JPII 14 (2) (2025) 378-393

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

METHODOLOGICAL SYSTEM OF PROFESSIONAL TRAINING OF FUTURE PHYSICS TEACHERS IN THE PROCESS OF TEACHING THE COURSE "MOLECULAR PHYSICS"

B. Orazov[1], G. Issayeva*[2], Zh. Syzdykova[2], F. Nametkulova[2]

[1]Department of Physics,Tashenev University, Republic of Kazakhstan
[2]Faculty of Mathematics, Physics and Informatics,
Abai Kazakh National Pedagogical University, Republic of Kazakhstan

DOI: 10.15294/jpii.v14i2.20436

Accepted: January 21st, 2025. Approved: June 29th, 2025. Published: June 30th 2025

ABSTRACT

In the context of digitalizing the educational process for training future physics teachers, enhancing the methodological component of the "Molecular Physics" course in higher education institutions of Kazakhstan is crucial. This study aims to develop and implement a methodological system for the professional training of future physics teachers through the "Molecular Physics" course. The research employs a mixed-methods approach, including both qualitative and quantitative data collection techniques. The study justifies the theoretical need for reorganizing the methodological system and explores the potential benefits of the proposed methodology in enhancing the study of "Molecular Physics" among students in Kazakhstan's higher education institutions. Data were gathered through pre- and post-tests, surveys, and a controlled experiment involving 162 participants, divided into experimental and control groups. The study outlines pedagogical conditions essential for the successful implementation of this methodology, including developing motivation among future teachers, improving teaching methodologies, and utilizing effective digital technologies. It recommends implementing this methodology through controlled tasks for independent study, employing both traditional and non-traditional teaching methods, organizing various forms of independent student work, establishing a clear scoring system, and providing feedback through innovative assessment methods. The research introduces a structural and content model for professional training that consists of three interrelated components: methodological, content-activity, and criterion-evaluation. The practical value of this work lies in its updated methodological system, which is grounded in practical methods and technologies aimed at improving the study of physics in higher education institutions in Kazakhstan. This approach not only enhances the educational process but also aligns with the evolving demands of digital education.

Keywords: higher education; digital technologies; components of readiness; pedagogical conditions

INTRODUCTION

The exponential growth of information in today's digital society requires specialists capable of creative knowledge assimilation, rapid adaptation, and forecasting of trends (Batyrbekova, 2020). In Kazakhstan, this necessitates rethinking the higher education system, particularly in the training of future physics teachers, to align curricula with societal needs and technological change (Aitbaeva & Shaihozova, 2022). The problem addressed in this study concerns the absence of a comprehensive, empirically grounded methodological framework tailored to the course "Molecular Physics" in Kazakhstani higher education, which hinders the preparation of future physics teachers for the demands of a digitalized and competence-based educational environment. One of the central challenges in Kazakhstani higher education is to enhance the training of professio-

***Correspondence Address**
E-mail: issayevagulnara09@gmail.com

nals whose competencies align with the dynamic labour market (Onyshchenko & Serdiuk, 2025). This issue is emphasized in the State Programme for the Development of Education and Science of the Republic of Kazakhstan for 2020-2025 (2020), which advocates for urgent systemic reforms based on leading international practices.

In recent decades, Kazakhstan's professional and pedagogical education system has undergone major reforms due to internal and external pressures (Marugkas et al., 2023). Key developments include curriculum modernization, professional advancement of educators, infrastructure strengthening, and intensified international cooperation (Zalewski et al., 2019). However, the implementation of updated educational standards – such as those established in the Order of the Minister of education and science of the Republic of Kazakhstan No. 604 "On Approval of State Compulsory Educational Standards for All Levels of Education" (2018) – has led to a marked reduction in classroom hours for physical disciplines. This reduction necessitates a revised methodological system for training future physics teachers that ensures disciplinary depth despite curricular constraints.

As noted by Kuzmicheva et al. (2022) and Riznyk (2023), the modernization of pedagogical education in Kazakhstan aims to cultivate competencies relevant to digital environments, critical thinking, and autonomous learning. In this regard, the course "Molecular Physics" holds particular importance, serving as a key component of the methodological formation of future physics educators. Its instructional design must increasingly rely on digital tools that stimulate cognitive engagement and deepen conceptual understanding (Boyle, 2019).

According to Ualihanova and Omarov (2023), the growing complexity of scientific knowledge demands renewed approaches to teaching "Molecular Physics." In the current context, it is not sufficient for future teachers to possess only deep theoretical knowledge; they must also exhibit flexibility, creativity, and the capacity to anticipate scientific and educational trends. This is supported by Semerikov et al. (2021), who stress that effective instruction requires the development of scientific reasoning and research skills, while Weissman et al. (2019) emphasize the importance of making scientific content accessible and pedagogically effective.

Moreover, changes in general secondary education standards place increased pressure on higher education to prepare teachers who are not only content experts but also proficient in research and reflective practice (Sohn & Kwon, 2020). In this regard, the professional development of physics teachers demands robust methodological support and structured exposure to inquiry-based learning (Kuznietsov & Kuznietsova, 2024).

Moldabekova et al. (2023) affirm that "Molecular Physics" plays a foundational role in fostering subject-specific expertise, while also enabling systematic self-improvement and effective pedagogical practice. However, despite its importance, this discipline often lacks integrated methodologies that adequately link theory with practice in the Kazakhstani context. Recent research has proposed several innovative solutions. For instance, Zharmukhanbetov et al. (2024) emphasize the integration of project-based learning with STEM to enhance disciplinary understanding and transferable skills such as teamwork and creativity. Similarly, dos Reis Belíssimo and Nardi (2024) highlight the role of sustained identity formation in cultivating teachers who are aligned with current educational demands. Interdisciplinary instruction is another promising avenue. Yermekova et al. (2024) suggest embedding environmental education within physics curricula to improve applied learning outcomes, while Kozhabekova et al. (2024) promote a competence-based approach that prioritizes cognitive and instructional skills necessary for scientific literacy. Nevertheless, despite these advances, a systemic gap remains. There is no unified, empirically validated methodological model that integrates digital technologies, pedagogical conditions, and measurable competencies into a coherent framework for the "Molecular Physics" course. Most studies to date address isolated pedagogical strategies rather than constructing a holistic structure aligned with national educational goals.

The aim of the research is to develop, implement, and assess an innovative methodological system for the professional training of future physics teachers, with a specific focus on the course "Molecular Physics", aligned with the digitalisation and modernisation priorities of Kazakhstan's higher education.

The specific objectives of the study are:

To analyse existing methodologies of teaching "Molecular Physics" in Kazakhstani universities and identify areas in need of reform.

To define pedagogical conditions and design a structural-content model that enhances the effectiveness of professional training for future physics teachers.

To determine methodological tools, including digital platforms and assessment mechanisms, that support competency development in the context of "Molecular Physics" instruction.

METHODS

In the process of the research, the pedagogical conditions necessary for successful implementation of the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics" have been developed. The structural and content model of implementation of professional training of future physics teachers in the process of teaching the course "Molecular Physics" has been developed. The model consists of three interrelated components: methodological, content-activity and criterion-evaluation.

The research employed a mixed-methods approach, combining quantitative data collection through tests and surveys with qualitative pedagogical observation. Data were analysed using descriptive statistics, Pearson's chi-square tests, and Cohen's *h* to determine the statistical and practical significance of differences between control and experimental groups ($p<0.05$).

