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Developing Future Teachers' Competences in IT and Robotics Using Virtual and Augmented Reality: A Study of Teaching Effectiveness

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Abstract

The research addresses the need for innovative learning methods to develop competencies in future specialists, driven by rapid digitalization and globalization of social relations. The work aims to study the technologies of virtual (VR) and augmented reality (AR) in the context of developing the information and communication competencies of future teachers. Logical analysis, functional analysis, abstraction, deduction, and induction were utilized. The objects of the study were characterized, their key features were determined, and their role in the formation and development of information and communication competencies was identified. It was noted that using VR and AR technologies in the modern digital age is crucial for enhancing information literacy, communication competence, and motivation in the learning process. During the experiment, which involved senior students, namely 81 students from Kostanay Engineering and Economics University named after M. Dulatov and 60 students from U. Sultangazin Pedagogical Institute, Akhmet Baitursynuly Kostanay Regional University, a program using VR and AR technologies was developed and implemented. It was found that the level of communication competencies at the optimal indicator increased by 40%, and the learning efficiency increased by 31%. The study highlights the importance of structured training in enhancing communication competence and digital readiness among future educators in Kazakhstan. It suggests that teachers need to develop digital competencies, especially in using VR and AR technologies, to adapt to modern educational demands. This research enhances teacher education by equipping educators with essential digital skills for effective teaching.

1. Introduction

One of the new directions in the field of modern information technologies in the period of active technological development is the study of the effectiveness of immersive technologies in education. Immersive technologies are digital innovations that allow a person to be fully immersed in a virtual environment through sensory experiences and cognitive processes. The most well-known and common forms of immersive technologies are virtual (VR) and augmented (AR) reality. VR is a computer-generated simulated environment that the user can interact with by immersing themselves in it, manipulating objects, and performing various actions. AR, on the other hand, is an environment that augments the real world with computer-generated virtual objects in real time. Thus, AR enriches the perception of the real world and adds artificial elements to it, while VR creates an entirely new artificial environment. At this stage of the digitalization of education, it is quite relevant to introduce the above technologies into the learning process. In this regard, it is necessary to conduct a detailed analysis of the features of VR and AR and highlight the prospects for their use in the Republic of Kazakhstan. In addition, the terms "mixed reality" (MR) and "augmented reality" (XR) are often used in the context of VR and AR. Billingsley et al. (2019) believe that mixed reality is a combined technology that combines elements of VR and AR so that physical and digital objects can simultaneously coexist and interact in real time. The term "augmented reality" is used as a generalization for different types of immersive technologies, including virtual, augmented, and mixed reality; the prefix XR indicates that the device integrates several technologies. As noted by Marks and Thomas (2022), these technologies provide an opportunity to raise the educational process to a new level all over the world.

At present, the emergence of new ways of human interaction with the digital world leads to serious changes in the education system. In the work of Yildirim et al. (2020), the authors state that the introduction of digital technologies in education contributes to increasing the flexibility and adaptability of the educational process; in particular, digitalization allows the development of individual educational trajectories for each student, taking into account his or her personal characteristics and learning needs. This approach, according to Yildirim et al., can significantly improve the efficiency and effectiveness of the modern educational system. The transition to the digital economy sets new requirements for future specialists. They should possess not only professional skills but also developed personal qualities, the ability to self-develop, and mobility. In Kazakhstan, the digital economy is developing rapidly. This requires the introduction of special technologies in the educational process and the training of pedagogical staff who will use them in their work. To form the professional readiness of future teachers, it is necessary to search for innovative methods. It is worth noting that they should include training in the correct use of modern information management and digital tools in a methodical and conscious aspect.

The work of Akdere et al. (2021) stresses the importance of special training of teaching staff in the conditions of digitalization of modern education, as well as the need to develop the digital competence of future teachers in the field of digital technologies. According to the authors, teachers should have the skills to use digital tools and platforms to effectively apply them in the educational process. At the same time, Stavroulia et al. (2019) believe that the introduction of the latest technologies and tools is designed to improve learning outcomes and motivate students to learn new material. In their opinion, digitalization opens up additional opportunities for a variety of teaching formats and methods, as well as for the development of learner autonomy and engagement. Thus, the training of teachers and the active introduction of digital technologies are designed to change the education system qualitatively. The format of educational activities is constantly changing, and future teachers need to master modern digital technologies.

In conformity with Sáez-López et al. (2020), excessive enthusiasm for digital technologies in the educational process can negatively affect the formation of basic methodological principles of teaching and learning in students. According to the authors, priority should be given to the development of pedagogical thinking and mastery of traditional tools, and digital technologies should be used to expand opportunities and improve the effectiveness of learning. In modern conditions of technology development, there is a growing need to create a digital educational environment in educational institutions, which will contribute to the formation of future teachers' range of skills to use these tools. When implementing the process of training future teachers, it is important to pay special attention to mastering specialized and promising technologies for teaching, in particular, for developing digital content of an interactive nature, including educational resources in the form of VR and AR applications. This is underpinned by the fact that VR and AR technologies represent a powerful visualization tool and an effective means of communicating curriculum information to students (Puggioni et al., 2020; Dick, 2021). They modernize the learning process by introducing new tools and methods and enhancing capabilities that are inherently didactic and cognitive.

The study of VR and AR technologies will enable future teachers to determine how effective they are in their professional teaching activities. The use of VR and AR in education can be realized when conducting virtual laboratory work with the participation of pupils and students. Visualization through AR allows students to gain a deeper understanding of the processes and motivates them. Some researchers believe that the use of the above technologies contributes to the visibility and attractiveness of educational material (Kim & Irizarry, 2021). In their opinion, visualization of information, interactive interaction, and game elements make the learning process more

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dynamic and interesting for students. This, in turn, has a positive effect on the involvement of students in the learning process and improves the absorption of knowledge. Thus, with the help of modern digital tools, traditional teaching methods can be significantly enriched. Therefore, training future teachers to use VR and AR technologies in the educational process remains an urgent task at present.

