

ABSTRACT

for the dissertation submitted for the degree of Doctor of Philosophy (PhD)
in the specialty 6D011000 – Physics (series of articles)

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FORMATION OF INNOVATIVE READINESS OF PHYSICS STUDENTS FOR DIGITAL LEARNING WITHIN THE FRAMEWORK OF THE UNIVERSITY 4.0 MODEL

General description of the work. The dissertation work, completed in the format of a series of articles, is devoted to the study of the formation of innovative readiness of physics students for digital learning within the framework of the «University 4.0» model, as well as to the experimental determination of the effectiveness of using digital technologies and innovative teaching methods in the higher education system.

Relevance of the research. Under contemporary conditions, the higher education system is undergoing profound transformation in accordance with global trends of digitalization and innovative development. Online platforms, virtual laboratories, artificial intelligence, and innovative teaching methods are becoming increasingly relevant. In this regard, universities are transitioning to the new educational model of University 4.0, which is oriented toward the integration of education, science, digital technologies, and innovative activities.

Thus, modern education is aimed at developing professional competencies, digital literacy, the ability for independent information retrieval, critical thinking, and the effective use of innovative technologies in educational activities. Under these conditions, particular importance is attached to the preparation of students capable of functioning effectively within a digital educational environment and adapting to new learning conditions.

The Law of the Republic of Kazakhstan «On Education» establishes the legal foundations for the use of digital technologies and distance learning formats in higher and postgraduate education institutions, creating conditions for the formation of an innovative university ecosystem, as well as for strengthening the integration of the triad «education–science–industry». These processes determine the strategic and regulatory framework for the transition of modern higher education toward the «University 4.0» model. At the same time, the Law «On Science and Technological Policy» defines the integration of education, science, and industry as one of the key principles of state policy and is aimed at strengthening the innovative activities of universities at the institutional level. The President of the Republic of Kazakhstan declared 2026 as the «Year of Digitalization and Artificial Intelligence», which further confirms the priority of digital transformation at the national level and enhances the significance of training specialists possessing high professional competence and well-developed innovative thinking within a digital environment.

In this context, the development strategy of Al-Farabi Kazakh National University identifies the implementation of the «University 4.0» and «Digital University» concepts, as well as the development of students' digital and innovative competencies, as priority directions. Correlating with state development programs up to 2030, the «University 4.0» model serves as a relevant paradigm determining the long-term vector of higher education transformation.

Despite the active development of digitalization, educational practice still demonstrates insufficient student readiness to use innovative technologies in the learning process, as well as inadequate development of pedagogical mechanisms for forming students' innovative readiness for digital learning. An analysis of domestic and international studies indicates that the scientific literature insufficiently addresses the structure of innovative readiness among physics students, the criteria and indicators for its assessment, and the pedagogical conditions for its formation within the university educational process. In this regard, there is a need to develop scientifically grounded pedagogical approaches that ensure the effective formation of innovative readiness among physics students for digital learning within the framework of the «University 4.0» model.

The author has developed the educational and methodological manual entitled «Modern Methods of Teaching Physics» which examines actual pedagogical technologies, innovative approaches, and teaching methodologies aimed at developing students' research skills, critical thinking, and cognitive activity.

Research aim: The aim of the study is to theoretically substantiate the formation of innovative readiness of physics students for digital learning within the framework of the «University 4.0» model, to determine its structure, and to experimentally validate the pedagogical conditions for its effective implementation in the educational process.

Research objectives:

1. To develop a pedagogical system that promotes the formation of innovative readiness of physics students for digital learning within the framework of the «University 4.0» model.
2. To develop a structural and functional model for the formation of innovative readiness of physics students for digital learning under the conditions of the «University 4.0» model.
3. To prepare practical and educational-methodological foundations for the formation of innovative readiness of physics students for digital learning within the framework of the «University 4.0» model.
4. To implement the process of forming innovative readiness of physics students for digital learning within the framework of the «University 4.0» model and to experimentally validate its effectiveness.

Research methods:

Study is based on the key scientific research approaches, including systemic, activity-based, and process-oriented approaches, in the context of forming physics students' innovative readiness for digital learning within the «University 4.0» model.

To substantiate the provisions presented in the doctoral dissertation (series of articles), general scientific methods of system analysis and synthesis were employed, as well as situational, pedagogical, statistical, and sociological methods.

The research methods include: empirical methods (observation, questionnaires, experimental validation of the research hypothesis); statistical methods (conducting experimental work and processing its results).

Object of the research: The educational process in higher education institutions.

Subject of the research: The process of forming innovative readiness of physics students for digital learning within the framework of the «University 4.0» model.

Scientific statements submitted for defence:

1. The developed multicomponent pedagogical system, including emotional, motivational, cognitive, personal, and organizational components, contributes to the formation of innovative readiness of physics students for digital learning within the framework of the «University 4.0» model.

2. The structural and functional model for the formation of innovative readiness of physics students reflects the conceptual, content-related, criterion-evaluative, and result-oriented blocks, and establishes their interrelations and interdependence, ensuring the integrity of the student training process.