The issue of the inherent level of the methodological system of training future physics teachers in the process of teaching the course "Molecular Physics" was studied in the Kazakh Pedagogical University named after Abai in the framework of the research's ascertaining stage. The study was conducted during 2023-2024 years at the Department of Methods of Teaching Mathematics, Physics, and Informatics at the Faculty of Mathematics, Physics, and Informatics. The experiment involved 162 respondents whose age ranges from 18 to 21 years old. There were 81 participants in the control group and 81 participants in the experimental group. All participants were randomly assigned to each group to avoid pre-existing biases in group composition. The experimental results were evaluated on high, medium and low levels (Attokurova, 2023).

Bachelor's degree programme 6B01502 – Physics. The mission of the faculty is to train highly qualified teachers and specialists in the field of mathematics, physics, and computer science on the basis of advanced methods, national heritage and world approaches. The presented educational programme of teacher training is developed in accordance with the professional standard "Teacher", National and Sectoral Qualification Frameworks in the field of education. The educational programme 6B01502 – Physics is one of 30 innovative educational programmes that are being implemented for qualitative transformation in the Centre for Academic Excellence (CAE), envisaged under the state funding programme, including Science, Technology, Engineering, Arts and Mathematics (STEAM) technology training of teachers in biology, mathematics, physics, chemistry, geography, computer science, art education, music education and others; as well as special educators to work with children with autism spectrum disorder and and digital pedagogy majors (Shoiynbayeva et al., 2021).

After the introduction of the model of professional training of future teachers of physics during the study of the course "Molecular Physics" repeated testing of the respondents of the experimental group, who were trained according to the experimental methodology, was conducted. The intervention lasted for a full academic year and was implemented as part of the "Molecular Physics" course. The educational programme, within the framework of which the training of future physics teachers during the study of the course "Molecular Physics" is carried out, is developed taking into account the requirements of employers, in accordance with the national development priorities of the Republic of Kazakhstan until 2025 and the development strategy of "Abai University" for 2022-2025.

To determine the components of the level of methodological component in the professional training of future physics' teacher during the study of the course "Molecular physics" in the control and experimental groups, the following methods were used: to assess one motivation to obtain a profession of a physics teacher, the author's questionnaire developed for students, future physics teachers was compiled. It was proposed to use the digital application Google Forms to conduct the questionnaire (Petrochko et al., 2024). To reduce selection and instrumentation biases, tools were standardized across groups, learning activities were consistently implemented, and survey responses were anonymized to minimize instructor influence. The questionnaire included such items as: "To what extent do you aspire to become a physics teacher after graduation?", "Do you consider good academic performance to be a key motivator in studying physics?", and "Do you associate physics teaching with opportunities for leadership or social impact?".

Content validity was ensured through expert review by university lecturers specializing in pedagogy and subject methodology. Descriptive statistics (means and standard deviations) were calculated for individual item responses. For group-level comparisons of categorical outcomes (low, medium, high) in each of the three components, Pearson's chi-square test of independence was applied to evaluate whether the distribution of competency levels differed significantly between the control and experimental groups. Additionally, effect sizes were calculated using Cohen's *h*, allowing for the assessment of the practical significance of observed differences. All statistical analyses were conducted at a significance level of $p<0.05$. Processing of answers according to the proposed key in the questionnaire showed that motivation for "good grades" is important for future physics teachers (47.6% – situational level), and aspiration for leadership was 52.4%. At 34.2% of respondents (low level), insufficient consciousness of the values of performing their work was determined.

To test the content-activity component, the tasks aimed at assessing the professional competences of future physics teachers during the study of the course "Molecular Physics" were integrated. The level of formation of the content-activity component of readiness was assessed by answering theoretical and practical questions related to the content of the course "Molecular Physics". The testing was conducted using the Kahoot! platform. It allows creating interactive quizzes with different types of tasks (confirmation choice, true/false), as well as free participation in them in real time, which leads to a more efficient process (Nyssan, 2023).

The criterion-evaluation component was proposed to be tested by means of a test to assess the level of formation of professional competencies in future physics teachers during the study of the course "Molecular Physics". For this purpose, the Exam.net platform was used, which allows creating tests with different types of tasks (choosing answers, true/false, it is the same), outputting students' results and giving them feedback.

RESULTS AND DISCUSSION

In connection with the need to update the content of higher education in Kazakhstan, graduates of pedagogical specialities should receive theoretical and methodological knowledge that allows them to compete in the labour market. A qualitatively selected methodological system of teaching the course "Molecular Physics" is one of the key components in the professional training of a future physics teacher. This approach will emphasize the actual problems of modern physics, which makes it possible to flexibly choose the content of teaching material for different levels and types of educational institutions (Liu et al., 2020). Higher education in Kazakhstan in the twentieth century requires updating approaches to the implementation of professionally oriented training, in particular, future teachers of physics (Basharuly, 2017).

The study concludes that one of the most significant factors influencing the modernization of professional pedagogical education is Industry 4.0 – the fourth industrial revolution characterized by the introduction of digital technologies in all spheres of life (Šukolová & Nedelová, 2017). In the conditions of rapid development of digital technologies and the digitalization of society, the training of highly qualified teaching staff becomes one of the priority tasks of the state (Aviv et al., 2021). Modernization of professional and pedagogical education in Kazakhstan, taking into account the requirements of "Industry 4.0", allows not only improving the quality of education, but also educating a new generation of citizens capable of adapting in a rapidly changing world (Goren & Galili, 2019).

For the future teacher of physics, it is relevant to master the skills of effective application of general laws and methods of scientific research, having universal character for solving specific problems in the field of physics of atom, atomic nucleus and solid state, at interdisciplinary boundaries with other fields of physical knowledge and in pedagogical activity. Given the differentiation of the content of the course "Molecular Physics" with other courses of physical direction, changes in the sequence of studying the material, introduction of new methods and technologies of teaching in the educational process of higher educational institutions of Kazakhstan, the system of physical and mathematical training of future specialists is subject to reorganization.

"Molecular physics" in higher educational institutions of the Republic of Kazakhstan in the educational programmes belongs to the normative disciplines being mandatory for study (Rakhimberdinova et al., 2022). In the process of teaching the course "Molecular Physics", future teachers of physics study such topics as the structure and properties of molecules, kinetic theory of gases, thermodynamics, statistical physics, solid state physics, liquid physics, and plasma physics. Various teaching methods are used to study these topics, such as lectures, laboratory work, seminars, practical classes, and the use of digital technologies. In modern conditions of training of future teachers of physics in higher education institutions of the Republic of Kazakhstan, methodical foundations of teaching the course "Molecular Physics" acquire special importance in the professional formation of a future specialist (Kozhevnikova & Kozhevnykov, 2024). Since students' learning activity should model their future professional activity, the introduction of a professionally oriented approach to teaching this discipline becomes relevant (Dashko, 2023). Since during training students need to perform learning activities that should model their profession in the conditions of digitalization of education, it is necessary to pay special attention to the methodological component of the study of the course "Molecular Physics", which occupies an important role in the formation of a high-level specialist (Kanchana et al., 2019).

The use of digital technologies in the process of studying the course "Molecular Physics" has many advantages, namely, increasing the motivation and activity of students, improving the assimilation of knowledge and understanding of complex concepts, and developing skills of independent research and analysis. The introduction of digital technologies in teaching the course "Molecular Physics" in the process of professional training of future teachers of physics opens new opportunities for better assimilation of knowledge and development of professional competences of future specialists (Ivanova et al., 2024). The purpose of studying the course "Molecular Physics" in higher educational institutions of the Republic of Kazakhstan is: the formation of students' deep and systematized knowledge of basic principles of molecular physics necessary for their professional activity, development of intellectual abilities of personality: abstract and logical thinking, intuition, cognitive interest, independence and will, improvement of algorithmic and graphic culture.