Based on the above, the paper aims to analyze VR and AR in the context of the modernization of the educational process. To this end, it is necessary to fulfill a range of tasks, namely, to determine the features of immersive technologies in the educational process, to conduct an empirical study among students of Kostanay Engineering and Economics University named after M. Dulatov and U. Sultangazin Pedagogical Institute, as well as the development of educational programs for their further application in educational institutions in Kazakhstan. The primary objective of this study is to evaluate the efficacy of incorporating digital technologies, notably VR and AR, into the educational system to improve future instructors' professional preparation. The goal is to assess how these technologies affect the development of digital competencies, communication skills, and teaching abilities among pedagogical students. Furthermore, the study aims to uncover the most successful approaches for introducing VR and AR into educational programs, promoting a better knowledge of how these tools might improve both didactic and practical learning experiences in teacher training.

2. Materials and Methods

The materials used were electronic VR and AR devices, namely VR and AR goggles, a helmet, and a special camera; computer programs such as Unreal Engine, Unity 3D, Lumberyard, and IrisVR. A combination of qualitative and quantitative research methodologies was employed to gain a thorough knowledge of how future educators might acquire competencies in VR and AR technology. Functional analysis, logical analysis, abstraction, analogy, deduction, induction, and synthesis were the main approaches used to assess both theoretical and practical elements of digitalization in education.

This study was realized through the use of different types of analysis. Thus, the method of functional analysis provided an opportunity to reveal the phenomenon of digitalization and identify its characteristic features and principles of implementation, in particular, its role in influencing the education sector. It helped to identify the role of digital technologies in the educational sector by breaking down the key elements and principles of their implementation. The method of logical analysis was used to determine the main principles and requirements for future teachers in the context of the digitalization of education, determining problems and contradictions. Furthermore, due to the use of this method, the key concepts, namely "digitalization of education", "information and communication competencies", "virtual reality", "augmented reality", and "information and educational environment" were defined, and their relationship with the formation of competences in future specialists was described. The method of logical analysis was applied to study the effectiveness of such technologies for learning as VR and AR, their impact on student motivation, and their role in enhancing practical experience. This allowed for identifying educational objectives, the range of necessary programs and tools, their integration into the learning process, defining logical structures, searching for patterns, determining cause-and-effect relationships, and identifying trends.

The method of abstraction provided an opportunity to investigate the key object of the work, the development of competencies in students of pedagogical specialty in the field of information and communication technologies, to highlight the range of features and inherent elements. The method of analogy was applied to understand the role of digital technologies in education, as it allowed finding similarities and differences between digital technologies and other aspects of education to identify the foundations for improving the learning and education process. It also helped to determine potential challenges and problems associated with the digitalization of education. The deduction method helped to identify the role of digital technology in learning by uncovering its main characteristics, principles, and elements. In turn, the method of induction helped to identify the key competencies of the future teacher based on the characteristics of the use of innovation and communication technologies in the educational sector. The method of synthesis provided an opportunity to reveal the perspectives of digital technologies in education based on the obtained information. Thus, the methods of functional and logical analysis were used to identify the role of digital technologies in the educational segment. The methods of abstraction, analogy, deduction, induction, and synthesis were implemented to identify current problematic aspects and prospects for further development of the process of digitalization of education, as well as to analyze the conditions for preparing the development of information and communication competencies of future specialists.

The data analysis methodologies were carefully designed to guarantee that the study was reliable and valid. The experiment's design, which included incorporating VR and AR technologies into courses such as "Digital Technologies in Science and Education" and "Teaching Methods in Vocational Education", created a structured setting for evaluating the instruments' influence on students' abilities. The praximetric approach was utilized to examine student actions, allowing for a thorough evaluation of the actual usage of VR and AR in educational contexts. The method assessed students' ability to incorporate digital technology into their learning processes and

acquire practical skills for future teaching occupations. Surveys were administered to capture participants' subjective experiences and suggestions on the use of VR and AR technology. In this study's parametric analysis, quantitative data from the survey and student activities were examined using the Student's t-test to measure differences in pre- and post-training competency levels at each phase of the training program. The t-test was used because it is a reliable tool for detecting the statistical significance of differences between two groups.

To further validate the findings, descriptive statistics such as mean, median, and standard deviation were used to aggregate data and offer an overall picture of participants' performance before and after training. By estimating average competency levels at each step of the experiment, the researchers were able to identify broad patterns and draw comparisons across different groups, such as gender or age. Frequency analysis was used to divide students' competence levels into multiple groups, offering insight into how the training program altered the overall competence distribution at various points of the experiment. The study evaluated the effectiveness of an intervention using inferential and descriptive statistical approaches, assuring the findings were reliable and valid, properly assessing the development of digital competence, and replicable in comparable circumstances. This study, which was based on the implementation of the developed training program in the educational process, allowed identifying the main advantages and disadvantages of using VR and AR technologies in this segment.

The basis of the study was the implementation of the experiment, which involved senior students of Kostanay Engineering and Economics University named after M. Dulatov and U. Sultangazin Pedagogical Institute. The study aimed to assess the readiness of future educators to utilize these technologies in real-world teaching environments by focusing on senior students nearing the completion of their pedagogical programs, as they are most likely to apply the skills learned in their professional careers. The experiment consisted of the introduction of VR and AR technologies into the educational process and the introduction of the disciplines "Digital Technologies in Science and Education" and "Teaching Methods in Vocational Education (by branches)". The sample of the study is targeted, and it consists of 141 senior students of pedagogical specialty from Kostanay Engineering and Economics University named after M. Dulatov and U. Sultangazin Pedagogical University. The sample size was considered sufficient to provide reliable statistical data while remaining manageable for an in-depth experimental design. The gender distribution of 93 women and 48 men corresponds to the real gender composition of students in pedagogical programs, where female students generally outweigh males in many educational institutions. This natural gender ratio gives more realistic insights into future teachers' technology acceptance and competence growth, which is critical in the context of educational digitalization. The content of the pre-training differed according to the age groups of the students: 19-20 years old and 20-21 years old. Several actions were applied to the participants of the experiment, namely: the use of VR and AR technologies (glasses, helmets, and cameras) by each of them during the educational process when teaching various disciplines; an introduction to the study of specially designed disciplines "Digital technologies in science and education"; and "Teaching methods in vocational education (by branches)".

