiness is a systemic factor that determines the depth and positivity of the perception of immersive technologies in the professional training of future teachers.

An important component of the study was to determine the level of readiness of future teachers to use immersive technologies in their professional activities. Respondents were asked to rate their readiness on a five-level scale from "absolutely not" to "yes, definitely". The obtained results give an idea of the general attitude of students of pedagogical specialties to the implementation of these innovative tools in their own pedagogical practice (Figure 3).

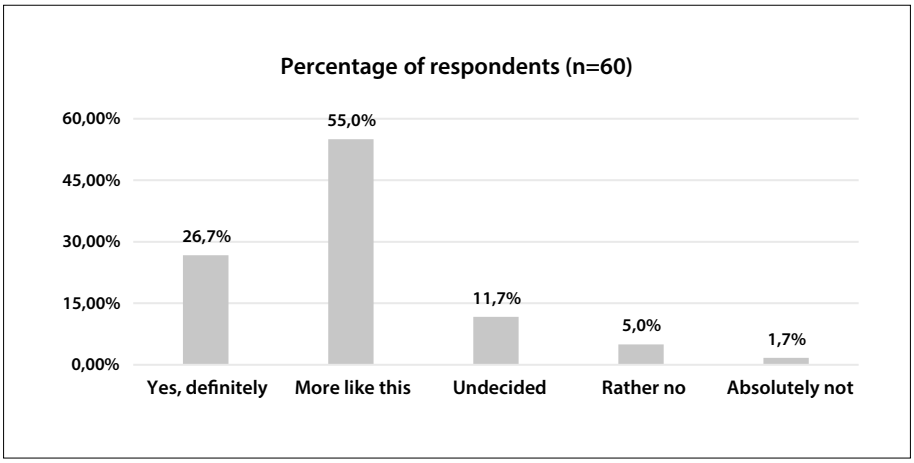

Figure 3. Readiness of future teachers to use immersive technologies in their professional activities (distribution of answers, %)
Source: compiled by the author

The results of the study demonstrate a generally positive attitude of future teachers towards the use of immersive technologies in their professional activities. The majority of respondents (81.7%) expressed their readiness to implement these technologies, of which 26.7% chose the option "yes, definitely" and 55% – "rather yes". The share of those undecided in their attitude is 11.7%, while only 6.7% of respondents expressed a negative attitude (5% – "rather not", 1.7% – "absolutely not"). This distribution of responses indicates a favorable ground for the introduction of immersive technologies into pedagogical practice and indicates the prospects for investment in this area. It is worth noting that the results are in line with global trends of positive perception of immersive technologies among the new generation of teachers.

An important component of the study was the analysis of respondents' proposals for optimizing the implementation of immersive technologies in teacher training. Content analysis of open-ended responses allowed us to systematize these proposals into five key areas: institutional, educational, methodological, personnel, technical, and international. The largest number of proposals (37.2%) concerned educational and methodological support, which reflects the respondents' awareness of the primary importance of adapting immersive technologies to specific educational contexts and creating appropriate Ukrainian-language content.

DISCUSSION

The results of the study demonstrate the significant potential of immersive technologies in the training of specialists in the pedagogical education sector, which correlates with the key trends identified in world educational practice. The high assessment of the effectiveness of immersive technologies for the development of digital competence (mean score 4.6 on a 5-point scale) and mastering modern educational technologies (mean score 4.5) is consistent with the results of the systematic analysis by Selvakumar and Sivakumar (2025), who found that immersive technologies contribute to the formation of technological literacy of future teachers and the development of their digital skills. At the same time, the lower performance indicators for the development of student assessment skills (3.5) and classroom management (3.7) confirm the findings of Hales and Kalyvaki (2017) regarding the limitations of immersive environments in modeling complex social interactions and situations requiring subtle psychological adaptation. The significant difference in the availability of immersive technologies between metropolitan (83% of students had experience with VR equipment) and regional educational institutions (35%) reflects the global trend of uneven distribution of educational innovations, which is also noted in the study by Alnagrat et al. (2022), who emphasize the need to bridge the digital divide in the implementation of XR technologies in education.