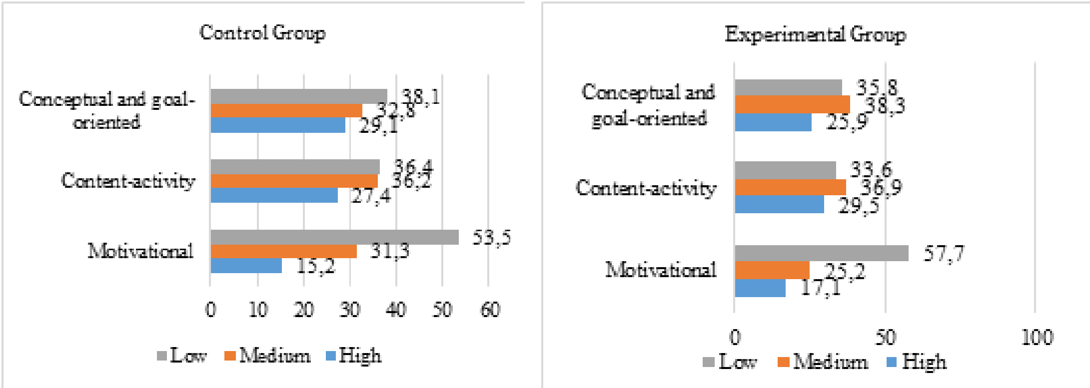
When developing curricula and programmes for the course "Molecular Physics", it is critical to take into account intra-subject and interdisciplinary links. Intra-subject links ensure the systematicity and consistency of the presentation of educational material, and its logical structure. Interdisciplinary links allow students to see the relationship of "Molecular Physics" with other sciences, which contributes to the formation of a holistic worldview.

Modern standards of higher education in the Republic of Kazakhstan have been analysed. Due to the dynamic development of many professions today, specialists are required to possess physical methods to solve professional problems, professionally oriented knowledge and skills in molecular physics, which is one of the key factors that increase the competitiveness of university graduates in the labour market (O'Hara & Pritchard, 2008).

Training of highly qualified physics teachers is one of the priority directions of the education system development in the Republic of Kazakhstan (Kovalchuk et al., 2020). Modern requirements to the educational process stipulate the necessity of continuous improvement of the methodological system of training of future physics teachers, ensuring the formation of necessary competencies (Shevchuk & Hunaza, 2025). The strategy of the programme is aimed at the formation and implementation of the established competence model, as well as expanding the possible range of employers (Annenkov et al., 2023). The mission of the educational programme is to form the human resource potential of highly qualified specialists – teachers of physics – competitive in the domestic and international labour market in accordance with their demands and development prospects of the country and the region.

The methodology is based on the implementation of readiness components. It is proposed to implement the motivational component using the coaching method to support high educational motivation of future physics teachers, to expand learning and autonomy, to develop self-assessment and self-reflection, the ability to adjust and organize their own learning (Onipko et al., 2023). To form the content-technological component, it is proposed to use the programme and methodological support in the form of professional direction tasks in the course "Molecular Physics". It is proposed to track and correct the results of the educational activity of future physics teachers during the study of the course "Molecular Physics" using the Moodle learning management system.

The criterial-evaluative component was proposed to be realized by means of self-assessment of the formation of professional competencies during the study of the course "Molecular Physics". The results obtained after the fulfilment of the outlined tasks were processed and presented in Figure 1.



Source: compiled by the authors

Figure 1. Results of Evaluation of the Development of Professional Competencies in the Control and Experimental Groups at the Founding Stage of the Experiment

Figure 1 reflects the baseline distribution of professional competency levels in the control and experimental groups prior to the intervention. The majority of students in both groups demonstrated low or medium readiness across all components. In the motivational domain, 53.5% of students in the control group and 57.7% in the experimental group were classified as having low motivational readiness, while the proportion of high-level responses remained modest at 15.2% and 17.1% respectively. A similar pattern is observed in the content-activity component, where low-level responses constituted 36.4% in the control group and 33.6% in the experimental group, with high-level responses accounting for only 27.4% and 29.5%. The conceptual and goal-oriented component showed comparable distributions, with low-level performance recorded at 38.1% in the control group and 35.8% in the experimental group. Statistical analysis using chi-square tests confirmed that these differences were not statistically significant across all components, with p-values well above the 0.05 threshold. For instance, in the motivational component, $\chi^2(2, N = 162) = 1.27$, $p = .530$; in the content-activity component, $\chi^2(2, N = 162) = 0.54$, $p = .763$; and in the conceptual and goal-oriented component, $\chi^2(2, N = 162) = 0.45$, $p = .799$. The corresponding effect sizes calculated using Cohen's h were minimal and did not exceed 0.15 in any domain, indicating negligible practical differences.

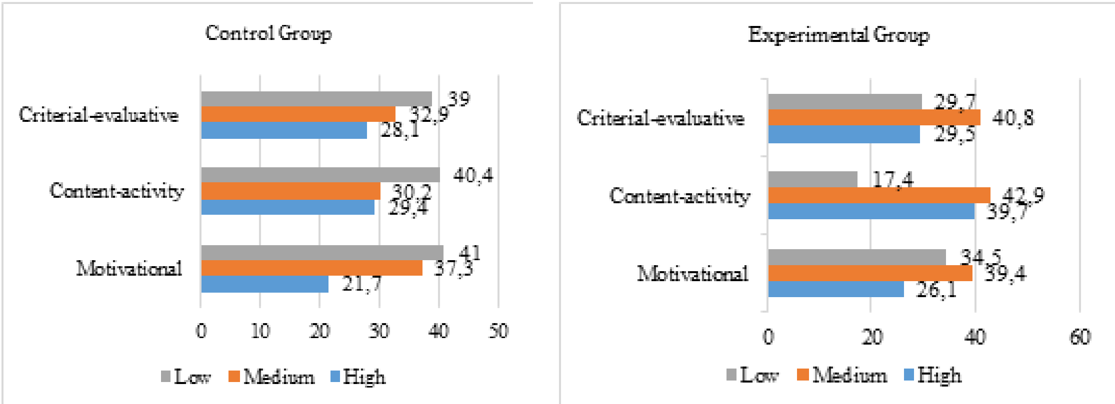
The analysis of the data obtained during the ascertaining stage of the experiment indicates the need to improve the training of future physics teachers in higher education institutions of the Republic of Kazakhstan. This, in turn, will be the key to the development of their professional competence on the basis of digital educational resources (Nurizinova et al., 2024). The results of the study at the formative stage of the experiment showed that the respondents of both control and experimental groups have a low and average level of motivation for learning. This indicates their unwillingness to develop in the professional direction. The insufficient level of content-technological component formation also emphasizes the need to update the methodological system of professional training of future physics teachers in the process of studying the course "Molecular Physics".

The conceptual and goal-oriented component of readiness needs improvement. This is due to the fact that it is important to be able to evaluate one's achievements and knowledge in this area. Thus, it was necessary to conduct the formative stage of the experiment. Its purpose was: to implement in the educational process pedagogical conditions and methodological system of professional training of future physics teachers during the study of the course "Molecular Physics". This methodology is an author's model of professional training of future teachers of physics with technologies of formation of its components. In the control group, the classes were conducted following the traditional methodology, and in the experimental group – according to the proposed methodology, using digital educational resources.

The coaching method was used to form the motivation component. This is a kind of creative partnership between the teacher and students, which allows them to realize their personal and professional potential. Teachers of the course "Molecular Physics" acted as a coach. Coaching as a pedagogical technology was used in the study to: support high educational motivation of future physics teachers, enhance learning and autonomy, develop self-esteem and self-reflection, ability to adjust and organize their own learning.