3. Results

In the digital economy, education must be adapted to the new realities. Digital technologies make it possible to make the learning process more flexible and individualized, which meets the needs of modern learners (Adler et al., 2023). However, the transition to the digital economy requires from future specialists not only professional skills but also developed personal qualities, such as mobility and the ability for self-development (Morimoto et al., 2022). Its development in Kazakhstan requires the introduction of appropriate technologies in the education system and the training of teachers who can use modern digital tools in their work. This contributes to the search for innovative methods of forming the professional readiness of future teachers, which includes the conscious and methodologically competent use of modern information management and digital tools. At the moment, the importance of digital training of pedagogical staff in modern conditions of informatization of pedagogical education and the need to form a certain level of competence of future teachers in the field of technology are increasing. In this regard, it is quite important to create a digital educational environment in educational institutions, which will contribute to the development of skills to work with modern digital tools in future teachers.

In preparing future teachers, it is important to focus on the importance of learning and using technology, particularly educational resources in the form of VR and AR applications. This is reinforced by the fact that VR and AR technologies represent a powerful visualization tool and an effective way to provide learning information to students, which rejuvenates the learning process and expands its possibilities, including new tools and methods that enrich the didactic and cognitive aspects of education. Networked educational platforms are currently being developed to meet the new requirements of digital reality (Kumar, 2021). These requirements include not only specific methods of transferring information and digital resources but also ways of presenting knowledge and methods of verifying it in a digital environment, and specific digital tools for managing educational activities between all subjects of the educational plan process. In this aspect, the role of the teacher as the main person who

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possesses the necessary competencies and realizes the process of developing this competence among other persons in the information-oriented society increases (Zhu & Li, 2021).

The field of educational robotics is relatively new and actively evolving, causing controversy in the definition of concepts such as "robot" and "robotics", as well as in the definition of educational robotics in comparison to related fields such as engineering education and STEM. Questions about what constitutes a robot and whether there is a difference between robotics education and educational robotics are being debated in both online platforms and offline environments. This situation is complicated by the fact that both robotics and education are changing rapidly and significantly. Among the goals of educational robotics are educational, educational, and developmental aspects. The first ones include the realization of the role of robotics knowledge and skills in the learning process, future professional training, and society. It also contains the understanding of robotic systems as structured ways of perceiving the surrounding reality, the development of competencies required to work with electronic components, devices, and appliances, and the ability to develop algorithms to solve problems in an application programming environment. It also includes the development of the ability to reflect on one's thinking and the use of various resources such as textbooks, reference books, Internet sources, and others to fulfill one's educational needs. The second one includes the formation of a positive attitude towards robotics as a means of forming an intellectual culture and appreciation of modern technological achievements and their impact on the improvement of life. These goals also include the development of emotional and value attitudes toward the environment and awareness of the importance of acquiring knowledge and skills in the field of robotics for future professional and social self-realization. Also, the stimulation of interest in scientific knowledge of the environment and the development of productive teamwork skills are essential. Developmental goals include the development of academic, scientific, and engineering abilities, as well as the stimulation of students' cognitive activity through participation in various project activities. The key one is the formation of readiness for theoretical and/or empirical learning of new things, providing the need for self-improvement and self-realization using knowledge and skills in the field of physical-technical literacy, as well as the ability to apply the acquired knowledge and skills in real life. A crucial element of an effective robotics education program is the availability of trained personnel and a methodological base.

There are several steps required to successfully teach educational robotics:

1. Initial stage. This stage is important because it introduces the students to the concept of robotic systems, studies the history of robots, and develops the skills of constructing robotic devices and systems. Using the Arduino platform for this purpose is the best choice.

2. Second stage. The Robotics course is integrated into the curriculum of the Informatics subject and is studied in the Algorithmization and Programming section. Pupils use electronic components and breadboards to study the basic principles of radio-electronic components. Particular attention is paid to the ability to work with circuit diagrams, to assemble circuits on development boards or breadboards, and to master programming a microcontroller on an Arduino board.

3. Third stage. At this stage, students solve practical problems, mastering the work with analog and digital sensors, interfaces, and motors. They apply their programming knowledge to create autonomous automated systems. The structure of the modules can be cyclically updated to incorporate new electronics and more complex tasks as they progress.

These stages make it possible to effectively introduce educational robotics into the educational process and allow students to develop skills in construction, radio electronics, and programming on the way to creating autonomous robotic systems. The introduction of educational robotics into the educational space will lead to an increase in the quality of education and student interest in the subject, the creation of new models of educational activities that use information and communication technologies, the development of information competence, the implementation of innovative profile education, the use of game technologies, and the integration of modern ICT technologies in additional education.

The professional training of future teachers will become ahead of the curve if predictive analytics tools are used in its development to assess the potential of various solutions to pedagogical tasks and their consequences and consider possible problematic aspects that may arise during the implementation of professional plan activities. As shown by the survey that was conducted at Kostanay Engineering and Economics University named after M. Dulatov and U. Sultangazin Pedagogical Institute among 141 future teachers, a significant part of them have difficulties in setting up pedagogical interaction in the digital environment, despite the active use of social networks, new applications, and resources for everyday purposes (Fig. 1).