The patterns of higher evaluation of the effectiveness of AR applications among philology students (mean score 4.7) and virtual laboratories among science students (mean score 4.8) revealed in the study confirm the hypothesis that a differentiated approach to the implementation of immersive technologies is needed depending on the subject area. These results complement the findings of Makedon et. al. (2025b), who emphasizes the particular effectiveness of immersive technologies in STEM education, but our study proves that, with proper adaptation, immersive technologies are highly effective in the humanities as well. The correlation between the level of students' digital competence and their assessment of the effectiveness of immersive technologies reflects the key role of technological readiness in the perception of innovation, which is consistent with the model of technology acceptance proposed by Suh and Prophet (2018). However, contrary to the predictions of these researchers, our data show a generally higher level of readiness of Ukrainian students to integrate immersive technologies into their own pedagogical practice (81.6% of

respondents expressed a positive attitude), which may be explained by the cultural characteristics and specifics of the Ukrainian educational system, which is actively transforming under the influence of military challenges.

The barriers to the introduction of immersive technologies identified in our study (insufficient technical support, lack of teaching materials in Ukrainian, lack of systematic teacher training, limited funding) largely coincide with the obstacles identified by Grybiuk (2021), who studied the specifics of introducing immersive technologies in children's education in Ukraine. However, our research has identified an additional factor - the specifics of the education system in wartime, which creates a unique context for innovation. This factor is not reflected in international studies and is of particular interest for understanding the adaptability of educational systems in crisis conditions. The most effective models of integrating immersive technologies into the educational process identified in the study (modeling real professional situations, combined use of different types of immersive technologies, involving students in the development of immersive educational products) correlate with the principles of constructivist pedagogy and the learning by doing approach, which corresponds to current trends in teacher education identified by Shyshkina and Nosenko (2023), who emphasize the need to integrate artificial intelligence technologies and immersive environments to form.

The limitations of our study include a relatively small sample (60 students), which may affect the representativeness of the results, and a focus on subjective assessments of the effectiveness of immersive technologies rather than objective indicators of learning achievement. In addition, the experience of using immersive technologies among respondents is uneven, which may affect the accuracy of their assessments. It is also important to note that the study was conducted under martial law, which could affect the availability of respondents and the general psychological state of participants. Despite these limitations, the findings provide valuable insights into the potential of immersive technologies in teacher training and can serve as a basis for developing practical recommendations for their implementation in the educational process.

The practical implications of our study include the need to create a unified national strategy for the introduction of immersive technologies in teacher education, which will take into account the identified barriers and the specifics of different subject areas. Particular attention should be paid to the development of methodological materials in the Ukrainian language and the training

of teachers in the use of immersive technologies. The theoretical implications are to expand the understanding of the role of immersive technologies in the formation of professional competencies of future teachers and to identify the relationships between various factors that affect the effectiveness of their implementation. Further research should focus on developing objective criteria for evaluating the effectiveness of immersive technologies, studying their long-term impact on the professional development of teachers, and investigating the synergistic effect of combining different types of immersive technologies in the educational process.

CONCLUSIONS

The results of the study convincingly demonstrate that immersive technologies are a powerful tool for transforming the professional training of future teachers, which can significantly increase the effectiveness of the formation of digital, methodological and inclusive competencies. The differentiated nature of the impact of different types of immersive technologies depending on the subject specialization is revealed: AR applications demonstrate exceptional effectiveness for language and literary education, while VR environments are optimal for natural sciences, which indicates the need to develop specialized methods for their integration into the educational process. A critical gap has been identified between metropolitan and regional educational institutions in the availability of immersive technologies, which requires systemic measures at the level of state educational policy to ensure technological equality.

Of particular value is the high readiness of future teachers to implement immersive technologies in their professional activities (more than 80% of respondents), which indicates a favorable ground for technological innovation in domestic education, even in the face of military challenges. The empirically proven effectiveness of three models of integrating immersive technologies into the educational process (modeling real professional situations, combined use of different types of immersive technologies, involvement of students in the development of immersive educational products) creates a practical basis for their implementation in teacher training programs. Despite the limitations of the study due to the relatively small sample and the focus on subjective assessments, the results obtained form a comprehensive vision of the prospects

for the immersive nature of teacher education in Ukraine.

The study established a correlation model confirming the link between students' digital competence and the assessment of the effectiveness of immersive technologies in teacher training. A positive correlation coefficient proves that improved digital training leads to higher assessments of the pedagogical value of VR and AR environments. Digital competence is a basic variable. It shapes students' readiness to work with immersive tools and influences their understanding of their pedagogical potential.

The model revealed a differentiation in the relationship. The strongest correlation was found for parameters related to digital skills and technology mastery. For complex pedagogical skills, the correlation was moderate. The results indicate an uneven impact of digital competence on different aspects of professional readiness. Technical competencies correlate more strongly with the assessment of immersive technologies than pedagogical ones.

