ABSTRACT

of the dissertation by Amirbekova Elmira Mamyrovna,
submitted for the degree of Doctor of Philosophy (PhD)
in the study program
8D01504 - Chemistry Teacher Training

Research Topic: Application of modern technologies of visual and virtual reality in teaching Chemistry.

Research Rationale: In the context of the digitalization of education, enhancing the quality and effectiveness of chemistry training has become a pressing objective. Traditional teaching methods often fail to provide sufficient visual clarity or student engagement when it comes to complex chemical processes and phenomena. The use of modern visual and virtual reality technologies enables the modeling of microscopic objects and processes, the execution of virtual experiments, free from risks and associated costs, and a deeper understanding of course material, all while boosting student motivation. Consequently, the integration of augmented reality (AR) and virtual reality (VR) technologies into chemistry training is regarded as a significant direction for the advancement of modern pedagogy.

Currently, the education system is undergoing profound changes driven by the rapid development of digital technologies. The continuous advancement of information and communication technologies, along with the integration of artificial intelligence and virtual reality tools into the educational sphere, is facilitating the renewal of learning content and the transformation of teaching methods and approaches. The educational paradigm of the 21st century focuses not merely on the acquisition of knowledge, but also on its effective application, creative adaptation, and the development of critical and systems thinking. The Concept for the Development of Higher Education for 2023-2029 outlines key directions for the digitalization of the educational process and the implementation of modern technologies. In this context, the integration of innovative digital technologies into the learning process represents a significant area of focus within both pedagogical theory and practice.

Chemistry, as a core natural science subject, plays a significant role in shaping students' scientific worldview, practical skills, and research capabilities. Due to the complex and abstract nature of chemistry, students often struggle to gain a clear understanding of many chemical concepts and processes. For instance, the structure of atoms and molecules, the nature of chemical bonds, and the mechanisms of reactions or interactions between substances at the microscopic level frequently remain purely theoretical, lacking experimental demonstration. This situation can negatively affect both academic performance and the overall quality of learning outcomes in the subject.

The fundamental requirements for education in the Republic of Kazakhstan are defined in the Law "On Education". In this model, the educator acts as a facilitator in the educational process, assisting students in independently

understanding the world, unlocking their potential, and acquiring knowledge tailored to their individual interests and needs. One key direction in the development of education involves shifting from traditional educational curricula toward measures designed to prepare students for the future, including the cultivation of global competencies within study programs.

In recent years, the use of visual and virtual reality technologies in education has been viewed as an effective solution to this problem. These technologies complement traditional teaching methods, transforming the learning process into an interactive, immersive, and experience-oriented format.

The use of augmented reality (AR) and virtual reality (VR) technologies in the training of future chemistry teachers can enhance their professional preparation in line with the demands of modern education. These technologies are designed to help future educators develop skills in selecting digital educational resources, adapting them to specific learning objectives, and integrating them into the structure of a lesson. By creating methodological tasks within a virtual learning environment, assessing student knowledge, and analyzing learning outcomes, future teachers can refine their pedagogical decision-making skills. This will enable them not only to master chemical content but also to identify effective ways to explain complex topics, tailored to the age and educational level of their students. Incorporating AR and VR technologies into teacher training will bridge the gap between subject-specific methodological expertise and digital competencies, providing a solid foundation for future chemistry teachers as they transition into their professional practice.

In domestic pedagogical science, the integration of digital technologies into the teaching of chemistry is being progressively explored.

Research by Ye.A. Amantayeva, M.K. Dyussembekova, and K.D. Zhanpeissova examines the impact of the pandemic on the digitalization of education in Kazakhstan. The study analyzes the challenges encountered by the Kazakhstani education system during the transition to online learning, as well as the urgent measures taken by the state and the business sector to address them. Drawing on data from the State Statistical Committee, various information sources, a SWOT analysis, and hypothesis testing, the authors assess the pandemic’s influence on the digital transformation of education, explore its future prospects, and identify key areas for further improving the quality of digital education. The study frames the policy of digital transformation in Kazakhstan’s education sector as a pressing issue that warrants further investigation.