To improve the level of formation of the content-technological component, it is proposed to use programme and methodological support in the form of professional tasks in the course "Molecular Physics". Tracking and correction of the results of educational activity of future physics teachers during the study of the course "Molecular Physics", it is proposed to carry out with the help of the learning management system Moodle. This system allows creating and conducting online courses, and also includes a tool for creating tests with different types of tasks. Moodle also allows tracking students' learning outcomes and giving them the necessary feedback.

After the introduction of the model of professional training of future physics teachers in the process of studying the course "Molecular Physics", the respondents of the experimental group, who were trained according to the experimental method, were tested again. The results of respondents' distribution by levels at the stage of the forming experiment are presented in Figure 2.



Source: compiled by the authors

Figure 2. Results of Evaluation of the Development of Professional Competencies in the Control and Experimental Groups at the Founding Stage of the Experiment

Figure 2 presents the outcomes of the forming stage following the implementation of the proposed methodological system. The data demonstrate a clear improvement in the distribution of competencies within the experimental group, particularly in the content-activity component. In this domain, the percentage of students at the high level rose from 29.5% to 39.7%, while those at the low level declined sharply from 33.6% to 17.4%. In contrast, the control group showed only minimal changes, with high-level responses remaining largely stable at 29.4% and low-level responses increasing slightly to 40.4%.

A similar trend is evident in the motivational component. The proportion of experimental group students with low motivational readiness decreased from 57.7% to 34.5%, while high-level motivation increased from 17.1% to 26.1%. The control group also experienced improvement, but less markedly, with high motivation levels rising from 15.2% to 21.7% and low levels decreasing from 53.5% to 41%. In the conceptual and goal-oriented component, gains were also recorded. High-level responses in the experimental group increased from 25.9% to 29.5%, and low-level responses decreased from 35.8% to 29.7%, indicating a moderate upward shift in overall readiness. Chi-square tests confirmed that the differences between the experimental and control groups at this stage were statistically significant. The motivational component yielded $\chi^2(2, N = 162) = 7.83$, $p = .020$, the content-activity component $\chi^2(2, N = 162) = 15.62$, $p < .001$, and the conceptual-goal-oriented component $\chi^2(2, N = 162) = 6.21$, $p = .045$. Corresponding effect sizes calculated using Cohen's h indicated a medium effect in the motivational domain ($h = 0.39$), a large effect in the content-activity domain ($h = 0.61$), and a medium effect in the conceptual-goal-oriented domain ($h = 0.32$).

The results obtained at the stage of the formative experiment emphasized the necessity of solving the problem of updating the methodological system of professional training of future physics teachers in the process of studying the course "Molecular Physics". The study considered the formation of this definition as a holistic pedagogical process based on the interaction of teachers and students within the educational process. Thus, the theoretical and practical analysis of the investigated problem, allowed distinguishing the risks that complicate the process of updating the methodological system of professional training of future teachers of physics in the process of studying the course "Molecular Physics". Based on the results obtained as a result of the study, the pedagogical conditions of professional training of future physics teachers during the study of the course "Molecular Physics" have been developed.

The first condition is "Development of motivation in future teachers to study the course "Molecular Physics". The essence of the pedagogical condition is the formation of a system of motives and needs of students, stimulating them to study the course "Molecular Physics". The level of formation of motivation to learning is manifested in the tendency to autonomy, independence of task performance, attitude to the learning process, the use of means for independent assimilation of knowledge, the desire for self-development and self-improvement, as well as in the degree of motivation to study the course "Molecular Physics". The second condition – improving the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics" – focuses on improving the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics". This is achieved by careful selection of forms, methods, and means of teaching.

The main method of implementation of the principle of professionally oriented learning is the fulfilment of tasks of professional direction. The implementation of this condition is carried out by solving tasks differentiated by groups of students, taking into account the principle of complex differentiation (Yekimov et al., 2022). Such tasks include: tasks of professional direction directly related to the future professional activity of students; tasks for independent work with the use of application programmes that allow future physics teachers to apply theoretical knowledge in practice, using software relevant to their future profession; professionally-oriented projects – complex tasks that require students to work independently, analyse information, apply the acquired knowledge and skills to solve the problems of the future profession.

To increase the effectiveness of such training, appropriate materials for exercises are needed, including: lists of tasks for the course "Molecular Physics" systematized by topics and levels of difficulty; methodological instructions, detailed guides to the performance of tasks, containing explanations, algorithms for solving and examples; brochures, information materials, supplementing the curriculum and providing students with additional information on topics related to the future profession; appropriate software in the form of specialized software for the course "Molecular Physics". The implementation of the third pedagogical condition: the use of effective digital technologies implies the active use of digital technologies in the learning process. It is recommended to use mathematical software packages for methodological purposes (Shyshenko et al., 2024). The classification of such programmes includes: tutorial programmes: designed for primary learning of the material, containing interactive elements, explanations, and examples; simulators: they allow students to consolidate the acquired knowledge and skills by solving typical problems with automatic checking of the results; controlling programmes: serve to assess the level of knowledge and identify gaps in the mastering of the material; information and reference programmes: provide students with access to reference information, formulas, theorems, and other necessary information; simulation programs: simulate real-world processes and phenomena, allowing students to study them under different conditions; modelling programs: allow students to create their models to solve problems and investigate different hypotheses (Hunsu et al., 2023). In the context of the proposed methodological system of professional training of future physics teachers in the process of teaching the course "Molecular Physics", it is recommended to use the following programmes: Geogebra, Mathcad, Wolfram, Photomath (Hervás-Gómez et al., 2017).

The use of this methodology allows increasing students' motivation to study the course "Molecular Physics", improving the quality of their training and forming the necessary competencies for future professional activity. Implementation of the methodology of professional training of future teachers in the process of teaching the course "Molecular Physics" in universities of Kazakhstan is an important factor in improving the quality of training of future specialists.

It is recommended to implement the proposed pedagogical conditions by introducing the structural and content model of professional training of future physics teachers in the process of teaching the course "Molecular Physics", which encompasses three interrelated components:

1. Methodological component: specification and content of the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics"; definition of the stage of the process of implementation of the proposed methodology.

2. Operational-activity component: includes didactic and methodical processing of the course material "Molecular Physics"; develop-

ment of a system of specially structured tasks, laboratory, and research works aimed at the formation of professional skills.

3. Criterial-evaluative component: consists of a system of indicators of the formation of professional skills, including: mastering the methods of scientific cognition; application of ways of thinking (analysis, synthesis, generalization, abstraction); ability to apply knowledge and ways of activity depending on the learning task.

The proposed model is oriented to the formation of exactly those professional competencies during the study of the course "Molecular Physics", which are necessary for future teachers of physics. It can be used in the educational programmes of higher education of the Republic of Kazakhstan and allows improving the quality of training of future physics teachers, to form the necessary competencies, to prepare them for scientific and pedagogical activity. The clear structure of the model provides a systematic approach to the use of methodological approach of training of future teachers of physics. The model includes a system of tasks, laboratory and research works, which can be used in the educational process of studying the course "Molecular Physics" and is a relevant tool for training future teachers for professional activity. The availability of criteria for assessing the formation of professional competencies during the study of the course "Molecular Physics" makes it possible to monitor the dynamics of professional skills' development in future teachers (Gedvilienė et al., 2019).

It is recommended to implement the first condition by forming positive motivation of future physics teachers in the process of teaching the course "Molecular Physics" through discussions and analyses of achievements in the field of physics of famous personalities. The second condition – improvement of the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics" – reflects the level of improvement of the methodological component of professional training of future physics teachers in the process of teaching the course "Molecular Physics". To implement the second condition in the process of studying the course "Molecular Physics" lectures with problem elements were used.