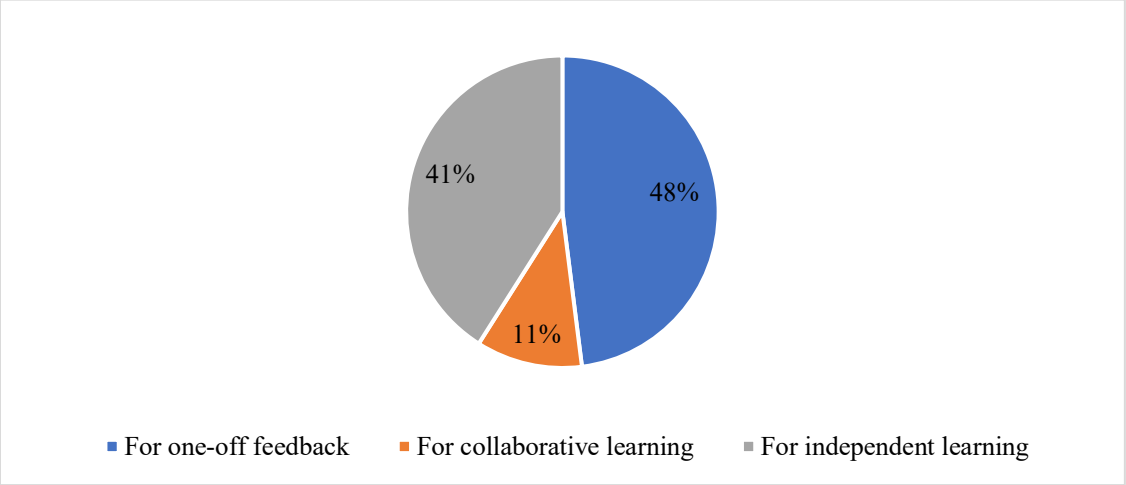

Fig. 1 *Use of digital technologies in learning*

Source: compiled by the authors.

According to the survey results, digital technologies are most often used for one-off feedback. However, just over 1/10 of respondents are willing to use them for collaborative learning or regular interaction with colleagues and learners. In addition, 48% of respondents prefer to use resources already available and follow a digital behavior strategy that has been set by the developer. Also, 41% of respondents are willing to self-manage learners' activities on digital resources and share such resources with colleagues. This finding directly links back to the research objective of assessing how digital tools can be leveraged not only for feedback but also for collaborative learning. While the survey indicated that only 11% of respondents used digital tools for regular collaboration, the results also suggest a gap in utilizing the full potential of VR and AR technologies for ongoing communication and group projects. This highlights an area for future development, aligning with the broader objective of enhancing collaborative digital practices in educational settings. It should be noted that communication resources in digital terms influence a constant and continuous exchange of information, which can take place both in real-time (synchronous) and delayed time (asynchronous). This broadens the range of tasks that can be solved in education: from individual feedback to collaborative online projects, from the search for ready-made digital solutions to collective discussions of professional issues in online professional communities. The results significantly support the research goal of demonstrating how VR and AR may expand instructional approaches. By combining these tools, the study demonstrates how students may participate in a wide range of instructional tasks, from solo assignments to collaborative projects, that improve both cognitive learning and digital abilities. This adaptability in employing digital tools addresses the study issue of VR and AR's potential to deliver a more adaptive and immersive educational experience for future educators.

Social contacts are becoming more diverse, including not only members of the study group but also professionals from different fields and potential employers. The multitude of ways of presenting information in the digital environment, including text, images, audio, and their combinations (multimedia), makes it possible to adapt information to different perceptions. The phenomenon of visual communication, which uses images, symbols (e.g., emoji), and information graphics as a new "visual" language of the digital environment, is important (Hanid et al., 2020). These types of digital interaction not only enliven virtual communication but also allow the expression of the potential of subjects through digital artifacts and traces of their online activity. These digital artifacts, as well as networked communicative discourses, generate a new kind of didactic interaction in which learners explore the digital traces left by other actors and use them to search for new knowledge, reinterpret, and communicate. Consequently, the products of communicative digital activities reflect the actions and motives of the communicative subjects. Therefore, one of the most important aspects in the implementation of training is the preparation for communication plan activities in a rapidly changing digital educational environment.

On the one hand, the anticipatory nature of the professional training of future teachers includes the acquisition of new professional knowledge in the aspect of expanding the possibilities of digital communication tools and the associated increased information exchanges between all participants in the learning process. The readiness to use technical communication tools in learning activities is not something new in professional training, but it requires revision and rethinking in light of the rapid increase in available digital communication services, in which remote feedback between teachers and learners is enhanced. On the other hand, anticipatory training should ensure that educators can successfully carry out their professional activities based on the qualitative changes that are taking place in educational communication in the digital environment. This includes the ability to solve new problems based on non-linear digital interactions and analysis. It is worth noting that the quality of

advanced training is assessed not only by the knowledge and skills learned but also by the subject's educational orientations, its educational needs, and requirements for independent educational activity. Taking into account the trends, the emphasis shifts from teaching to learning, which entails an increase in the role of students' extracurricular work. Extracurricular independent work makes up a significant part of the time allocated to the mastering of academic disciplines at both undergraduate and graduate levels, it is an integral part of the educational process. Its purpose is to perceive and comprehend the educational material received in classroom classes, as well as to expand the content of the discipline by searching for information independently (Faqih & Jaradat, 2021).