In their work, R. Izmagambetova, R. Karsybayeva, and Ye. Aitzhanova examine effective ways to apply augmented reality (AR) and virtual reality (VR) technologies within the educational process, highlighting their significance for enhancing teaching methods. The authors propose modern pedagogical approaches that enable students to grasp educational material through visual and interactive means, thereby fostering greater interest in the learning process and facilitating the practical application of acquired knowledge.

In their study, B.S. Arymbekov, K.M. Turekhanova, and K. Fedus examined the impact of augmented reality (AR) technology on student academic performance,

motivation to learn a subject, and attitudes toward technology. The results indicated that the use of AR technology has a positive effect on the mastery of educational material. This finding is particularly significant for chemistry training, as the visualization of atomic and molecular structures, chemical bonds, and reaction mechanisms through three-dimensional models helps students grasp complex topics. In this context, the application of AR technology in chemistry lessons provides a visual explanation of the subject matter, boosts student interest, and deepens their understanding of chemical phenomena. It is highly relevant to explore the methodological potential for integrating this technology into chemistry teaching and to evaluate its effectiveness through experimental research.

In their study, Z.K. Kalkabayeva and N.T. Shyndaliyev examined the functionality of key virtual and augmented reality applications used in the educational process. They concluded that employing these applications as digital educational resources offers a unique way to increase students' interest in the subject matter and improve the quality of learning.

The integration of virtual laboratories and three-dimensional (3D) visualization tools into the educational process within our country's academic institutions remains insufficiently systematic. There is a clear need to refine the scientific and methodological framework required for the effective application of these technologies. Furthermore, variations in the digital competence of educators, and in their proficiency with modern educational tools, present specific challenges during implementation. In the field of chemistry, in particular, visual and virtual reality technologies are highly valuable; they facilitate the visual explanation of complex concepts and phenomena, enable the modeling of chemical processes, and help foster greater student interest in the subject. Consequently, defining the theoretical foundations for using these technologies in chemistry training, developing effective methodological approaches, and evaluating their practical impact on the educational process represent a significant and timely area of focus within contemporary pedagogical science.

This field is also developing at a rapid pace within global pedagogical practice. Recent scientific research has comprehensively demonstrated the effectiveness of virtual and augmented reality technologies in the sphere of education.

In their study, Triana R. and Napitupulu I.T.A. examined how the characteristics of virtual reality (VR) technology influence learning outcomes. The research revealed that features such as immersion, visualization, and interactivity affect students' motivation and engagement, ultimately improving learning outcomes in terms of perceived educational effectiveness.

Kolil V.K., Muthupalani S., and Achuthan K. investigated the impact of using virtual experimental platforms in chemistry training on students' practical self-efficacy. The results indicated that the use of virtual laboratories boosted students' confidence in conducting chemical experiments and facilitated the development of laboratory skills.

Allcoat D. and von Mühlenen A. explored the effects of VR-based learning on student outcomes, emotional perception, and active participation in the

educational process. Their study showed that VR technologies enable students to better grasp course material, increase their interest, and foster active learning behaviors. The authors emphasize that VR technology complements traditional teaching methods, helping to create an interactive, experience-oriented educational environment.

In their research, Santos Garduño H.A., Esparza Martínez M.I., and Portuguez Castro M. concluded that the use of virtual reality in chemistry has a positive impact on motivation. They measured motivation across four dimensions: attention, relevance, confidence, and satisfaction.

The application of modern visual and virtual reality technologies in chemistry training serves as an effective means of integrating theory with practice, while promoting personalization and interactivity throughout the learning process. Research in this area will provide pedagogical science with new methodological solutions, improve the quality of chemistry teaching, and fully unlock the cognitive potential of students.