3. The developed educational and methodological support complex for the formation of innovative readiness of physics students, based on the integration of experimental and digital activities, ensures the gradual development of relevant competencies under the conditions of educational digitalization.

4. The model for the formation of innovative readiness of physics students demonstrates high effectiveness and practical significance, which has been confirmed experimentally and supported by the Cohen's d parameter equal to 2.57.

Theoretical significance of the study:

The theoretical significance of the study lies in the scientific substantiation of the process of forming innovative readiness of physics students for digital learning within the framework of the «University 4.0» model, as well as in the development of the theoretical and methodological foundations of the digital transformation of higher education.

The study clarifies the content of the concept of «innovative readiness» of physics students for digital learning, identifies its structural components (motivational, cognitive, emotional, personal, and organizational), and reveals their interrelationships within the context of the modern digital educational environment.

A structural and functional model for the formation of innovative readiness of physics students was developed and theoretically substantiated. The proposed model includes the following blocks: conceptual, content-related, criterion-evaluative, and result-oriented. This model expands scientific understanding of the possibilities for integrating digital technologies, innovative teaching methods, and pedagogical conditions into the system of professional training of future physics teachers.

Practical significance of the research:

1. The syllabus, working curriculum, and teaching and methodological complex of the discipline «Modern Methods of Teaching Physics» have been developed and implemented in the educational process. These materials are based on the use of virtual reality, interactive simulation, online courses, and other digital tools aimed at forming the innovative readiness of physics students for digital learning.

2. A teaching and methodological manual titled «Modern Methods of Teaching Physics» has been prepared for physics students and recommended for use in the educational process.

3. An official certificate of state registration of copyright for the teaching and methodological manual «Modern Methods of Teaching Physics» has been obtained from the National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan (No. 65431, dated 17.12.2025).

4. The research results may be used in higher education institutions as a practical basis for the formation of innovative readiness of physics students for digital learning, for improving educational programs, and for the effective implementation of digital educational technologies within the framework of the «University 4.0» model.

Compliance of the research with the directions of scientific development and state programs: Under contemporary conditions, the higher education system is being modernized in accordance with the requirements of digitalization and innovative development. The Law of the Republic of Kazakhstan «On Education» establishes the use of digital technologies and distance learning, while also creating conditions for the integration of education, science, and industry.

The Law «On Science and Technological Policy» further strengthens this direction by orienting higher education institutions toward the development of innovative activities. The declaration of 2026 as the «Year of Digitalization and Artificial Intelligence» confirms the priority of digital transformation and highlights the necessity of training specialists capable of functioning effectively within a digital environment.

In the development strategy of Al-Farabi Kazakh National University, the concepts of University 4.0, Digital University, and the development of students' digital competencies have also been identified as key priorities. In this context, the formation of innovative readiness of physics students for digital learning within the framework of the University 4.0 model is considered an actual scientific problem.

Personal contribution of the author. Since the dissertation research was carried out in the format of a series of scientific publications, the author's individual scientific contribution to each of them was specified.

In 2022, the research concept and the pedagogical model were developed, and a theoretical analysis was conducted; in 2023, the methodology was developed, empirical data were collected and statistically processed; in 2024, a pedagogical experiment was carried out, the results were analyzed, and conclusions were formulated.

Approbation of the work. The results of the dissertation research (series of articles) have been published in the following outlets:

Articles published in journals indexed in the international scientific databases Web of Science and Scopus:

1. **Jugembayeva B.**, Murzagaliyeva A., Revalde G. Pedagogical Model for Raising Students' Readiness for the Transition to University 4.0 // Sustainability. – 2022. – Vol. 14 – P. 8970. *Scopus Q1, Percentile – 86.*
2. **Jugembayeva B.**, Murzagaliyeva A. Physics Students' Innovation Readiness for Digital Learning within the University 4.0 Model: Essential Scientific and Pedagogical Elements That Cause the Educational Format to Evolve in the Context of Advanced Technology Trends // Sustainability. – 2023. – Vol. 15 – P. 233. *Scopus Q1, Percentile – 86.*
3. **Jugembayeva B.**, Murzagaliyeva A. Innovation readiness for digital learning within the University 4.0 Model // Asia Pacific Education Review. – 2024. – Vol. 25 – P. 1363–1377. (процентиль 83, Q1, <https://doi.org/10.1007/s12564-023-09909-2>)

The research results have been presented in foreign and Kazakhstani publications, as well as in the proceedings of international scientific conferences held in the Republic of Kazakhstan and in countries of the near and far abroad.

Scopus database h-index of the author: $h = 4$.

Author's course program: Teaching and methodological manual «Modern Methods of Teaching Physics», Atyrau University named after Kh. Dosmukhamedov, 2025. — 133 pages. ISBN 978-601-262-613-1 (Protocol No. 8 dated 23.05.2025).

Copyright certificate:

A teaching and methodological manual “Modern Methods of Teaching Physics” has been developed and registered as an object of copyright (Certificate of state registration of rights to the object of copyright issued by the National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan No. 65431 dated 17.12.2025).