Further research should focus on developing objective methods for evaluating the effectiveness of immersive technologies by measuring specific indicators of professional readiness, creating adaptive immersive environments that take into account the individual educational trajectories of future teachers, and studying the long-term effects of using immersive technologies on teachers' professional development. Another relevant area is the study of the potential of immersive technologies to provide psychological support to future teachers and build their stress resistance in war conditions. Ultimately, immersive technologies open the way to a fundamentally new paradigm of teacher education, where virtual and real are harmoniously combined, creating a powerful synergistic effect that makes learning not only more effective but also more adaptive to the challenges of the modern world.

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Appendix A

Research questionnaire "Immersive technologies in the training of pedagogical education specialists"

I. General information about the respondent

1. Specialization: _____
2. Course of study: ☐ 3rd year ☐ 4th year ☐ Master's degree
3. Self-assessment of digital competence: ☐ Beginner ☐ Intermediate ☐ Adequate ☐ High

II. Experience in using immersive technologies

4. Have you had any experience of using the following technologies in the educational process? (Check all that apply)
   ☐ Virtual Reality (VR)
   ☐ Augmented Reality (AR)
   ☐ Mixed Reality (MR)
   ☐ 360° video
   ☐ Interactive 3D models
   ☐ Other (specify) _____
   ☐ No/low experience of using immersive technologies
5. If you have had experience using immersive technologies, please rate it on a 5-point scale:
   ☐ 1 (very negative) ☐ 2 ☐ 3 ☐ 4 ☐ 5 (very positive)

III. Evaluation of the effectiveness of immersive technologies

6. Assess the effectiveness of immersive technologies for the formation of the following aspects of professional training on a 5-point scale (where 1 is "not at all effective" and 5 is "extremely effective"):
   Methodological training: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Formation of digital competence: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Development of communication skills: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Mastery of modern educational technologies: ☐ 1 ☐2 ☐3 ☐4 ☐5
   Preparation for distance learning: ☐1 ☐2 ☐3 ☐4 ☐5
   Developing skills in developing educational materials: ☐1 ☐2 ☐3 ☐4 ☐5
   Gaining experience in classroom management: ☐1 ☐2 ☐3 ☐4 ☐5

Development of student assessment skills: ❑1 ❑2 ❑3 ❑4 ❑5
Adaptation to inclusive education: ❑1 ❑2 ❑3 ❑4 ❑5
Overcoming pedagogical stress: ❑1 ❑2 ❑3 ❑4 ❑5

7 What specific immersive technologies do you consider to be the most effective for teacher training in your specialty? Why?

_____

IV. Prospects for the use of immersive technologies

8. What areas of immersive technologies application in teacher training do you consider the most promising? (Please select up to 3 options)
❑Creation of virtual language environments for practicing communication skills
❑Simulation of pedagogical situations for practicing methodological skills
❑Development of interactive teaching materials using AR technologies
❑Virtual excursions to cultural and historical sites
❑Simulation of lessons with virtual students
❑Formation of inclusive skills through simulation of special educational needs
9. In your opinion, what barriers prevent the widespread introduction of immersive technologies in teacher education? (Check all that apply)
❑Insufficient technical support
❑Lack of teaching materials in Ukrainian
❑Lack of systematic teacher training
❑Limited funding ❑Conservative educational system
❑Lack of motivation among teachers
❑Other (specify) _____
10. Would you like to use immersive technologies in your future pedagogical activities?
❑Yes, definitely
❑Rather yes
❑Undecided
❑Rather no
❑Absolutely not

Appendix B

Primary research data (n=60)

Table 1B. Data on respondents and their experience of using immersive technologies

№	Course	Digital competence	Experience in using technology	Evaluation of experience
1	3	3	1,2,4	4
2	3	2	2,4	3
3	4	3	1,2,4,5	5
4	4	4	1,2,4,5	5
5	M	3	1,2,4	4
6	M	4	1,2,3,4,5	5
7	3	2	2,4	3
8	4	3	1,2,4	4
9	M	3	1,2,4,5	4
10	3	2	2,4	3
11	3	3	1,2,5	4
12	4	4	1,2,3,5	5
13	M	3	1,2,5	4
14	4	3	1,2,5	4
15	3	2	2,5	3
16	M	4	1,2,3,5	5
17	3	2	2,5	3
18	4	3	1,2,5	4
19	M	3	1,2,5	4
20	4	1	2	2
21	3	3	2,4	4
22	3	2	2,4	3
23	4	3	2,4,5	4
24	4	3	2,4,5	4
25	M	3	2,4	4
26	M	4	1,2,4,5	5
27	3	2	2,4	3
28	4	3	2,4	4