State of Research on the Topic. Virtual technologies (VT), virtual reality (VR), and augmented reality (AR) are significantly transforming modern education. These tools offer new opportunities for enhancing students' knowledge acquisition, interaction, and practical skills. International scholars, including T.A. Mikropoulos, A. Natsis, Thelugu Novah Mary Guruloo, Kamisah Osman, P. Chan, T. Van Gerven, J.-L. Dubois, K. Bernaerts, O.A. Ruzakova, E.S. Grin, Xin He, A.K. Almusawi, S. Durugbo, L. Bugawa, and Richelle Castro, have examined the effective application of these technologies in chemistry teaching via virtual laboratories, which prepare future professionals for work in an innovative environment.

Domestic scholars are also actively exploring this field. Researchers such as A.B. Turkmenbayev, E.A. Abdykerimova, N.T. Shindaliyev, Z.K. Kalkabayeva, L.Ye. Ramazanova, K.Zh. Turebayeva, A.V. Grinshkun, B.D. Sydykhov, D.Yu. Ydyrysbayev, Z.A. Batyrkhan, N.A. Kurmangaliyeva, M.M. Orazymbet, A.R. Turganbayeva, N.N. Kerimbayev, B. Arymbekov, K. Turekhanova, A.K. Sadvakasova, A.I. Kydyrbekova, Zh.Ye. Zulpykhar, A.A. Azamat, B.A. Orazbayeva, N.K. Uderbayeva, N. Karelkhan, K.K. Daurenbekov, A.B. Zakirova, and others have demonstrated the effectiveness of using visual and virtual reality in education and have substantiated the significance of immersive experiences.

These technologies are applied in many fields, such as engineering, physics, biology, geometry, medicine, tourism, and museum studies, serving as a powerful tool for integrating knowledge and experience.

Consequently, the application of modern visual and virtual reality technologies in chemistry teaching remains insufficiently explored. At present, this gives rise to several contradictions:

- at the socio-pedagogical level: a contradiction between modern educational standards and the increasing demands placed on the professional competence of future specialists, compounded by the fact that the training process for future chemistry teachers in higher education institutions does not fully meet contemporary requirements;

- at the scientific-theoretical level: a contradiction between the broad didactic and methodological potential of immersive technologies (such as virtual laboratories and augmented or virtual reality models) in chemistry teaching and the lack of research into the theoretical foundations for enhancing the professional-methodological training of future chemistry teachers through these technologies;

- at the scientific-methodological level: a contradiction between the need to integrate visual and virtual reality technologies into school-level chemistry teaching and the insufficient development of the methodological systems, teaching materials, and software required to prepare future chemistry educators to effectively utilize these technologies.

Given these contradictions, there is a clear need for research on the topic: "Application of Modern Visual and Virtual Reality Technologies in Teaching Chemistry".

The Aim of the Study is to identify the theoretical and methodological foundations for preparing future chemistry teachers to use modern visual and virtual reality technologies, to develop a structural-content model, and to determine effective ways to apply it in practice.

The Object of the Study is the process of preparing future chemistry teachers in higher education institutions.

The Subject of the Study is the content and methodology for developing the professional-methodological competence of future chemistry teachers, based on modern visual and virtual reality technologies.

The Research Hypothesis posits that if a scientific-methodological system (model) for utilizing modern visual and virtual reality technologies in the training of future chemistry educators within higher education institutions is developed and integrated into the educational process, the professional-methodological competence of these future specialists will be enhanced. This is because such a system facilitates the visualization of chemical processes at both micro- and macro-levels and promotes the active engagement of students in their own methodological practice.

Research Objectives: In alignment with the object, subject, aim, and hypothesis of this study, the following primary objectives have been defined:

1. To establish the theoretical and methodological foundations for the use of modern visual and virtual reality technologies in the training of future chemistry educators.
2. To develop a structural-content model for training future chemistry educators in the application of modern visual and virtual reality technologies.
3. To identify the pedagogical conditions necessary for the effective implementation of augmented and virtual reality technologies in the professional training of future chemistry educators.
4. To evaluate the effectiveness of the proposed methodology for training future chemistry educators in the use of modern visual and virtual reality technologies through an experimental study, and to provide statistical validation of the results.

