# ABSTRACT

for the dissertation submitted for the degree of Doctor of Philosophy (PhD) in the educational program «8D01501 - Physics»

**RAKHMETOVA MAIRAGUL**

## IMPROVEMENT OF ENVIRONMENTAL COMPETENCE OF FUTURE PHYSICS TEACHERS

**General description of the work.** This dissertation addresses the problem of forming and enhancing the ecological competence of future physics teachers through the teaching of physics in higher education. The study explores the integration of sustainable development principles into teacher training curricula and substantiates their necessity for fostering students' environmental responsibility and raising their ecological competence.

The research aims to develop a comprehensive model of ecological competence enhancement by synthesizing pedagogical theories and experimentally validating its effectiveness.

Specialized teaching materials and instructional methods are proposed to strengthen students' professional, methodological, and research skills in the ecological domain. The scientific and methodological foundations, together with the experimental results, contribute to the professional growth of future physics teachers, ensure the effective integration of ecological education elements into the learning process, and are directed toward improving the overall quality of education.

**Relevance of the research.** At present, the number of government programs in Kazakhstan aimed at fostering sustainable development and ecological culture is increasing, and the demand for specialists with ecological education and «green» technologies is growing. However, the results of international studies such as PISA and TIMSS reveal an insufficient level of ecological literacy among students and their responsibility for environmental protection. Despite the growing global need for ecological literacy, this issue is insufficiently reflected in Kazakhstan's educational standards and curricula.

In this regard, the ecological integration of higher education content is a strategic task. It is particularly important to utilize the ecological potential of physics disciplines («Molecular physics and thermodynamics,» «Electricity and magnetism,» «Environmental physics»), since explaining natural processes and energy cycles contributes to the formation of students' ecological thinking.

**Research aim:** To determine the scientific and methodological foundations for enhancing the ecological competence of future physics teachers, to develop its structural-content model and educational-methodological system, and to prove their effectiveness through a pedagogical experiment.

**Research objectives:**

1.Based on the analysis of domestic and foreign literature and pedagogical experience, to identify the theoretical and methodological prerequisites and

substantiate the structural-content model for enhancing the ecological competence of future physics teachers.

2. To develop and implement an educational-methodological system (elective course, electronic textbook, teaching aids, system of ecological tasks and assignments) that integrates ecological content into the disciplines «Molecular physics», «Electricity and magnetism», and «Environmental physics».

3. To evaluate the effectiveness of the proposed system in the course of a pedagogical experiment and scientifically substantiate its efficiency through statistical data processing.

**Research methods:** study of educational-methodological documentation and pedagogical practice of higher education institutions; theoretical analysis of the research problem; observation; comparison; generalization; modeling; conducting surveys; performing practical tasks; statistical processing of obtained data and their pedagogical interpretation.

**Object of research:** the process of training future physics teachers in higher education institutions.

**Subject of research:** methodology for enhancing the ecological competence of future physics teachers.

**Scientific hypothesis:** if the theoretical and methodological foundations and pedagogical conditions for enhancing the ecological competence of future physics teachers are identified, and a structural-content model and educational-methodological system based on ecological integration of the disciplines «Molecular physics», «Electricity and magnetism», and «Environmental physics» are developed, then the ecological competence of future physics teachers will be effectively enhanced, and students' ecological knowledge and practical skills will be comprehensively developed.

**Scientific novelty and features of the research.** For the first time:

1.The theoretical and methodological foundations for enhancing the ecological competence of future physics teachers have been clarified, and a structural-content model for its implementation has been developed.

2. Pedagogical conditions have been identified, and scientific-methodological foundations for their implementation in the process of professional training have been proposed.

3. An educational-methodological complex has been developed, based on the integration of ecological content into the disciplines «Molecular Physics», «Electricity and Magnetism», and «Environmental Physics», the effectiveness of which has been proven through a pedagogical experiment.

**Theoretical significance.** It is defined by the identification of scientific and methodological foundations for enhancing the ecological competence of physics teachers. In addition, the research results supplement pedagogical theories in this field and allow for the clarification of substantive and methodological approaches to integrating ecological content into the teaching of physics based on the principles of sustainable development.

**Practical significance.** The practical significance of the study lies in the development and implementation into the educational process of the modular

educational program under the trajectory 6B01502 – «Physics Teacher,» aimed at enhancing the ecological competence of future physics teachers, as well as in the creation of the elective course «Environmental Physics» and a textbook, the teaching and methodological manual «The development of ecological knowledge and skills in teaching physics courses», and the electronic resource on the topic «Ecological problems in molecular physics.» The teaching and methodological manual «The development of ecological knowledge and skills in teaching physics courses» was granted a certificate of state registration as an object of copyright by the National Institute of Intellectual Property of the Ministry of Justice of the Republic of Kazakhstan (No.11147, June 25, 2020).

The listed teaching materials have been included in university programs and are used in practice. They represent accessible resources that contribute to the professional development of teachers, including practical tasks and assessment tools. The research results can be applied in the practice of teacher training and retraining systems. Developed lesson plans with ecological content, tasks, and project assignments have been adapted for integration into pedagogical practice. Their development was based on the challenges of the modern education system and the needs of teachers identified during the study.