The preparation of future educators for digital educational interactions is often unsystematic and occurs without a clear plan. The use of digital communication is limited to single innovations and is often subject to strict limits set by the university's digital environment. This study proposes to assess the level of development of a teacher's communicative competence as one of the indicators of readiness to use digital technologies to achieve the goals of professional activity. As a result of the analysis, a methodology for preparing future educators for digital educational interactions was developed and implemented. The effectiveness was evaluated using several methods, including analyzing the content of student activity products using the gravimetric method, conducting questionnaires, and applying statistical methods of data processing. The content of the anticipatory training varied according to the age group of the students. Students started with information interactions with the resources of the digital environment, which is characterized by redundancy, the use of various channels of information transfer, and constant updating of educational resources. The following tasks are addressed in this aspect: searching and retrieving information, choosing a strategy for interacting with a digital resource, orienting and navigating through its content, analyzing data from a critical perspective, determining the relevance and importance of the information obtained, and transforming digital resources to fit individual information needs. Accordingly, a methodology was developed and implemented that contains several steps:

Mastering the use of digital technologies. Digital communication has a peculiarity of perception of participants and the interaction process itself. There are two objects of perception in digital interaction: the perception of the person of digital communication (self-understanding and understanding of the communication partner) and the mechanism of intersubjective interaction (social connections, contacts, predicting the course of interaction and its results). This stage takes 1.5 months. Students perform such activities as engaging in online or delayed communication with participants in the educational environment using digital communication tools, namely the Unreal Engine computer program and the creation of electronic discourse resources that can be used for further work based on the Unreal Engine program.

Using the acquired skills in practical activities. Future educators must master the skills of creating different types of electronic messages, analyzing messages from other participants in the digital environment, and the ability to conduct business digital communication. Developing the ability to identify one's partner in digital educational communication, mastering the language of electronic messages appropriate to the nature of the interaction, as well as the ability to overcome the emerging barriers in the digital educational environment and take into account the limitations associated with the limited channels of interpretation of information – all these tasks take priority in the 2nd stage of training, which lasts 2 months. Accordingly, such tasks were performed as identifying a partner in a digital learning environment through the use of VR goggles; creating and exchanging email messages with the inclusion of Unity 3D and Lumberyard computer programs; and overcoming barriers when using the specified programs and VR glasses.

Professional communication. The final stage of anticipatory preparation of future teachers for digital educational interactions is the stage of professional communication, which involves students. At this stage, digital communication goes beyond learning and becomes a tool for professional development, self-presentation, and interaction with a wide audience. At the master's level, students move from using individual methods of digital interactions to designing complex scenarios to solve problems in their future professional activities. To do this, they need to be able to build multidimensional connections between participants in the educational process, predict their development, analyze the results of digital interactions, and make necessary adjustments depending on the situation. This stage lasted 1.5 months. To assess the level of communication competence of future teachers, diagnostics are conducted at the beginning and the end of each stage of training. Such substages were highlighted as conducting diagnostics to assess the level of communication competence through a survey; designing complex scenarios through the use of the IrisVR computer program and VR helmet; self-presentation and interaction with a wide audience of developed scenarios; and carrying out repeated diagnostics to assess the level of communication competence.

Following the proposed criteria and indicators, three levels of communicative competence were identified: threshold, acceptable, and optimal. A student with a threshold level of communicative competence realizes the potential of digital communications for education, but he/she should improve the skills of their use in future pedagogical activity. At the acceptable level, the student makes good use of digital technologies for information retrieval, has the skills to choose methods of interaction depending on the situation, sometimes participates in discussions in the digital environment, can organize joint activities, and seeks to expand the scope of interactions

for self-presentation. The optimal level of communicative competence is inherent in the ability to use a variety of communication strategies and algorithms, which the future teacher can choose depending on the aspect to be solved. He constantly improves his experience in educational interactions and shares his skills with colleagues and communities of professional plans. Obtaining the mentioned indicators was done through a survey among students to determine the level of communication competence. The answers provided were rated on a scale of 1 to 100 points, and the distribution of the total number of students into levels was done by calculating the arithmetic mean. At the end of the first stage, which included mastering digital skills, it was found that slightly more than 1/4 of the students met the threshold level of communicative competence, more than 1/2 had an acceptable level, and the rest had an optimal level. Then, the second stage was carried out to use the acquired skills in practical activities (lasted 2 months), according to which the level of acceptable and optimal level of communicative competence among students was significantly increased. In the third stage, which was implemented to use professional communication skills, more than half of the students had the optimal level of communication competence. The following results were obtained among students on passing the 3 stages of communication competence development within the framework of the proposed training methodology (Table 1).

Table 1 *Level of communication competence*

	Stage 1	**Stage 2**	**Stage 3**
Threshold	23%	19%	16%
Permissible	60%	44%	27%
Optimal	17%	37%	57%

Source: compiled by the authors.

These findings closely respond to the research purpose of assessing the influence of digital technologies on communication ability. Table 1 shows a considerable change from threshold to optimum levels of competency, demonstrating how VR and AR deployment improves digital proficiency and professional preparation. The provided data allows the conclusion that by the end of each stage of advanced training, the students moved from one level of communication competence to another. This allowed for a significant increase in the indicator from the threshold to the optimal level. This is consistent with the goal of improving professional preparation through the intentional use of digital resources in education. The findings show that the majority of participants (more than half by the end of the third stage) achieved an optimal level of communication competence, indicating that the systematic use of VR and AR technologies, as outlined in the training methodology, directly improves students' ability to adapt to modern teaching environments. This evolution supports the research's goal of leveraging immersive technology to increase digital literacy and professional competencies in future educators.

The last stage of professional communication preparation reinforces the study's goal of training prospective teachers to work in complicated, real-world educational settings. The improvement in communication skills, with over 57% of students reaching a desirable level at the end of the process, demonstrates that the technique used is extremely effective in encouraging professional development. This meets the study goal of determining the impact of VR and AR on instructors' abilities to utilize digital communication tools and collaborate with peers and students in current educational contexts.