The Core Idea of This Research is that the preparation of future chemistry teachers at the university level, specifically for the effective use of modern visual

and virtual reality technologies within the context of the digitalization of education, is achieved through the phased development of the structural components of their professional readiness.

Methodological and Theoretical Foundations of the Research. The theoretical and methodological rationale for the research problem draws upon scholarly works and concepts that define the essence of terms such as “metaverse”, “virtual reality”, and “augmented reality” (e.g., Hwang G.J., Chien S.Y., Radianti J., et al.). It also substantiates the importance of integrating modern visual and virtual reality technologies into the professional training of future chemistry teachers (e.g., Turkmenbayev A.B., Abdykerimova E.A., Shyndaliyev N.T., Kalkabayeva Z.K., Ramazanova L.Ye., Turebayeva K.Zh., Grinshkun A.V., Sydykhov B.D., Ydyrysbayev D.U., Batyrkhan Z.A., Kurmangaliyeva N.A., Orazymbet M.M., Turganbayeva A.R., Kerimbayev N.N., Arymbekov B., Turekhanova K., et al.). The research is grounded in a methodological framework that incorporates systems, activity-based, technological, competency-based, and person-centered approaches.

Research Sources. Law of the Republic of Kazakhstan “On Education”, regulatory documents of the Republic of Kazakhstan concerning the development of higher education and the state compulsory standard of higher education, Concept for the Development of Higher Education and Science in the Republic of Kazakhstan for 2023-2029, Law of the Republic of Kazakhstan “On the Status of a Teacher”, regulatory and methodological documents relating to the digitalization of higher education, domestic and foreign scientific works on methods of teaching chemistry, digital education, the use of visual, augmented and virtual reality technologies, teaching aids, digital educational resources, AR/VR platforms and virtual laboratories, diagnostic and practical experimental materials obtained during the study.

Research Methods.

1. Theoretical research methods: analysis, synthesis, and systematization of scientific, pedagogical, and psychological literature. Comparative analysis of domestic and international research on the use of multimedia, AR, and VR technologies in chemistry teaching. Analysis of theories regarding the visualization and modeling of chemical content.

2. Empirical methods: monitoring the educational process, conducting surveys, and administering diagnostic tasks. Organizing a pedagogical experiment involving experimental and control groups. Assessing students’ academic achievements, as well as determining their motivation and cognitive engagement.

3. Quantitative methods: used for analyzing data obtained during the research and interpreting quantitative results. Statistical processing, including surveys and quantitative analysis of test results, was employed. Diagnostic indicators, such as mean values, percentages, and dynamics, were calculated. Data were presented through charts and tables.

4. Modeling methods: modeling the educational process, specifically, developing a structural-content model for the application of digital technologies, including AR and VR tools.

Scientific Novelty of the Research:

1. The theoretical and methodological foundations for the use of modern visual and virtual reality technologies in the training of future chemistry teachers were identified.

2. A structural-content model for preparing future chemistry teachers to use modern visual and virtual reality technologies was developed.

3. The pedagogical conditions for the effective application of augmented and virtual reality technologies in the professional training of future chemistry teachers were determined.

4. The effectiveness of the methodology for preparing future chemistry teachers to use modern visual and virtual reality technologies was verified through an experiment, and the results were statistically substantiated.

Theoretical Significance of the Study: The theoretical significance of the study lies in the systematization and refinement of the theoretical and methodological foundations for applying modern visual and virtual reality technologies in chemistry teaching. The research identified the didactic potential of augmented and virtual reality technologies for teaching chemistry and established the pedagogical conditions for their effective integration into the educational process. Furthermore, the study defined the structure and content of training for future chemistry teachers in the use of these modern visual and virtual reality technologies, while providing a theoretical basis for their motivational, cognitive, behavioral, and reflective components. The findings contribute to the theoretical framework for enhancing chemistry teaching methods through the use of digital technologies.