In order to comprehensively understand physical concepts and laws, as well as to establish interrelationships with practical features of certain specialities, recommendations on the structure and blocks of lectures have been developed, namely: formulation of the base of applied tasks, development of a general model of studying the course "Molecular Physics", mastery of the methodology of solving different types of tasks. It is proposed to include such questions in lecture materials and independent work of students, which will ensure the increase of interest in the course "Molecular Physics", and renewal of professional motives. As a result, students learn to apply knowledge and skills in the context of real professional situations, which contributes to avoiding formal presentation of the material and expanding the opportunities for interdisciplinary communication.

In lecture and seminar classes, within the framework of the presented methodology, methods of active interaction of students can be used, organization of lecture classes with current control for immediate verification of acquired competencies and correction of mistakes. At the seminar classes it is possible to use computer programmes for the interpretation of physical concepts; within the framework of independent work – laboratory practice with the use of computer programmes, it is possible to consider practical examples of the use of physical laws in real life, allowing students to establish links with their future professional activity. In the process of using such lectures, it is possible to use information schemes that allow not only organizing lecture material on a certain topic qualitatively, but also simplifying its perception; it is also possible to use such schemes for solving professionally oriented tasks.

In the context of the implementation of the third condition, it is recommended to actively use digital technologies in laboratory and seminar classes in the course of studying the course "Molecular Physics" in order to optimize the work of teachers and adapt the learning process to the needs of students. Mathematical software packages, which should be used in laboratory works, can be divided into the following categories: tutorial (help students to master new topics and concepts); simulators (allow consolidating knowledge and skills by performing practical tasks); controlling (designed to test knowledge and understanding of the material); information and reference (provide access to the necessary information and resources); simulation (simulate real processes and phenomena, allowing students to explore them in a safe environment); modelling (allowing students to create their own models and investigate their behaviour).

Independent work of students is an important component of professionally oriented training of the course "Molecular Physics". It can be used to prepare for lectures and independent study of the material, to repeat the material before various forms of control, to write essays, to prepare for exams, to do homework (Marushko, 2022). The forms of independent work recommended to be used within the framework of the methodology are as follows: self-organization, group work, and mass work (Nardi et al., 2020). Methods of independent work: independent discussion of educational material, work in pairs, tutor support, problem methods, project activity, methods of collective mental activity, and application of the latest digital technologies in learning. The following criteria for evaluating the professional competences of future physics teachers during the study of the course "Molecular Physics" are proposed and presented in Table 1.

Table 1. Criteria for Assessing Professional Competencies of Future Physics Teachers During the Study of the Course "Molecular Physics"

Levels of learning achievement	**Criteria for assessing learning achievements**
Elementary	Pupil recognizes some physical and names them at an everyday level; describes some physical objects according to certain attributes.
Medium	The student independently performs some physical experiments in laboratory classes from the Molecular Physics course; describes individual observations of the flow of physical experiments.
Sufficient	The pupil compares and classifies physical objects; identifies understanding of fundamental physical theories and facts, giving examples to support this; describes observation of physical experiments.
High	The pupil applies knowledge in standard situations, is able to analyse, summarize and systematize the provided information, draw conclusions; uses knowledge in non-standard situations, establishes connections between phenomena; independently finds and uses information according to the task set; analyses additional information; uses knowledge reasonably, including in problem situations; independently evaluates phenomena related to substances and their transformations.

Source: compiled by the authors

The application of the developed teaching methodology can contribute to: improving the quality of training of students from the course "Molecular Physics", the development of their independence and creativity; and the formation of skills to use modern digital technologies in professional activities. Implementation of the methodology in the training programme of the course "Molecular Physics" and the use of digital technologies is an effective tool to improve the quality of training of future specialists.

Thus, the study of the course "Molecular Physics" according to the presented methodological system plays a pivotal role in the training of future teachers of physics, as this course provides a deep understanding of nature, development of critical thinking skills, preparation for teaching modern topics, development of skills in working with laboratory equipment, education of scientific outlook. Studying Molecular Physics can also help future teachers to develop teamwork and communication skills; increase their confidence in teaching science; and make teaching more interesting and engaging for themselves and their students (Sabatayeva et al., 2018). It is considered necessary to present the following recommendations for the training of future physics teachers in institutions of higher education: to continue improving the teaching methodology of the course "Molecular Physics" using modern pedagogical technologies and developments; to develop methodological recommendations for teachers on the use of computer programmes in the teaching process; to conduct systematic monitoring of the effectiveness of the developed teaching methodology (Semenovska et al., 2023).

The present study is of value for teachers of the course "Molecular Physics" of higher educational institutions, as it contains practical recommendations to improve the learning process and improve the quality of student training. Thus, the introduction of digital technologies and the organization of students' independent work in the process of studying the course "Molecular Physics" allow improving the process of training of future physics teachers, making it more interesting, effective and efficient.

Behind the results of experimental research, it is argued that in the Republic of Kazakhstan considerable attention is paid to this issue, and in institutions of higher education active work is carried out to improve the process of training of future teachers, in particular future teachers of physics. One of the important directions of this work is to improve the content and teaching methods of the course "Molecular Physics". This course is one of the basic courses in the training of future physics teachers, and its study provides them with the necessary knowledge and skills to form a scientific outlook in schoolchildren, understanding of the basics of physical phenomena and laws of the microcosm (Kholina et al., 2020).

From the perspective of inclusive education policy, the modernization of the "Molecular Physics" course contributes to building an equitable learning environment where future physics teachers are better equipped to accommodate diverse student needs. The updated methodology encourages differentiated instruction, independent learning, and digital accessibility. By cultivating pedagogical adaptability, such initiatives align with the goal of creating inclusive, student-centered educational environments.

Orazov and Issayeva (2023) concluded that the training of future physics teachers should meet the world standards and is one of the priority tasks of higher education institutions. The opinion presented in the cited works is supported, as the course "Molecular Physics" serves as a foundation of pedagogical and engineering education. At the formative stage of the experiment, the conclusions are made that the study of future physics teachers of the course "Molecular Physics" contributes to the formation of the necessary basic knowledge for understanding such disciplines as theoretical mechanics, theory of machines and mechanisms, hydraulics, heat engineering, resistance of materials, materials science, electrical engineering and microelectronics. Nevertheless, over the last two decades, there has been a steady tendency to reduce the classroom hours allocated to the study of the course "Molecular Physics" (Slovinscki et al., 2021). This leads to a systemic deterioration of the level of physics and mathematics training of future physics teachers, which negatively affects their mastery of specialized disciplines and acquisition of professional competence. In addition, there is a devaluation of the prestige of pedagogical specialities compared to legal and economic education, which makes the career of a teacher less attractive for gifted applicants. That is why an updated methodological system has been developed and experimentally tested, aimed at significant improvement of teaching "Molecular Physics" in pedagogical institutions of higher education, increasing the number of hours allocated to the study of the outlined course with an emphasis on classroom teaching, improving the qualifications of teaching staff and their constant motivation for professional development.