Analysing VR and AR technologies allows future teachers to identify the advantages and disadvantages of these pedagogical tools, master them, and determine how effective they can be in their future teaching work. Learning using VR and AR has been previously addressed by researchers, for example, in the use of virtual laboratory work with school and college students. According to the researchers, visualization using AR allows students to become more immersed in the processes and motivates them to analyze theory in more detail. It should also be noted that the use of AR in the study of various phenomena increases the level of visibility and interest in the discipline. Therefore, training future teachers to use the mentioned technologies in the learning process remains an urgent task. The following methods were used in the research process: literature analysis in the field of psychology and pedagogy, generalization of the experience of professional training of future teachers to form their digital competence, as well as observation, experiments, and praximetric methods.

The approach used in the study is considered a pedagogical technology and is aimed at developing students' readiness to implement VR and AR technologies in their professional activities. This technology is a purposeful and personally oriented interaction between teacher and student, in which the teacher, taking into account the level of students' readiness to use these technologies, their motivation, and value orientations, applies innovative teaching methods and tools, stimulating active cognitive participation of students. The formation of readiness and competencies of students to implement VR and AR technologies in their professional activities is one of the most important tasks of modern education. It can be realized most effectively in the process of training in the Master's program in the direction of "Pedagogical Education". At the initial stage, as part of the study of the discipline "Digital Technologies in Science and Education", students are provided with knowledge about the possibilities and technical features of VR and AR technologies. The structure of this discipline may be as follows. The theoretical

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module will study VR and AR technologies in the educational process, technologies for designing educational VR and AR applications, the use of mobile technologies in digital education, and the application of educational VR and AR applications in mobile education. The technology module will include laboratory work on such topics as introduction to VR and AR technical devices, ways of designing the structure of an AR or VR application, functionality of VR application design tools, software tools for designing AR applications, development of educational AR applications and their implementation in the learning process, designing educational VR content for further use in digital education, creating surveys and quizzes using mobile applications, development of VR and AR applications in mobile education, design of VR and AR applications in mobile education, and design of VR and AR applications in mobile education (Lytvynenko & Harmash, 2023).

Further, at the next stage, during the study of the discipline "Teaching methods in vocational education (by branches)", students of pedagogical specialty learned the methodological aspects of the application of AR and VR technologies in the education of schoolchildren. This knowledge will be integrated into their practice during the pedagogical practice, which represents the final stage of readiness formation. Following this, the effectiveness of training was studied, which included the study of indicators on the assimilation of material by students and their final evaluations. Before the introduction of the discipline "Teaching methods in vocational education (by branches)" the most common score among students was "3" (37 students), after the training on the mentioned discipline – the most common score was "4" (34 students), as well as the prevalence of the assessment "5" increased and the indicators of assessments "1" and "2" decreased by more than 2 times. It is worth considering the primary and final grades in terms of their prevalence among students (Table 2).

Table 2 *Primary and final grades among students, %*

Evaluation	Primary	Final
1	5	1,5
2	8	3
3	37	32
4	28	34
5	22	29,5

Source: compiled by the authors.

The progression of students' final grades from "3" as the most frequent grade to "4" and "5" after training demonstrates the effectiveness of VR and AR-based teaching approaches for enhancing overall academic performance. This finding is closely related to the study goal of employing digital technology to improve both knowledge retention and practical application in educational settings. It demonstrates that immersive technologies not only increase digital capabilities but also have a measurable influence on academic achievement, which aligns with the study's objectives. It is now necessary to compare the overall measures of training effectiveness (Fig. 2).

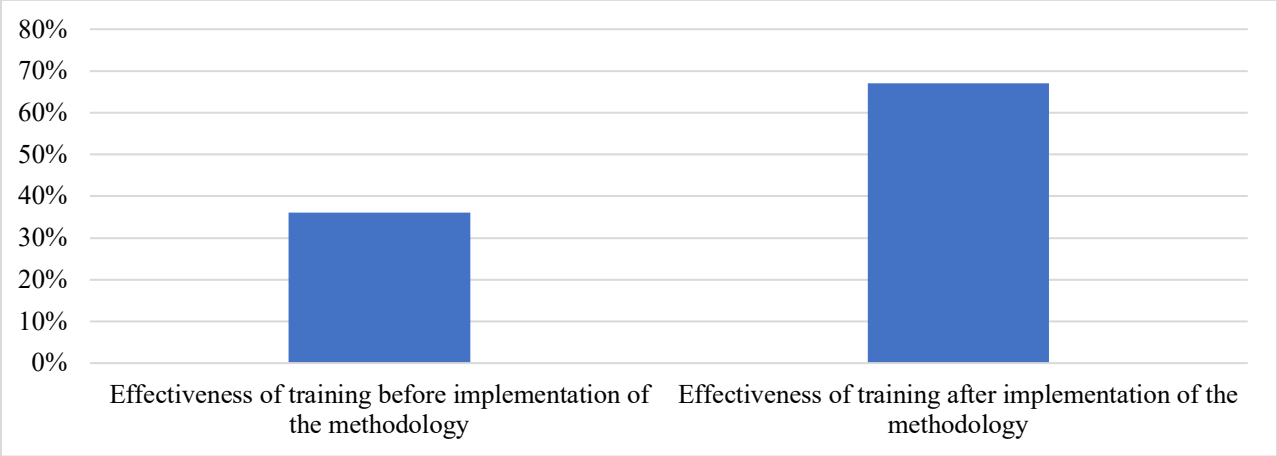

Fig. 2 *Evaluation of training effectiveness*

Source: compiled by the authors.

The study found that digital technologies, including VR and AR, play an important role in improving the learning experience. Students reported higher levels of interest and motivation after incorporating these technologies into their education. The findings contribute to the greater discussion of digitization in education by

highlighting how VR and AR improve learning experiences. The immersive nature of these technologies, as seen by the students' increased engagement and learning results, gives credibility to the idea that current digital tools make education more flexible and personalized. This is consistent with larger trends in educational research, in which digitalization is viewed as a method of catering to different learning styles and demands. Furthermore, the findings suggest that adopting these technologies into teacher education not only enhances technical skills but also nurtures important human traits like mobility, self-development, and problem-solving abilities. This broader implication demonstrates that digital technologies are more than simply instruments for studying information. They also aid in the development of critical soft skills required for the future workforce.