Practical Significance of the Study:

- An electronic textbook titled “Application of Modern Visual and Virtual Reality Technologies in Chemistry Teaching” was published (Appendix Б).

- A visual chemistry laboratory platform, “LabVerse”, was developed – a novel contribution to the field of applying modern visual and virtual reality technologies in chemistry teaching (Appendix Ә).

- Two copyright certificates were obtained (Appendix А):

1. Electronic textbook titled “Application of Modern Visual and Virtual Reality Technologies in Chemistry Teaching” // Certificate of registration in the State Register of Copyright-Protected Objects, No. 64407, dated November 20, 2025.

2. “LabVerse” (visual chemistry laboratory platform) // Certificate of registration in the State Register of Copyright-Protected Objects, No. 70360, dated April 17, 2026.

Key provisions submitted for defense:

1. The integration of modern visual and virtual reality technologies into the training of future chemistry teachers serves as a fundamental didactic condition for enhancing the quality and effectiveness of chemistry education. This is achieved through the immersive visualization of chemical processes at both micro- and macro-levels, the optimization of instructional time, and the stimulation of students’ independent research activities.

2. A structural-content model for training future chemistry teachers in the use of modern visual and virtual reality technologies is based on the integration of motivational, cognitive, operational (activity-based), and reflective components; this model also defines the trajectory for the future specialist's professional self-development.

3. The effective application of augmented and virtual reality technologies in chemistry teaching enriches the content and methods of professional training for future chemistry teachers. The success of this process depends on pedagogical conditions that boost learning motivation, facilitate the understanding of complex chemical processes, and promote the conscious mastery of course material. The systematic implementation of these conditions fosters the readiness of future chemistry teachers to select augmented and virtual reality technologies aligned with specific educational goals, to apply them in lessons based on sound methodological principles, and to utilize them independently and creatively in school practice.

4. Based on the developed methodological system, the progression in the readiness of future chemistry teachers to employ modern visual and virtual reality technologies is assessed using a set of defined criteria (motivational, cognitive, behavioral, and reflective) and corresponding indicators. The resulting levels of readiness reflect the growth in the quality of professional training, categorized into low, medium, and high levels.

The Author's Personal Contribution lies in identifying the theoretical and methodological foundations for applying modern visual and virtual reality technologies in the training of future chemistry teachers, developing a structural-content model, and defining the necessary pedagogical conditions. Experimental work was conducted, the results of which were analyzed using mathematical-statistical methods and subsequently implemented in practice. Based on the research findings, an electronic textbook titled "Application of Modern Visual and Virtual Reality Technologies in Chemistry Teaching" and a virtual chemistry laboratory platform, LabVerse, were developed.

The Reliability and Validity of the Research Results are grounded in an analysis of scholarly, theoretical, and methodological literature relevant to the research problem; the systematic pursuit of the study's aims and objectives; a phased organization of practical and experimental work; and both quantitative and qualitative analysis of the findings. The alignment of the research methods with the study's aims, combined with a comparative analysis of the results from the experimental and control groups, ensures the reliability of the research conclusions.

Presentation and Dissemination of the Research Results: The main research provisions and findings were presented at International Scientific and Practical Conference "Modern Teacher Education: Globalization Trends and National Identity", dedicated to the 85th anniversary of South Kazakhstan State Pedagogical University (Shymkent, 2022); published in "Collection of Scientific Papers of the Tashkent-2023 International Forum" (Tashkent, 2023); and presented at the 3rd International Congress on Educational Sciences of the Turkic World, hosted by Gazi University (Ankara, 2023); the 7th International Research Competition "Start in Science – 2024" (Penza, 2024); the 4th International Congress

on Educational Sciences of the Turkic World, hosted by Gazi University (Ankara, 2024); International Winter School "Natural Sciences and Pedagogical Innovations in the Context of Digitalization" (Shymkent, 2025); the 12th International Education and Innovative Sciences Congress (Ankara, 2025); International Scientific Conference "Developing Sustainable Futures through Multidisciplinary Approaches and Innovation" (Tokyo, Japan, 2025); and research and teaching methodology seminars at the department and faculty.