**Scientific statements submitted for defence:**

1. The structural-content model for improving the ecological competence of future physics teachers is based on the integration of the target-motivational, content, activity, and result components. It is specified across the subject-physical, ecological-content, experimental-research, methodological-design, and value-reflective dimensions, ensuring the comprehensive development of professional and ecological competences.

2. The introduction of the elective discipline «Environmental Physics» into the 6B01502 – «Physics Teacher» educational program, together with the implementation of teaching and methodological guides aimed at integrating environmental content into the disciplines «Molecular Physics» and «Electricity and Magnetism», contributes to deepening future physics teachers' environmental knowledge, developing their research and practical skills, and fostering their environmental competence.

3. In the experimental group of future physics teachers who completed the special course, a positive dynamic was observed across all components of ecological competence: the level of interest in the motivational component increased from 16.85 % to 29.80 %; the indicator of mastering ecological knowledge in the content component rose from 35.76 % to 72.19 %; and the development of practical and research skills in the activity component grew from 43.05 % to 74.17 %.

**Reliability and validity of the obtained results:** The methodological basis of the study; the use of a complex of methods; consistency with the stated goals and objectives; the content of the experimental work; confirmation of the research hypothesis; coherence of theoretical propositions with practical results; verification of their effectiveness in the experiment and implementation in practice ensured the validity and reliability of the results. This is confirmed by the author's personal pedagogical experience as a senior lecturer at the Department of Physics and

Technical Disciplines of Khalel Dosmukhamedov Atyrau University. The reliability of the dissertation is also supported by publications in foreign journals with a high impact factor, as well as in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

**The author's individual contribution.** The author independently carried out the entire research process from beginning to end, including the literature review and all quantitative calculations. All work was conducted in consultation with academic supervisors.

**Approbation and implementation of research results.** During the preparation of the dissertation, 13 works were published: scientific articles totaling more than 7 printed sheets, 1 monograph, 2 teaching manuals, 2 articles in foreign journals, 1 article in a journal with a non-zero impact factor indexed in Thomson Reuters and Scopus, and 7 articles in the proceedings of international conferences.

**Publications in International Scientific Databases Web of Science and Scopus:**

1.Rakhmetova M., Abykanova B., Syrbayeva S., Amangossova A., Bilyalova Z., Sharmukhanbet S. (2026). *Cultivating Ecological Responsibility in Physics: A Data-Driven Study on Integrating Environmental Competence and Identity.* Perspectives on Global Development and Technology https://doi.org/10.1163/15691497-20262001 (Scopus Q3, Percentile – 39).

**Publications in Journals Recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan:**

1.Rakhmetova M.T., Imashev G. «The Role of Interdisciplinary Connections in the Development of Environmental Education», International Scientific Journal Science and Life of Kazakhstan, № 12/9(155), 2020, pp. 243-246.

2. Rakhmetova M. (2022). Development of Students' Environmental Knowledge Based on the Integration of Physics and Biology Lessons. Scientific Journal of Pedagogy and Economics, (4), 141-155.

3. Rakhmetova M.T., Abykanova B.T., Chorukh A. (2023). Opportunities for Enhancing Students' Ecological Competence in the Secondary School Physics Course. Bulletin of Yasawi University, 3(129), pp. 295–307. https://doi.org/10.47526/2023-3/2664-0686.22

4. Rakhmetova M., Abykanova B., Kairjan M., Kuanysheva A.A. From Environmental Education to Eco-Identity: A Model for the Development of Environmental Competencies in Physics Students. Bulletin of Khalel Dosmukhamedov Atyrau University, 2026; 80(1):242–255. https://doi.org/10.47649/vau.26.v80.i1.21

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. **Other Publications:** Research results have also been published in domestic and foreign editions: Kaz Project Centre (Atyrau, 2020), Sciencia Scripts (Moldova, 2022).

1.Rakhmetova M.T., Imashev G. «Investigation of Innovative Approaches to the Development of Environmental Education in the Process of Teaching Physics in High School», EXORTIUM International Scientific-Methodological Journal, pp. 26-34, No. 1, January–March, 2021.

2. Rakhmetova M.T., Imashev G. «The Development of Ecological Knowledge and Skills in Teaching Physics Courses», Monograph, Atyrau: Kaz Project Publishing House, 2020, 132 p.

3. Ways to improve the environmental competence of future teachers, Uluslararası 19 Mayıs Yenilikçi Bilimsel Yaklaşımlar Kongresi, 23–24 November 2022, Samsun, Congress Proceedings, ISBN: 978-625-6380-89-9.

4. Rakhmetova M.T., Imashev G. Environmental Physics. Teaching manual. ISBN: 978-620-5-06391-0. Sciencia Scripts, Moldova, 2022.

5. Rakhmetova M.T. Elective Course «Ecology and Energy». Almaty: Kazakh University, 2022. Proceedings of the International Conference of Students and Young Scientists «Farabi World», 2022, p. 404.

**Scope and structure of the dissertation:** The dissertation consists of normative references, definitions, designations and abbreviations, introduction, three chapters, conclusion, list of references, and appendices. The work includes 30 tables, 20 figures, and 239 sources, with a total volume of 186 pages.