According to surveys, while many students struggled at first with pedagogical interactions in a digital setting, their confidence and competence improved dramatically with time. By the end of the program, the majority of participants reported a desire to engage in collaborative learning and improve their use of digital resources. The study also underlines the need to prepare future instructors to employ VR and AR technology in the learning process. Analyzing these technologies enables future teachers to discover the advantages and disadvantages, master them, and assess their performance in their future teaching roles. According to the study, using AR to examine diverse phenomena boosts the discipline's visibility and interest level. This study provided an opportunity to evaluate the effectiveness of the developed methodology. In light of the rapid development of the digital sphere, it is necessary to constantly improve the level of digital training of future teachers. A modern teacher needs to have high competence in the field of innovative digital pedagogical tools. The proposed methodology of student training is a means of achieving new educational results and contributes to the formation of the appropriate professional level of the teacher. This level is determined by new functions and types of pedagogical activities and also contributes to the implementation of the new generation's educational standard.

From a broader viewpoint, the study's findings hint at a change in how technical education and teacher training programs should be constructed. The remarkable improvement in students' digital capabilities achieved via the controlled use of VR and AR indicates these technologies' ability to change traditional teaching approaches. This has ramifications for educational practices, as institutions may need to change their curricula to include more digital tools and go beyond traditional ways. Using immersive technology, instructors may provide students with more engaging, interactive learning experiences, which can lead to greater information retention and student results. This proposes that future technical education programs should stress the integration of sophisticated technology, ensuring that both teachers and students have the skills required to flourish in the expanding digital economy.

The study's findings suggest areas for further research on VR and AR in education, such as their scalability, accessibility, and long-term influence on teaching and learning outcomes. Implementation at underserved institutions, cost-effectiveness at scale, potential obstacles to universal adoption, and long-term impacts on teaching efficacy and student achievement in technical domains are all important topics to explore. For policymakers, the findings recommend incorporating these tools into teacher training to improve digital competency. Future studies should look at their effects on student engagement and learning across disciplines, defining comprehensive digital education policy and cultivating a culture of technology adaptability in education.

4. Discussion

Over the past decade, computer technology has made significant strides in education, bringing the classroom into the Internet and AR space. One recent technological initiative in education is the use of immersive visualization systems (IVS). They utilize visual, audio, and other sensory cues to create an artificial reality – a virtual platform for learning purposes. The virtual environment can be an imaginary "territory" or a simulation of the real environment, which adds to the learners' experience, bringing the learning process closer to reality. As Turan and Atila (2021) write, these features of the IVS system are especially useful in training when it is necessary to recreate unique or dangerous places where spatial and temporal limitations are overcome, making the learning process safe and exciting; to reproduce risky or stressful situations; to develop professional skills to automaticity; or to conduct training by trial and error.

The current VR market is growing rapidly, and the value of immersive technology-related products could reach more than four hundred billion dollars by 2030, with the education system contributing significantly to this growth (Demitriadou et al., 2020). Although IVS technologies are recent, they have been the subject of active research in academia, where their application in vocational and higher education is being explored. However, it should be noted that the practical application of these technologies is still in its infancy. Chin and Wang (2021) believe that the successful implementation of immersive learning will depend on how successfully learners adapt to these technologies and get positive emotions from their use. It is worth agreeing with this and noting that more detailed research is needed on the perception of immersive technologies by learners and its correlation with the effectiveness of using IVS systems in the education system.

Most e-learning research is based on the use of the "technology acceptance model", which is an information systems theory that describes the decision-making process of users regarding the use of e-technologies, including

immersive technologies, as Sahin and. Yilmaz (2020) write. It should be added to the authors' position that this model analyzes the general perception of technologies and users' intentions to use them. According to this model, when introducing new technologies in education, several factors influence the decision of learners and adult users whether they will use these technologies or not.

Calabuig-Moreno et al. (2020) note that the first of these is "perceived usefulness", that is, the degree to which a person believes that the use of computer systems and electronic equipment will improve learning or work performance. That is, some students and adults may believe that technology will help them achieve their academic or professional goals, while others may believe that it will make their tasks more difficult. The second factor is "perceived ease of use", that is, an assessment of the effort required to learn the methods, techniques, and principals involved in using computer systems and/or electronic equipment. If a technology is perceived to be easy to use, then the barriers to mastering it are perceived to be negligible. Alternatively, if the system interface is complex and the benefits are marginal, users may view these technologies negatively. Some learners may believe that the intellectual effort invested in mastering the material will help them absorb the information more quickly and effectively, even without the use of immersive technologies. These external factors have a significant impact on the social aspects of acceptance of new technologies, including willingness to adopt and use them for learning purposes.

Cao and Cerfolio (2019) mention that the Technology Acceptance Model (TAM) by learners and adults is constantly being explored and expanded; some scholars are trying to update this model by highlighting and expanding areas of research, while others are working on the Unified Theory of Acceptance and Use of Technology (UTAUT). It is worth noting that, over time, commercial research has also emerged that analyzes e-commerce processes in the light of trust and risks associated with the use of computer technology in education. The resulting studies show that perceived enjoyment and ease of use are more important factors for learners than perceived usefulness (Cabero-Almenara et al., 2019). This is because learners have started to perceive the learning process as something that is enjoyable and not just a utilitarian activity.