Comparative international practice reveals that many countries face challenges similar to those in Kazakhstan and have developed effective solutions anchored in inclusive, inquiry-based, and technology-rich pedagogies. For example, in Finland, teacher education emphasizes socio-constructivist theory and autonomy through inquiry- and problem-based approaches that reflect differentiated and individualized learning design. The 2016 curriculum reform introduced phenomenon-based learning, supporting interdisciplinary education that mirrors the aims of Kazakhstan's revised "Molecular Physics" course in building inclusive environments and nurturing independent learning skills (English et al., 2022). Similarly, in Ontario Canada the Early Learning Kindergarten Program employs inquiry-based pedagogy rooted in sociocultural theory, which has demonstrated positive effects on student outcomes and supports the logic behind integrating real-world problems and student-centered methods into the Kazakh context (Takala et al., 2023). The alignment of this approach with the updated "Molecular Physics" course reinforces its pedagogical credibility (Van Dusen et al., 2021). Australia's National STEM School Education Strategy also addresses equity and inquiry-based teaching, particularly in underrepresented groups, and shows that structured professional development and collaborative networks enhance teacher preparedness and instructional quality (Jones et al., 2024). These international comparisons substantiate the appropriateness of Kazakhstan's direction in reforming the course and affirm the global relevance of inquiry-based and digitally supported teaching frameworks in science education.

de Oliveira (2018), investigating the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics", came to the conclusion that the training of future physics teachers should apply tasks that are directly related to the future professional activity of students. The use of the outlined approach is considered correct because the curriculum of the course "Molecular Physics" should include disciplines that introduce students to the physical methods used in their future specialities. The methodology proposed in the presented research suggests that practical classes and laboratory works during the study of the course "Molecular Physics" should be aimed at the application of physical methods by students to solve real professional problems (Petrova et al., 2018). In the process of using modern methods of teaching the course "Molecular Physics" should be used modern digital technologies that allow students to independently solve problems, conduct research, find and analyse information (Yermolenko et al., 2024).

In modern conditions of information and educational environment, according to Han et al. (2019), the issue of organizing professionally-oriented independent work of students, and future physics teachers, during the study of the course "Molecular Physics" becomes relevant. The study supports this opinion and proposes the implementation of the following pedagogical conditions – improvement of the methodology of professional training of future physics teachers in the process of teaching the course "Molecular Physics" based on the use of non-traditional lectures on the course "Molecular Physics", lecture with pre-planned errors, lecture with current control, lecture-visualisation. During laboratory and seminar classes in the process of studying the course "Molecular Physics" it is proposed to use digital technologies to optimize the work of teachers and adapt the learning process to the needs of students, mathematical software packages, and independent work is used to prepare for lectures and independent study of the material, repetition of material, various forms of control, writing essays, preparing for exams, homework (Hrechanyk & Sharov, 2023).

Moldabekova and Bitibayeva (2017) substantiate in their research the expediency of using motivational tasks of professional direction in the educational process of training future teachers of physics. They should contain professional concepts and terms that promote students' interest in the study of the subject and its practical application and learning tasks that simulate real professional situations and require the application of mathematical methods, developing professional thinking and skills needed in future activities. Having studied the opinion of researchers concerning the presented problems in order to improve the training of future physics teachers, it is considered appropriate to develop a methodological system of teaching the course "Molecular Physics", oriented to professionally oriented training. This system classifies different forms and methods of physics education according to the level of knowledge and skills assimilation, as well as to take into account the specifics of future professional activity of specialists (Shovkova, 2021). The implementation of the proposed methodological recommendations behind the results of the experiment contributes to the improvement of the quality of specialists' training in accordance with the requirements of the modern labour market, the formation of students' sustainable skills of independent problem-solving of professional direction, the development of professional thinking and creative approach to problem-solving. This approach can be effectively used in the system of training specialists in different technical and natural science areas.

Philipsen et al. (2019) investigated the possibility of using digital technologies in teaching physics disciplines. In their findings, the researchers testify that such technologies increase motivation for learning, activate cognitive activity, and provide visibility of learning. It is considered that the use of the outlined approach is quite convenient, because for effective training of future physics teachers in the study of the course "Molecular Physics" the following computer programmes should be used, such as Geogebra, Mathcad, Wolfram, Photomath. In the process of implementation of the third pedagogical condition, the study proved that these programmes automate calculations, expand the possibilities of using mathematical methods, contribute to a better assimilation of theory. It is concluded that the prospects for further research will be the development of a laboratory workshop for the course "Molecular Physics", using the programme GeoGebra for independent work. This allows students to explore some topics and see how mathematical methods work.

Lipnická et al. (2019) actively investigated the digitalization of the educational process in higher education institutions. In numerous works it has been proved that digital technologies in the study of the course "Molecular Physics" are a crucial factor in improving the quality of education, updating the content and methods of teaching, training specialists who meet the modern requirements of the labour market. The opinion of researchers is continued and the outlined approach in the pedagogical condition – application of effective digital technologies is reflected.

The current study shows a number of significant shortcomings, notwithstanding the outcomes of the methodical approach that was put in place for the professional preparation of aspiring physics instructors through the "Molecular Physics" course. Most significantly, the external validity of the results is hampered by the very small sample size of 162 students, all of whom were selected from the same institution – Abai Kazakh National Pedagogical University. Generalisation to other higher education contexts in Kazakhstan is hindered by the study's exclusive focus on one academic environment, especially in rural or less technologically advanced institutions. Furthermore, the evaluation of student growth was limited to a single academic year and failed to account for the transferability of learnt competencies into actual teaching practice or long-term retention. Despite attempts at anonymisation and standardisation, the use of self-reported data through surveys and online tools like Google Forms and Kahoot! raises the possibility of instructor effect and social desirability bias. Additionally, the study lacked triangulated data and direct classroom observations, which might have limited the breadth and authenticity of its evaluation of pedagogical change.

In order to demonstrate the scalability and adaptability of the suggested methodological methodology, future research should build on these findings by carrying out multi-site studies across a variety of Kazakhstani universities, including under-represented and resource-constrained places. Insight into the training model's long-term effects, particularly with regard to classroom procedures and student learning outcomes, could be gained by longitudinal designs that follow students from the time they first take the "Molecular Physics" course until the beginning of their teaching careers. Furthermore, in order to provide deeper, more complex insights about the model's effectiveness, qualitative techniques like focus groups, ethnographic classroom observations, and reflective teaching portfolios ought to be used in conjunction with the quantitative framework. In order to support curriculum-wide pedagogical reform, future research should also evaluate the cost-effectiveness, infrastructure requirements, and institutional preparedness for the widespread adoption of digital tools like Moodle, GeoGebra, and Exam.net. Additionally, it should investigate how the model can be expanded to other physics curriculum domains, such as electrodynamics and quantum mechanics.

In general, the study of the course "Molecular Physics" is a valuable experience for future physics teachers, which can help them to become more competent, qualified and confident in their knowledge teachers. Thus, based on the obtained results of the study, the practical value of the work is the improved methodological system of professional training of future physics teachers in the process of teaching the course "Molecular Physics".

CONCLUSION

This study confirms the practical effectiveness of a newly constructed methodological system for training future physics teachers through the "Molecular Physics" course in the context of digitalized higher education in Kazakhstan. The experimental results provide statistically significant evidence that the implemented model fosters superior outcomes in professional readiness compared to traditional methods. In particular, the proportion of students in the experimental group achieving high competency levels in the content-activity component increased from 29.5% to 39.7%, while low-level responses decreased from 33.6% to 17.4%. Similar positive trends were recorded for the motivational and criterion-evaluative components, with medium to large effect sizes (Cohen's h = 0.39-0.61), establishing the robustness of the intervention. The key contribution of this research lies in the design and validation of a comprehensive methodological model, comprising motivational, operational-activity, and criterion-evaluative components. This triadic structure not only integrates digital tools (e.g., Moodle, Kahoot!, Exam.net) and coaching techniques, but also enables targeted development of essential pedagogical competencies such as scientific reasoning, digital literacy, and learner-centered instruction. The model bridges theoretical content with practical teaching skills, thus addressing a previously unmet need in Kazakhstan's teacher training system for an empirically grounded, modular, and scalable framework tailored to STEM education. From a policy perspective, the findings support the strategic prioritization of modular competence-based models in teacher education programs. The adoption of the proposed methodological system offers a pathway to align training outcomes with national educational standards and labour market expectations. Policymakers in Kazakhstan's higher education sector should consider formal integration of such models into national curricula, particularly in teacher education standards for STEM disciplines. Furthermore, the increased use of digital platforms and project-based learning environments highlighted in this study provides a foundation for updating pedagogical norms and assessment protocols in teacher training institutions across the country. Expanding the implementation of this model to other foundational physics courses (e.g., Electrodynamics, Quantum Mechanics) would further enhance systemic instructional quality in the digital era.