№	Course	Digital competence	Experience in using technology	Evaluation of experience
29	M	3	2,4,5	4
30	3	1	4	2
31	3	3	2,5	4
32	4	3	2,5	4
33	M	3	2,5	4
34	4	3	2,5	4
35	3	2	2,5	3
36	M	4	1,2,5	5
37	3	2	2,5	3
38	4	3	2,5	4
39	M	3	2,5	4
40	3	1	5	2
41	3	3	2,4	4
42	3	2	2,4	3
43	4	3	2,4	4
44	4	3	2,4	4
45	M	3	2,4	4
46	M	4	1,2,4	5
47	3	2	2,4	3
48	4	3	2,4	4
49	M	3	2,4	4
50	3	1	4	2
51	3	3	2,5	4
52	4	3	2,5	4
53	M	3	2,5	4
54	4	3	2,5	4
55	3	2	2,5	3
56	M	4	1,2,5	5
57	3	2	2,5	3
58	4	3	2,5	4
59	M	3	2,5	4
60	3	1	5	2

Table 2B. Primary data on the effectiveness of immersive technologies (n = 60)

Respondent	Development of training materials	Classroom management	Assessment of students	Pedagogical stress	Inclusive education
1	4	3	3	4	5
2	4	3	4	4	4
3	5	4	4	4	5
4	4	3	3	3	4
5	4	4	4	4	5
6	3	3	3	3	4
7	4	3	4	4	4
8	4	4	4	4	5
9	5	4	4	4	5
10	3	3	3	3	4
11	4	3	4	4	4
12	4	4	4	4	5
13	5	4	4	4	5
14	4	3	3	3	4
15	4	4	4	4	5
16	3	3	3	3	4
17	4	3	4	4	4
18	4	4	4	4	5
19	5	4	4	4	5
20	3	2	3	3	4
21	4	3	4	4	4
22	4	4	4	4	5
23	5	4	4	4	5
24	4	3	3	3	4
25	4	4	4	4	5
26	3	3	3	3	4
27	4	3	4	4	4
28	4	4	4	4	5
29	5	4	4	4	5
30	3	2	3	3	4

Respondent	Development of training materials	Classroom management	Assessment of students	Pedagogical stress	Inclusive education
31	4	3	4	4	4
32	4	4	4	4	5
33	5	4	4	4	5
34	4	3	3	3	4
35	4	4	4	4	5
36	3	3	3	3	4
37	4	3	4	4	4
38	4	4	4	4	5
39	5	4	4	4	5
40	3	2	3	3	4
41	4	3	4	4	4
42	4	4	4	4	5
43	5	4	4	4	5
44	4	3	3	3	4
45	4	4	4	4	5
46	3	3	3	3	4
47	4	3	4	4	4
48	4	4	4	4	5
49	5	4	4	4	5
50	3	2	3	3	4
51	4	3	4	4	4
52	4	4	4	4	5
53	5	4	4	4	5
54	4	3	3	3	4
55	4	4	4	4	5
56	3	3	3	3	4
57	4	3	4	4	4
58	4	4	4	4	5
59	5	4	4	4	5
60	3	2	3	3	4

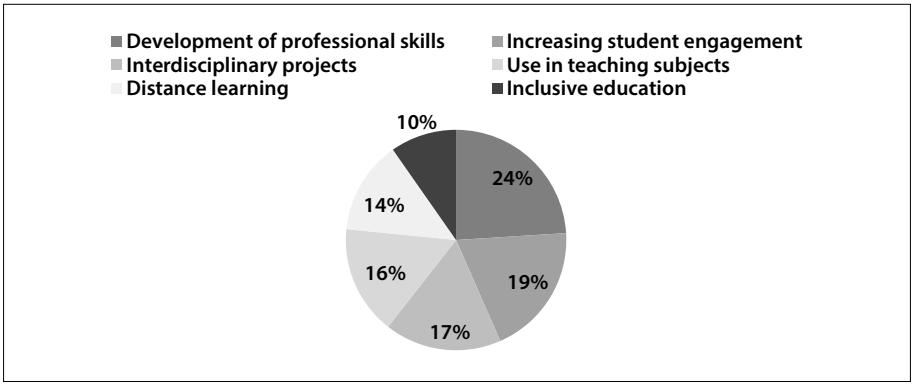

Figure 1b. Promising areas of immersive technologies implementation (%)

