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Competence-Based Educational Cluster Model for Developing Future Physics Teachers toward Quality Education to support Sustainable Development Goals (SDGs)

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ABSTRACT

This study aims to design a competence-based educational cluster model that enhances the professional development of future physics teachers. The research employs analytical and comparative methods to examine international practices and national policies on teacher education. Results indicate that cluster-based collaboration strengthens innovation, improves teacher readiness, and aligns educational standards with sustainable development principles. This integration is significant because it promotes the continuous growth of professional competence and connects education with labor market needs. The model reflects the principles of SDG 4 on quality education by fostering inclusive and equitable learning environments. The study concludes that educational clusters offer a sustainable pathway for improving teacher competence, promoting lifelong learning, and enhancing global academic cooperation.

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1. INTRODUCTION

Education in the 21st century is important. Many reports regarding this matter have been well-documented (Mohammed, 2023; Ibrahim et al., 2024; Gatta et al., 2023; Pablo et al., 2022; Hassan & Abdulkareem, 2023; Bantilan, 2024). In general, it requires systemic innovation that integrates competency-based learning with institutional collaboration (Al-Obaidi, 2026; Xamidullaeva & Fayzievna, 2023; Glushchenko, 2025). Within this framework, the educational cluster model has emerged as a key mechanism for linking teacher education, research institutions, and community organizations to strengthen quality education and sustainable development. A cluster approach provides a structure in which universities, schools, and research centers cooperate to train highly competent teachers through shared resources, joint curricula, and professional partnerships.

The concept of competence-based education emphasizes measurable learning outcomes that reflect both theoretical knowledge and practical application (Xamidullaeva & Fayzievna, 2023; Khamidullaevna & Muhabbat, 2024; Rizomatovich, 2026; Latifah et al., 2025; Alordiah et al., 2024). It supports the creation of a teacher who is not only skilled in the subject matter but also capable of creative thinking, collaboration, and self-development. Such competence includes scientific understanding, social responsibility, and the ability to adapt to innovative teaching environments. This approach aligns with the international movement toward the Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education, which aims to ensure inclusive and equitable education for all. Detailed information regarding SDGs is reported elsewhere (Ragadhita et al., 2026; Elfert, 2019; Rad et al., 2022; Edwards Jr et al., 2024; Abera, 2023; Giangrande et al., 2019; Kenny et al., 2023).

In Uzbekistan and Korea, the development of professional teacher competence through cluster-based collaboration has become an essential educational strategy. The integration of local and international practices, such as Germany's competence models and Russia's Atlas of New Professions, highlights the relevance of global frameworks in preparing future educators for rapidly changing educational and technological contexts. The educational cluster is thus not only a structural innovation but also a transformative pathway that connects institutional excellence with societal progress.

Based on previous studies (Khudiyberdiyeva, 2023; Khudoyberdiyeva & Tursunov, 2024), the current study focuses on the methodology of competence development for future physics teachers within the educational cluster framework. Its novelty lies in linking professional competence formation to sustainable educational strategies, emphasizing collaborative learning and lifelong professional growth. The purpose of this research is to design a competence-based educational cluster model that contributes to teacher excellence, innovation in education, and the realization of SDGs.

2. METHODS

Figure 1 illustrates the conceptual framework of the research methodology, which integrates analytical, comparative, and descriptive approaches to examine the development of professional competence among future physics teachers within the educational cluster. Examples of the experimental method for this matter are explained elsewhere (Susilawati et al., 2025). The figure presents the relationship between theoretical foundations, competence dimensions, and the implementation structure of the cluster-based model.

The research is grounded in the methodological principles of competence-based education, pedagogical integration, and sustainable development. The study adopts a

qualitative analytical design supported by document analysis and comparative review of educational systems. Scientific literature from Uzbekistan, Korea, Germany, and Russia was examined to identify effective mechanisms for competence formation and cluster implementation.

The first stage involved theoretical analysis of pedagogical and psychological sources that define the concept and structure of professional competence. This included work on the assessment of teacher competence and the professional maturity of educators. The second stage consisted of a comparative evaluation of international models, such as Germany's classification of 350 competence areas and Russia's Atlas of New Professions in 2021, to adapt them to the context of teacher education.

In the third stage, an expert review was conducted among pedagogical specialists and cluster coordinators to validate the proposed model. This process emphasized integration between subject knowledge, methodological competence, and social skills. Data were interpreted qualitatively to determine the essential components of the competence-based cluster system.

Finally, the model development phase synthesized findings from all stages to construct a structured framework for professional competence enhancement in educational clusters. The methodological emphasis was on connecting theory to practice, promoting teacher creativity, and aligning educational processes with the Sustainable Development Goals. This approach supports innovation in physics teacher training because it creates a sustainable model that unites knowledge acquisition, ethical responsibility, and pedagogical transformation within a collaborative educational ecosystem.