The research was conducted within the framework of the project "Developing Methodological Aspects of Using Virtual and Augmented Reality Technologies in Teaching Chemistry and Biology in the Context of Implementing an Integrative Approach in the Educational Process" (Individual Registration Number AP26102613), under Agreement No. 287/25-27 ГК dated 29 September 2025.

Publications Based On the Research Results:

The main findings and conclusions of the dissertation were published in domestic and international scientific editions in the form of 23 research articles. Of these, 3 articles were published in international peer-reviewed scientific journals (indexed in JCR, Web of Science Core Collection, Science Citation Index Expanded, Social Citation Index, or Scopus/CiteScore); 2 articles appeared in journals recommended by the Committee for Quality Assurance in Science and Higher Education (CQASHE) of the Ministry of Science and Higher Education of the Republic of Kazakhstan; 6 articles were included in the proceedings of international scientific-practical conferences held abroad; 2 articles were published in the proceedings of international scientific-practical conferences held within the Republic; 4 articles appeared in foreign periodicals; and 2 articles were published in domestic periodicals. Furthermore, one electronic textbook was produced, one digital educational platform was developed, and two certificates of authorship were obtained.

Articles published in international journals indexed in Scopus:

1. Amirbekova E., Shertayeva N., Mironova E. Teaching chemistry in the metaverse: The effectiveness of using virtual and augmented reality for visualization // Frontiers in Education. - 2023. - Vol. 8. - P. 1-9. (CiteScore 3.7; 62nd percentile) https://doi.org/10.3389/feduc.2023.1184768

2. Amirbekova E., Shertayeva N., Korobeynikova E., Aysina T. Effective innovative technological methods or a threat to students' cognitive abilities and psychological state? VR headsets in online chemistry learning // Open Learning: The Journal of Open, Distance and e-Learning. - 2024. - P. 1-13. (CiteScore 10.2; 96th percentile) https://doi.org/10.1080/02680513.2024.2390436

3. Shertayeva N., Shagraueva B., Zhorabekova A., Amirbekova E., Kossauova A., Shertayev Y. Methods of utilizing visualization and VR/AR technologies in the development of chemistry projects for 8th-grade students // Journal of Technology and Science Education. - 2026. - P. 233-247. (CiteScore 3.4; 68th percentile) https://doi.org/10.3926/jotse.3454

Articles published in journals recommended by the Committee for Quality Assurance in Science and Higher Education (CQASHE) of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

4. Shertayeva N.T., Amirbekova E.M., Shagrayeva B.B. Application of Visualization Methods in University Chemistry Teaching // Bulletin of Yasawi University. Pedagogical Sciences Series. – 2023. – No. 2. – pp. 267-276. – https://doi.org/10.47526/2023-2/2664-0686.21

5. Shertayeva N.T., Amirbekova E.M., Shagrayeva B.B., Bitursyn S.S. The Use of Electronic Resources as an Effective Method for Developing Students' Independent Learning in Chemistry // Bulletin of Akhmet Baitursynov Kostanay Regional University. Pedagogical Sciences Series. – 2024. – No. 4. – pp. 301-308. – https://doi.org/10.52269/22266070_2024_4_301

Articles published in the proceedings of international scientific and practical conferences held abroad:

6. Shagrayeva B., Shertayeva N., Tuimebayeva G., Amirbekova E., Ualikhan A. Specific Features of Content Development for a Web-Based Instructional Stand for the Organic Chemistry Course // Collection of Scientific Papers of the International Forum. – Tashkent, 2023. – pp. 386-389. – https://www.academia.edu/107629271/Women_in_STEM_2023_full