REFERENCES

Aitbaeva, A.B., & Shaihozova, Zh.N. (2022). Restudy of pedagogy in the digital age or issues of teaching design. *Pedagogical Sciences Series*, *2*(71), 4–12.

Annenkov, A., Medvedskyi, Y., Demianenko, R., Adamenko, O., & Soroka, V. (2023). Preliminary accuracy assessment of low-cost UAV data processing results. In D. Bozhezha & I. Savchyn (Eds.), *International Conference of Young Professionals "GeoTerrace 2023"* (pp. 1–5). Lviv: European Association of Geoscientists and Engineers.

Attokurova, A.Dj. (2023). Chapter 25 Professional training of a contemporary teacher of mathematics: Designing an educational program for a bachelor's degree in the direction of "Physics and Mathematics Education" on a modular-competency basis. *Studies in Critical Social Sciences*, *254*, 349–358.

Aviv, I., Svetinovic, D., & Lee, S.-W. (2024). Requirements Engineering for Web3 Systems: Preface. In G. Liebel, I. Hadar, & P. Spoletini (Eds.), *Proceedings – 32nd IEEE International Requirements Engineering Conference Workshops, REW 2024* (pp. 326–327). Reykjavik: Institute of Electrical and Electronics Engineers.

Basharuly, R. (2017). *Physics: Textbook for 7th grade of secondary school.* Almaty: Atamura. https://www.at.alleng.org/d/phys/phys824.htm

Batyrbekova, A.Zh. (2020). The use of educational and methodological tasks in the formation of methodological competence of future physics teachers. *Bulletin of Yasawi University*, *3*(117), 214–223. https://journals.ayu.edu.kz/index.php/habarshy/article/view/162

Boyle, J.T. (2019). Teaching mechanics. In *State of the Art and Future Trends in Material Modeling. Advanced Structured Materials* (pp. 23–48). Cham: Springer.

Dashko, Y. (2023). Information technologies in the educational process: Features and advantages. *Pedagogical Sciences, 6*(2), 46-51.

de Oliveira, M.J. (2018). Elementary concepts and fundamental laws of the theory of heat. *Brazilian Journal of Physics*, *48*, 299–313.

dos Reis Belíssimo, J., & Nardi, R. (2024). A longitudinal study on the development of the professional identity of future physics teachers. *International Journal of Innovation in Science and Mathematics Education*, *32*(2), 2–12.

English, J.L., Keinonen, T., Havu-Nuutinen, S., & Sormunen, K. (2022). A study of finnish teaching practices: how to optimise student learning and how to teach problem solving. *Education Sciences*, *12*(11), 821.

Gedvilienė, G., Tūtlys, V., & Daukilas, S. (2019). The role of the key competences of VET teachers in enhancing the quality of the teaching process. *The New Educational Review*, *55*, 255–271.

Goren, E., & Galili, I. (2019). Newton's law – A theory of motion or force? *Journal of Physics: Conference Series*, *1287*, 012061.

Han, M., Feng, S., Chen, C.L.P., Xu, M., & Qiu, T. (2019). Structured manifold broad learning system: A manifold perspective for large-scale chaotic time series analysis and prediction. *IEEE Transactions on Knowledge and Data Engineering*, *31*(9), 1809–1821.

Hervás-Gómez, C., Toledo-Morales, P., & Díaz-Noguera, D. (2017). Augmented reality applications attitude scale (ARAAS): Diagnosing the attitudes of future teachers. *The New Educational Review*, *50*, 215–226.

Hrechanyk, N., & Sharov, O. (2023). Cultural approach to training future teachers of higher education institutions: Theoretical and practical aspect. *Humanities Studios: Pedagogy, Psychology, Philosophy*, *11*(4), 42-51.

Hunsu, N. J., Olaogun, O. P., Oje, A.V., Carnell, P.H., & Morkos, B. (2023). Investigating students' motivational goals and self-efficacy and task beliefs in relationship to course attendance and prior knowledge in an undergraduate statics course. *Journal of Engineering Education*, *112*(1), 108–124.

Ivanova, O.S., Kit, N., & Storozhyk, M. (2024). Philosophy of education in the context of digital transformation of public life. *Humanities Studios: Pedagogy, Psychology, Philosophy, 12*(1), 141-148.

Jones, M., Geiger, V., Falloon, G., Fraser, S., Beswick, K., Holland-Twining, B., & Hatisaru, V. (2024). Learning contexts and visions for STEM in schools. *International Journal of Science Education*, *47*(3), 337–357.

Kanchana, S., Patchainayagi, S., & Rajkumar, S. (2019). Empowering students to become effective learners through activity based learning. *Humanities and Social Sciences Reviews*, *7*(5), 57–62.

Kholina, S., Babenko, O., Grudinina, V., & Velichkin, V. (2020). Model of advanced training of physics teachers at the present stage. *E3S Web of Conferences*, *210*, 18116.

Kovalchuk, V., Marynchenko, I., & Yashchuk, S. (2020). Creation of favourable educational environment in the higher education institutions of Ukraine. *Society. Integration. Education. Proceedings of the International Scientific Conference*, *1*, 465–480.

Kozhabekova, E., Yermekova, Z., & Sagyndykova, G. (2024). Competence-based approach as a new strategy for preparing future Physics teachers to form a scientific worldview of students. *Scientific Herald of Uzhhorod University. Series "Physics"*, *55*, 924–933.

Kozhevnikova, A., & Kozhevnykov, P. (2024). Specifics of innovative educational environment and its influence on the development of future teachers' innovative competence. *Scientific Bulletin of Mukachevo State University. Series "Pedagogy and Psychology", 10*(2), 72–80.

Kuzmicheva, A.E., Zhusupkalieva, G.K., Kozlov, V.S., Kazhmukanova, D.M., Gubasheva, A.O. (2022). The role of the iconic form of science in the realisation of physics learning objectives. *Bulletin of Al-Farabi Kazakh National University: Pedagogy Series*, *1*(70), 104–115.

Kuznietsov, Ye., & Kuznietsova, T. (2024). Innovative models of vocational education: A symbiosis of artificial intelligence, neuropedagogy, and the competency-based approach. *Professional Education: Methodology, Theory and Technologies*, *10*(1), 64–78.

Lipnická, M., Babiaková, S., & Cabanová, M. (2019). Self-evaluation of future teachers' didactic competencies. *The New Educational Review*, *57*, 115–126

Liu, Z.Y., Lomovtseva, N., & Korobeynikova, E. (2020). Online learning platforms: Reconstructing modern higher education. *International Journal of Emerging Technologies in Learning (iJET), 15*(13), 4–21.

Marugkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual reality in education: a review of theories, approaches and learning methodologies over the last decade. *Electronics, 12*(13), 2832.

Marushko, L. (2022). Methodological basis of training future teachers of natural specialties for professional activity on the basis of differentiation and individualization of learning. *Professional Education: Methodology, Theory and Technologies*, *8*(2), 194–212.

Moldabekova, M.S., & Bitibayeva, Zh.M. (2017). Methodology for the study of the electron irradiation influence on mechanical characteristics of certain composites in condensed matter physics for pedagogical higher education institutions. *Revista ESPACIOS*, *38*(25).

Moldabekova, M.S., Fedorenko, O.V., Mukamedenkyzy, V., & Asembaeva, M.K. (2023). On the development of transversal competencies of students of physical and technical specialties. *Recent Contributions to Physics*, *87*(4), 36–43.