However, it is worth noting that research on the room-based automatic virtual environment (CAVE) IVS systems is scarce, especially in the field of education, as their implementation requires significant resources (financial, human, and technical). Vasilevski and Birt (2020) write that most researchers focused on the experience of using new technologies in education and on the structure of curricula in different educational institutions, while others focused on evaluating the learning performance of young people learning using new technologies, others compared CAVE-based IVS with the real world, and others conducted a comparative analysis of different IVS. Thus, it can be concluded that students' perceptions of CAVE-based IVS systems in general have not received sufficient attention from researchers. In analyzing students' attitudes towards e-learning platforms within the TAM framework, an internal component of perceived enjoyment, "PENJ", was introduced in addition to the already known dimensions (perceived usefulness (PU) and perceived ease of use (PEOU)). This was done to explain why students are willing to adopt and use an e-learning platform. All three dimensions relate to behavioral beliefs (the behavioral beliefs), i.e., beliefs about the outcomes associated with the use of information technology. Thus, they shape attitudes toward the use of immersive technologies and influence the level of satisfaction with learning.

The first type of behavioral belief is related to extrinsic motivation, which means that perceived values and benefits play an important role. It was observed that PU influences learners' decisions on how the use of CAVE-based IVS systems can improve their success and affect their emotional and volitional satisfaction. The second type of behavioral belief is related to intrinsic motivation, which influences feelings of pleasure, joy, and fun. That is, there is an association of intrinsic motivation with perceived enjoyment (PENJ), based on which learning with IVS may be more emotionally satisfying. Since the structure of emotional-volitional satisfaction and emotional satisfaction are similar, they were combined into the concept of "overall satisfaction". PEOU played an important role in the adoption of new educational technologies in the late 20th century; if it is supported by extrinsic and intrinsic motivation, such attitudes may not only improve overall satisfaction (positive perceptions of IVS based on CAVE) but also shape satisfaction with learning in learning organizations (Akdere et al., 2021).

Modern research conducted at the beginning of the 21st century confirms these results regarding the use of multimedia (immersive) technologies for online and blended learning (Calabuig-Moreno et al., 2020). Analyses of the incorporation of robotic software assistants into the educational process lead to similar conclusions. Studies of massive open online courses have also found a correlation between students' positive attitudes and their self-efficacy in learning activities, which entails increased competence and satisfaction with learning (positive perception of the whole learning experience). Thus, the use of VR and AR technologies provides an opportunity for learners to improve their digital skills, change their approach to learning, and increase the level of motivation for students.

The methodology developed in the course of the research, which includes the application of innovation and communication technologies in combination with the developed disciplines in the educational process of future teachers, provides an opportunity to significantly increase the level of efficiency and quality of the educational process. Since the introduction of VR and AR technologies, the disciplines "Digital technologies in science and

education" and "Teaching methods in professional education (by branches)" have allowed the creation of the necessary conditions for the development of professional competencies of future teachers by the world processes of globalization and digitalization. The conducted experiment has shown that the efficiency index has significantly increased. Accordingly, the proposed methodology makes it possible to prepare highly competitive specialists and improve the educational process.

Technical and vocational education and training (TVET) instructors should use VR and AR technology to help students improve their cognitive and practical abilities through virtual real-world experiences, especially in subjects like engineering and health sciences. To properly apply these technologies, instructors require continual professional development in technology and curricular integration. Policymakers could encourage adoption by offering financial incentives, requiring digital literacy in curriculum, and developing uniform evaluation frameworks for digital capabilities. To promote student engagement, retention, and skill development, instructors should use interactive, student-centered techniques that reflect current workplace realities. Collaboration among educators, industry stakeholders, and technology developers is critical to ensuring VR and AR-based training programs teach relevant, job-market-ready skills and meet industry standards. Policymakers should address the economic hurdles to VR and AR integration in TVET, particularly in underserved regions, through public-private partnerships, targeted funding, and research and development projects to develop cost-effective, scalable solutions customized to TVET requirements.

5. Conclusions

This research investigated the use of VR and AR technology in the teaching of future educators, focusing on how these tools could help increase digital competences, communication skills, and professional development. One of the study's key findings is that incorporating VR and AR significantly enhances future instructors' digital skills. The statistics showed a significant improvement in students' communication skills and capacity to properly interact with digital technologies. By the end of the study's training process, more than 57% of students had acquired an ideal level of communication competence, a significant improvement from the initial assessments. This shift emphasizes the ability of VR and AR technology to offer immersive and adaptable learning experiences, which are critical in current educational settings.

Furthermore, the study identified that, while many students utilized digital technology for one-time feedback, there was a significant gap in their utilization for collaborative learning. Only a small percentage of users engaged in frequent collaborative activity using these technologies. This emphasizes the need for additional research in employing VR and AR for continuing communication and group tasks, which aligns with the study's goal of improving collaborative digital practices in educational contexts. The study also discovered that the successful application of VR and AR in teacher education necessitates a systematic approach to building communication skills. The study's approach included multiple stages, each with the goal of gradually improving students' digital communication and interaction abilities. This structured learning not only enhanced their technical skills but also prepared them for the difficulties of real-world educational situations, where digital communication is critical.

Educators should employ virtual and augmented reality technologies to create immersive learning experiences that enhance both technical and soft skills. Educators must get ongoing training in order to use these tools effectively. Policymakers should invest in digital technology and content production, reform curricula to include digital literacy, and develop standardized assessment methods. Public-private partnerships might make these technologies more accessible. Industry collaboration is critical for matching skills taught to workforce needs, with VR and AR developers creating personalized training packages for specific industries.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Bakhtiyar Zharlykassov, Tatyana Radchenko;* ***data collection:*** *Nurgul Uderbayeva;* ***analysis and interpretation of results:*** *Nursaule Karelkhan, Tatyana Radchenko, Aliya Imanova;* ***draft manuscript preparation:*** *Nurgul Uderbayeva, Bakhtiyar Zharlykassov, Aliya Imanova. All authors reviewed the results and approved the final version of the manuscript.*

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