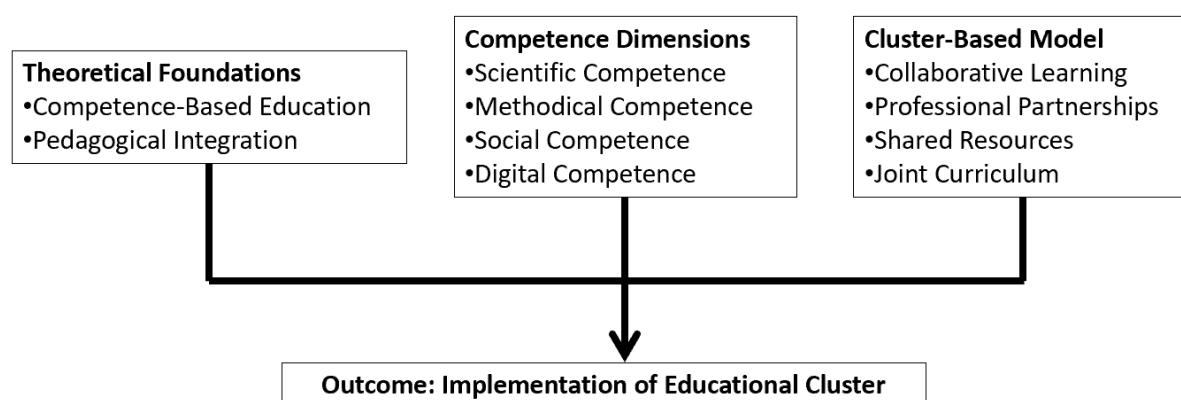


Figure 1. Conceptual framework of competence-based educational cluster methodology.

3. RESULTS AND DISCUSSION

As shown in **Figure 1**, the structure of professional competence development for future teachers is within the educational cluster model. Many reports regarding this matter for future teachers have been well-developed ([Saidirasilovna, 2025](#); [Rizomatovich, 2026](#); [Hasanovna, 2023](#)). There are four competences: Scientific Competence, Methodical Competence, Social Competence, and Digital Competence. They have an interrelation that collectively forms the foundation of professional readiness.

The results reveal that competence formation in educational clusters occurs through the integration of multiple dimensions of learning (academic, practical, and social). The analysis of international and national practices demonstrated that the cluster model enhances innovation, collaboration, and sustainability in teacher education. By combining the strengths

of universities, schools, and research centers, this approach creates a dynamic educational environment that supports continuous professional growth.

One of the key findings concerns the interdependence between professional competence and sustainable education. The cluster model allows teachers to apply their knowledge across disciplines, thereby fostering critical thinking, scientific reasoning, and pedagogical creativity. This multidimensional approach ensures that future physics teachers are not only well-versed in theoretical concepts but also capable of practical problem-solving and classroom innovation. Such integration reflects the principles of SDG 4 (Quality Education) and SDG 9 (Industry, Innovation, and Infrastructure) because it links education with technological advancement and professional relevance.

The study also identifies five essential competence domains that should be developed in teacher education programs, aligning with the Council of Europe's framework:

- (i) Social and political competence, emphasizing responsibility, cooperative decision-making, and conflict resolution.
- (ii) Intercultural competence, ensuring tolerance and the ability to work within diverse linguistic and cultural settings.
- (iii) Communication competence, involving proficiency in oral and written interaction and multilingual communication.
- (iv) Information and technological competence, focusing on the use of multimedia tools, critical media analysis, and digital pedagogy.
- (v) Lifelong learning competence, reinforcing the ability for self-directed growth and adaptation to innovation.

We also found the relationship between competence types and the expected outcomes of teacher education in the cluster system. It reflects how general scientific, socio-economic, and pedagogical competencies interact to create a unified framework for professional excellence.

Discussion of the research findings emphasizes that the competence-based educational cluster serves as a holistic mechanism for connecting academic content with social and industrial demands. The results confirm that professional competence is developed more effectively when supported by networked learning environments, interdisciplinary collaboration, and technology integration.

Another significant result involves the adaptation of competence frameworks to the emerging realities of education. The inclusion of roles such as online learning coordinators, educational trajectory developers, and digital tutors (as predicted in Russia's Atlas of New Professions) demonstrates that teacher education must prepare professionals for evolving contexts. These roles require not only pedagogical knowledge but also strong social, digital, and reflective skills.

Furthermore, the findings highlight that cluster-based teacher preparation aligns educational institutions with societal and economic systems, thereby contributing to sustainable human resource development. Educational clusters encourage active cooperation between the academic community and local organizations, enabling graduates to participate effectively in the labor market. This dynamic relationship supports the goals of lifelong learning and educational innovation (Adeoye, 2022).

In the context of physics education, the cluster model encourages students to master not only theoretical aspects of the discipline but also experimental and technological competencies necessary for modern pedagogy. The process of forming professional competence is strengthened because it connects scientific content with ethical and social values, thus ensuring the holistic development of the teacher.

Finally, the discussion confirms that competence development in an educational cluster results in teachers who are adaptive, innovative, and responsible for societal progress. This outcome reinforces the vision of education as a transformative tool for achieving sustainability. The model demonstrates that the integration of academic, technological, and moral competencies in teacher education leads to the creation of a professional community committed to lifelong learning and continuous improvement. This study adds new information regarding physics education, as reported elsewhere (Ibrahim, 2023; Al Husaeni, 2022).

4. CONCLUSION

The study concludes that the competence-based educational cluster model provides an effective framework for developing the professional competence of future physics teachers. The results confirm that collaboration among universities, schools, and research centers supports the integration of scientific, methodological, and social dimensions of teacher training. This approach ensures that education aligns with labor market demands and advances sustainable learning practices.

The findings demonstrate that competence development becomes more meaningful when connected with the goals of sustainable development, particularly SDG 4 (Quality Education). The educational cluster enhances teacher adaptability, creativity, and responsibility because it combines theory with practice and fosters innovation in pedagogical environments. Therefore, the proposed model contributes to the modernization of teacher education, ensuring that graduates are capable of lifelong learning, ethical decision-making, and constructive participation in the global educational ecosystem.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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