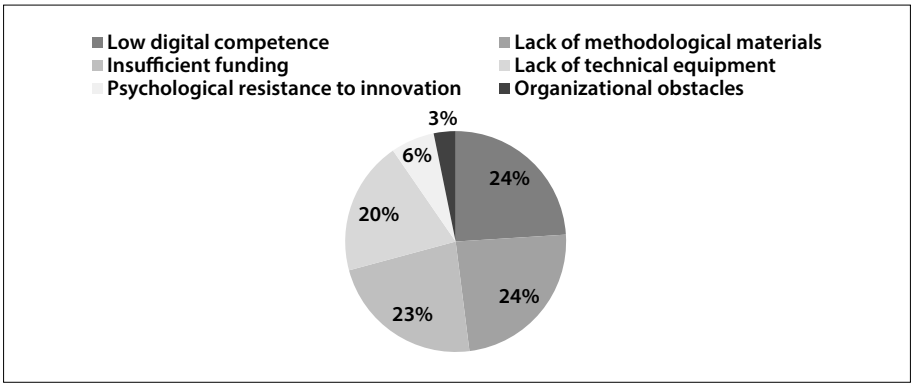

Figure 2b. Barriers to the adoption of immersive technologies (%)

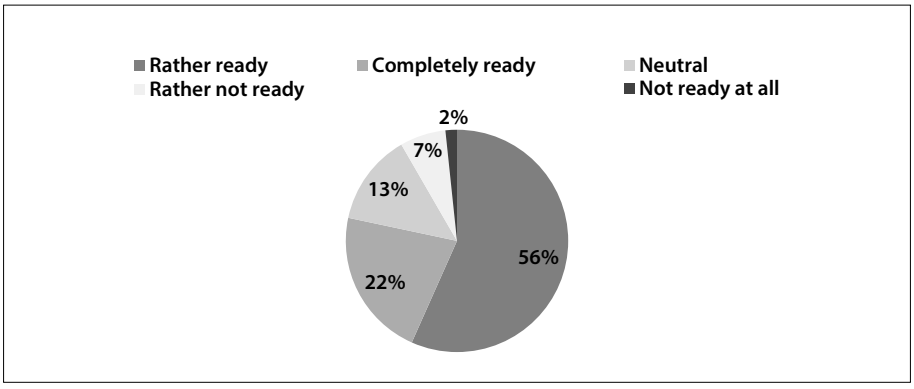

Figure 3b. Level of readiness to use immersive technologies (%)

Primjena imerzivnih rješenja u formiranju profesionalnih kompetencija budućih nastavnika

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Ključne riječi:
imerzivne tehnologije, pedagoško obrazovanje, profesionalne kompetencije, obrazovanje učitelja, digitalna kompetencija, predmetna diferencijacija, imerzivna obrazovna okruženja

Sažetak

Imerzivne tehnologije postaju moćan alat za transformaciju obrazovanja učitelja, stvarajući neviđene mogućnosti za formiranje profesionalnih kompetencija budućih učitelja kroz uranjanje u virtualna obrazovna okruženja. Ova studija ispituje različite imerzivne tehnologije učenja, uključujući virtualnu obrazovnu stvarnost, proširenu obrazovnu stvarnost, miješanu obrazovnu stvarnost, te istražuje obrazovne platforme kao sredstvo stvaranja imerzivnog obrazovnog okruženja. Uvođenje ovih tehnologija posebno je relevantno u kontekstu digitalizacije obrazovanja i poteškoća u nastavi uzrokovanih ratom, koje potiču potragu za inovativnim oblicima obrazovanja učitelja. Cilj istraživanja jest ispitati primjenu suvremenih online animacijskih tehnologija u obrazovanju visokoškolskih stručnjaka.

Metodologija se temelji na empirijskom istraživanju koje je obuhvatilo anketu provedenu na 60 studenata pedagoških studija. Istraživanje je pokazalo da se imerzivne tehnologije percipiraju kao najučinkovitije za razvoj digitalne kompetencije (prosječna ocjena 4,6 na ljestvici od 5 stupnjeva, 85% pozitivnih ocjena) te za usvajanje suvremenih obrazovnih tehnologija (4,5 bodova, 82%). Utvrđene su značajne razlike u dostupnosti imerzivnih tehnologija između obrazovnih ustanova u glavnom gradu (83% studenata imalo je iskustva s VR-om) i regionalnih obrazovnih ustanova (35%). Identificirana su tri najučinkovitija modela za integraciju imerzivnih tehnologija: modeliranje stvarnih profesionalnih situacija (učinkovitost 4,8 bodova), kombinirana upotreba različitih vrsta tehnologija (4,6 bodova) i uključivanje studenata u razvoj imerzivnih obrazovnih proizvoda (4,5 bodova). Rezultati istraživanja imaju praktičnu vrijednost za razvoj strategija za tehnološku modernizaciju obrazovanja učitelja u Ukrajini.