7. Amirbekova E.M., Şertayeva N.T., Çelik A.Y., Şagrayeva B.B., Bitursyn S.S. Application of virtual (VR) and augmented (AR) reality technologies in chemistry teaching // Gazi Üniversitesi Uluslararası Türk Dünyası Eğitim Bilimleri Kongresi - III. - 2023. https://gaziturkdunyasi.gazi.edu.tr/arsiv/23/program.html

8. Amirbekova E.M. Using IT-implements as a means of providing new educational opportunities in the process of mastering organic chemistry // 7th International Research Competition "Start in Science – 2024". – 2024. – pp. 81-85. – https://naukaip.ru/start/

9. Shertayeva N., Amirbekova E., Çelik A.Y. Investigating the Impact of VR/AR Technology on the Quality of Knowledge Acquisition in Chemistry // Gazi Üniversitesi Uluslararası Türk Dünyası Eğitim Bilimleri Kongresi - IV. - 2024. https://gaziturkdunyasi.gazi.edu.tr/kabul.html

10. Shertayeva N., Shagraueva B., Kossauova A., Amirbekova E. Using virtual reality technology in conducting laboratory classes in natural science disciplines // 12th International Education and Innovative Sciences Congress. - 2025. - P. 292-302. https://www.24kasim.org/en

11. Shertayeva N., Shagraueva B., Amirbekova E. Using virtual reality technology in conducting laboratory classes in natural science disciplines // International Scientific Conference "Developing Sustainable Futures through Multidisciplinary Approaches and Innovation". - 2025. - P. 13-17.

Articles published in the proceedings of international scientific and practical conferences held in Kazakhstan:

12. Amirbekova E., Shertayeva N. Using Modern Virtual Laboratories to Conduct Chemical Experiments // Proceedings of International Scientific and Practical Conference "Modern Teacher Education: Globalization Trends and National Identity", dedicated to the 85th anniversary of South Kazakhstan State Pedagogical University. – 2022. – pp. 298-302. – https://okmpu.edu.kz/sites/default/files/85_zhyldyk_zhinak_1_tom_.pdf

13. Shertayeva N.T., Amirbekova E.M. Investigating the Impact of VR/AR Technology on the Quality of Knowledge Acquisition in Chemistry // International Winter School “Natural Sciences and Pedagogical Innovations in the Context of Digitalization”. – M. Auezov South Kazakhstan University. – 2025. – https://auezov.edu.kz/rus/home-ru-ru/6709-

Articles published in foreign periodicals:

14. Shertaeva N., Saydalamova M., Amirbekova E., Sharf V., Abdazimova F. Using the project method in chemistry lessons // Norwegian Journal of Development of the International Science. - 2023. - P. 23. - https://doi.org/10.47751/skpu.1937.v40i2.3.

15. Shertayeva N., Amirbekova E., Anlamasova S., Aymetova S. The use of electronic resources for independent work of students in the study of chemistry // Danish Scientific Journal. - 2023. - P. 69-76. - https://doi.org/10.5281/zenodo.10054973

16. Shertayeva N., Amirbekova E.M., Serikbaeva A., Toltayeva G. Criteria-based assessment of multi-level tasks in the course of inorganic chemistry // The Scientific Heritage. - 2023. - P. 31-35. - https://doi.org/10.5281/zenodo.10077606

17. Shertayeva N., Amirbekova E., Saduali A., Tolesh U. Study of individual sections of the school chemistry course through multimedia technologies // Znanstvena Misel Journal. - 2023. - P. 34-36. - https://doi.org/10.5281/zenodo.10054579

Articles published in domestic periodicals:

18. Shertayeva N.T., Amirbekova E.M., Yalcin Celik A., Shagraueva B.B. Using IT-implements as a means of providing new educational opportunities in the process of mastering organic chemistry // Bulletin of Abay Kazakh National Pedagogical University. Natural and Geographical Sciences Series. – 2024. – pp. 123-134. – https://doi.org/10.51889/3005-6217.2024.79.1.011

19. Shertayeva N.T., Amirbekova E.M., Bitursyn S.S. Virtual and Augmented Reality for Visualization in Chemistry Teaching // ILIM. – 2024. – Vol. 40. – pp. 40-55. – https://ilim.okmpu.kz – https://doi.org/10.47751/skpu.1937.v40i2.3

Textbooks and Teaching Guides:

20. Shertayeva N.T., Amirbekova E.M. Application of Modern Visual and Virtual Reality Technologies in Chemistry Teaching: An Electronic Textbook. – 2025. – 164 p.

21. LabVerse – A Visual Chemistry Laboratory Platform. – https://labverse.kz/

Copyright Registration Certificates:

22. Amirbekova E., Shertayeva N. Electronic textbook titled “Application of Modern Visual and Virtual Reality Technologies in Chemistry Teaching” // Certificate of registration in the State Register of Copyright-Protected Objects, No. 64407, dated November 20, 2025.

23. Amirbekova E., Shertayeva N. “LabVerse” (visual chemistry laboratory platform) // Certificate of registration in the State Register of Copyright-Protected Objects, No. 70360, dated April 17, 2026.

Research Base: Department of Chemistry, Faculty of Natural Sciences, at Uzbekali Zhanibekov South Kazakhstan Pedagogical University; and Department of Chemistry, Higher School of Natural Sciences, at Mukhtar Auezov South Kazakhstan University.

Structure of the Dissertation. The dissertation consists of an introduction, three chapters, a conclusion, a list of references, and appendices.

The Introduction defines the relevance of the research problem and substantiates its significance within pedagogical science and the educational process. It analyzes the current state of theoretical and practical inquiry into the problem and demonstrates how the research topic aligns with contemporary educational requirements. The object and subject of the research are specified; the aims and objectives are established; and the methodological foundations, sources, and research methods are described. The core concept and the stages of the research implementation are outlined. The scientific hypothesis is presented, and the study's scientific novelty, as well as its theoretical and practical significance, are explained. The key principles proposed for defense are formulated, and the theoretical and practical grounds ensuring the reliability and validity of the research results are indicated.

The first chapter, **"Theoretical and Methodological Foundations for the Application of Visual and Virtual Reality Technologies in the Training of Future Chemistry Educators",** addresses the pedagogical and methodological aspects of integrating the metaverse and augmented/virtual reality (AR/VR) technologies into the digital environment of higher education. This chapter systematizes the didactic potential and practical experience of using AR/VR technologies in the training of future chemistry educators.

The second chapter, **"Methodology for Preparing Future Chemistry Educators to Use Visual and Virtual Reality Technologies",** describes the development of a structural-content model for training future chemistry educators to utilize modern visual and virtual reality technologies. It defines the pedagogical conditions necessary for incorporating AR/VR technologies into the training process for future chemistry educators within a digital educational environment.

The third chapter, **"Organization and Results of Experimental Work",** outlines the organization of an experimental study conducted using virtual and augmented reality technologies. It details the content of the experimental work focused on integrating modern visual and virtual reality technologies into chemistry instruction and analyzes the results of this implementation.

The Conclusion summarizes the study and assesses the extent to which the established aims and objectives were achieved. The theoretical and practical results obtained during the research are systematized, and their significance within the educational process is demonstrated. Based on the study, key conclusions are drawn, and the effectiveness of the developed model is evaluated.

The References includes scholarly works on the research topic, regulatory documents, and other materials utilized in the study. A total of 167 sources were referenced.

The Appendix contains documentation confirming the implementation of the developed textbook, the certificate of authorship for the digital educational platform, the textbook itself along with its corresponding certificate of authorship, as well as supplementary materials, including questionnaires and statistical data.