Nardi, R., Parma, F.W., & Belíssimo, J.R. (2020). Pre-service teachers' perceptions of the professional attributes of future physics teachers. *Journal of Physics: Conference Series*, *1512*(1), 012032.

Nurizinova, M., Skakov, M., Çoruh, A., Ramankulov, S., & Nurizinov, M. (2024). The development of digital educational materials on tribology and their application in the formation of the professional competence of future physics teachers. *International Journal of Innovative Research and Scientific Studies*, *7*(4), 1600–1613.

Nyssan, G. (2023). Improvement of the professional and methodical training of future physics teachers. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 514–525.

O'Hara, S., & Pritchard, R. H. (2008). Meeting the challenge of diversity: Professional development for teacher educators. *Teacher Education Quarterly*, *35*(1), 43-61.

Onipko, V., Yaprynets, T., & Antonets, A. (2023). General cultural key competence as a basis for future specialist training. *Ukrainian Professional Education*, *8*(2), 81–88.

Onyshchenko, N., & Serdiuk, N. (2025). Peculiarities of training future specialists in higher education institutions using innovative teaching technologies. *Scientia et Societus, 4*(1), 86-95.

Orazov, B. D., & Issayeva, G. B. (2023). Improving the professional training of future teachers of physics in the course of teaching "molecular physics". *Reports of the Academy of Sciences of the Republic of Kazakhstan*, *4*, 93–101

Order of the Minister of education and science of the Republic of Kazakhstan No. 604 "On Approval of State Compulsory Educational Standards for All Levels of Education". (2018). https://adilet.zan.kz/eng/docs/V1800017669

Petrochko, Z., Riabtseva, O., Lyktei, B., Liang, C., & Ostapchuk, V. (2024). Professional training of a future teacher for the organization of pupils' innovative activity in the educational process. *TEM Journal*, *13*(1), 493–501.

Petrova, M.M., Sushchenko, O., Trunina, I., & Dekhtyar, N. (2018). Big data tools in processing information from open sources. In *2018 IEEE 1st International Conference on System Analysis and Intelligent Computing, SAIC 2018 – Proceedings* (article number: 8516800). Kyiv: Institute of Electrical and Electronics Engineers.

Philipsen, B., Tondeur, J., McKenney, S., & Zhu, C. (2019). Supporting teacher reflection during online professional development: A logic modelling approach, *Technology, Pedagogy and Education, 28*(2), 237–253.

Rakhimberdinova, M., Nurekenova, E., Suieubayeva, S., Duarte, Á., & Ordabayeva, M. (2022). Predictors influencing the choice of master's programs in the tourism industry. *Journal of Environmental Management and Tourism, 13*(4), 1161–1177.

Riznyk, V. (2023). Adaptation of the Experience of Foreign Pedagogical Community of Higher Education in the Students' Critical Thinking Development in Ukraine. *Professional Education: Methodology, Theory and Technologies*, (18), 174-191.

Sabatayeva, B., Saduov, A., Madiyarova, E., Jempeissova, G., Selezneva, I., Shtiller, M., & Fursova, T. (2018). International students' satisfaction with university services: The case of postgraduate students from central Asia. *Espacios, 39*(9), 04.

Semenovska, L., Vazhenina, I., & Fazan, V. (2023). Individualization of learning as a development actuality information technological society. *Pedagogical Sciences,* (82), 30-34.

Semerikov, S.O., Teplytskyi, I.O., Soloviev, V.N., Hamaniuk, V.A., Ponomareva, N.S., Kolgatin, O.H., Kolgatina, L.S., Byelyavtseva, T.V., Amelina, S.M., & Tarasenko, R.O. (2021). Methodic quest: Reinventing the system. *Journal of*

Physics: Conference Series, 1840(1), 012036.

Shevchuk, L., & Hunaza, L. (2025). Analysis of international experience in implementing Artificial Intelligence in the educational process. *Scientia et Societus, 4*(1), 76-85.

Shoiynbayeva, G.T., Shokanov, A.K., Sydykova, Z.K., Sugirbekova, A.K., & Kurbanbekov, B.A. (2021). Methodological foundations of teaching nanotechnology when training future physics teachers. *Thinking Skills and Creativity*, *42*, 100970.

Shovkova, A. (2021). Axiological bases of innovative culture formation of the future teacher of the vocational education institution. *Ukrainian Professional Education*, (9-10), 59–66.

Shyshenko, I., Lukashova, T., Drushlyak, M., & Hvorostina, Y. (2024). Ways to develop soft skills in pre-service mathematics and physics teachers when studying certain topics of olympiad mathematics. *Scientific Bulletin of Mukachevo State University. Series "Pedagogy and Psychology"*, *10*(1), 56–67.

Slovinscki, L., Alves-Brito, A., & Massoni, N.T. (2021). Astronomy in curricula for the initial training of physics teachers: a diagnostic analysis. *Revista Brasileira de Ensino de Fisica*, *43*, 1–20.

Sohn, K., & Kwon, O. (2020). Technology acceptance theories and factors influencing artificial intelligence-based intelligent products. *Telematics and Informatics*, *47*, 101324.

State Programme for the Development of Education and Science of the Republic of Kazakhstan for 2020-2025. (2020). https://www.kaznpu.kz/en/2378/notice/

Šukolová, V., & Nedelová, M. (2017). Critical thinking in initial teacher education: Secondary data analysis from AHELO GS feasibility study in Slovakia. *The New Educational. Review*, *49*, 19–29.

Takala, M., Sutela, K., Ojala, S., & Saarinen, M. (2023). Teaching practice in the training of special education teachers in Finland. *European Journal of Special Needs Education*, *38*(6), 835-849.

Ualihanova, B.S., & Omarov, O. (2023). Improvement of pedagogical education in physics: Methodological system of advanced teaching of classical mechanics. *3i: Intellect, Idea, Innovation*, *4*, 259–268.

Van Dusen, B., Vogelsang, C., Taylor, J., & Cauet, E. (2021). How to teach a teacher: Challenges and opportunities in physics teacher education in Germany and the USA. In H.E. Fischer & R. Girwidz (Eds.), *Physics Education* (pp. 55-81). Cham: Springer.

Weissman, E.Y., Merzel, A., Katz, N., & Galili, I. (2019). Teaching quantum mechanics in high-school – Discipline-culture approach. *Journal of Physics: Conference Series*, *1287*, 012003.

Yekimov, S., Tsypko, V., Kuzminets, M., Timenko, V., Tokin, O., Lapmeka, M., & Haponenko, S. (2022). Improving the quality of training of physics teachers to attract applicants to physical specialties. *AIP Conference Proceedings*, *2647*(1), 020001.

Yermekova, Z., Stukalenko, N., Kozhabekova, E., & Kukubayeva, A. (2024). Training of the future physics teachers for implementation of the tasks of physical and environmental education. *Scientific Herald of Uzhhorod University. Series "Physics"*, *55*, 1177–1187.

Yermolenko, R., Klekots, D., & Gogota, O. (2024). Development of an algorithm for detecting commercial unmanned aerial vehicles using machine learning methods. *Machinery and Energetics, 15*(2), 33–45.

Zalewski, J., Novak, G., & Carlson, R.E. (2019). An overview of teaching physics for undergraduates in engineering environments. *Education Sciences*, *9*(4), 278.

Zharmukhanbetov, S., Abdrakhmanova, K., Ormanova, G., Singh, C.P., & Kudaibergenova, K. (2024). Deep analysis of integrated stem in teaching for future physics teachers using project-based learning. In V. Goar, M. Kuri, R. Kumar, & T. Senjyu (Eds.), *Advances in Information Communication Technology and Computing* (pp. 147–159). Singapore: Springer.