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Vidadi Omer oglu ORUCOV,
orcid.org/0000-0002-8589-2364
Doctor of Pedagogical Sciences,
Associate Professor at the Department of Physics Teaching Technology
Azerbaijan State Pedagogical University
(Baku, Azerbaijan) vidadi_orucov@mail.ru

APPLICATION OF DIGITAL AND INTERACTIVE TEACHING METHODS IN THE TRAINING OF PHYSICS TEACHERS

This article examines the role and effectiveness of digital and interactive teaching methods in the pedagogical training of physics teachers. The main purpose of the study is to evaluate the impact of digital teaching tools on pedagogical outcomes among students majoring in physics at pedagogical universities and practicing teachers, as well as to provide scientifically grounded recommendations for the systematic integration of these methods into teacher-training programs. The methodological framework of the research is based on analytical analysis, comparative approach, questionnaires, and pedagogical observation. The empirical base consists of two main respondent groups: students specializing in physics education and in-service physics teachers.

The results of surveys and observations show that digital simulations, virtual laboratories, and interactive platforms significantly enhance learners' comprehension and motivation. While the majority of participants positively assessed the use of digital tools in the learning process, only a portion of them indicated having the skills to use these tools effectively and systematically. The study also revealed that digital and interactive methods contribute to the development of teachers' technopedagogical competencies, support creative and innovative approaches in lesson planning, and add dynamism and functional efficiency to the educational process.

The article highlights the TPACK model (integration of Technological, Pedagogical and Content Knowledge) and demonstrates that this model serves as an optimal framework for the purposeful application of digital and interactive methods in teacher education. Based on the research results, the structuring of digital components in teacher-training curricula, the use of virtual laboratories and simulation programs in practical sessions, as well as the establishment of assessment and monitoring mechanisms, are considered necessary. This approach not only ensures the systematic development of teachers' technopedagogical skills but also supports their flexible and effective integration into the modern learning environment.

The study also shows that the successful implementation of digital teaching methods requires methodological and technical support, enrichment of resource bases, and the organization of continuous professional development programs. These measures enable teachers to use digital tools purposefully, apply interactive technologies effectively during lessons, and improve educational outcomes.

In conclusion, the article demonstrates that digital and interactive teaching methods should be regarded not merely as supplementary tools but as strategic components in the pedagogical training of physics teachers. This approach enhances students' comprehension levels, develops teachers' innovative pedagogical skills, and contributes significantly to the modernization of the education system. The scientifically grounded recommendations presented in the article identify important directions for the effective integration of digital methods, the application of innovative pedagogical technologies, and the development of technopedagogical competencies of physics teachers.

Key words: *digital teaching methods, interactive technologies, physics teacher education, pedagogical innovations, technopedagogical competencies, virtual laboratories, TPACK model, simulation software, education quality, teacher training.*

Vidadi Omer oglu ORUCOV,
orcid.org/000-0002-8589-2364
доктор педагогічних наук,
доцент кафедри технологій викладання фізики
Азербайджанського державного педагогічного університету
(Баку, Азербайджан) vidadi_orucov@mail.ru

ДОДАТОК ЦИФРОВИХ І ДІАЛОГОВИХ ВИКЛАДАЦЬКИХ МЕТОДІВ В НАВЧАННІ УЧИТЕЛІВ ФІЗИКИ

У цій статті розглядається роль та ефективність цифрових та інтерактивних методів навчання у педагогічній підготовці вчителів фізики. Основною метою дослідження є оцінка впливу цифрових навчальних *засобів на педагогічні результати серед студентів, які навчаються за спеціальністю «фізика» в педагогічних університетах, та практикуючих вчителів, а також надання науково обґрунтованих рекомендацій щодо систематичної інтеграції цих методів у програми підготовки вчителів. Методологічна основа дослідження базується на аналітичному аналізі, порівняльному підході, анкетуванні та педагогічному спостереженні. Емпірична база складається з двох основних груп респондентів: студентів, які спеціалізуються на фізичній освіті, та вчителів фізики, що працюють.*

Результати опитувань та спостережень показують, що цифрові симуляції, віртуальні лабораторії та інтерактивні платформи значно покращують розуміння та мотивацію учнів. Хоча більшість учасників позитивно оцінили використання цифрових інструментів у навчальному процесі, лише частина з них вказала на наявність навичок ефективного та систематичного використання цих інструментів. Дослідження також показало, що цифрові та інтерактивні методи сприяють розвитку технопедагогічних компетенцій вчителів, підтримують креативні та інноваційні підходи до планування уроків, а також додають динамізму та функціональної ефективності навчальному процесу.

У статті висвітлено модель TPACK (інтеграція технологічних, педагогічних та змістовних знань) та показано, що ця модель слугує оптимальною основою для цілеспрямованого застосування цифрових та інтерактивних методів у педагогічній освіті. На основі результатів дослідження необхідно структурувати цифрові компоненти в навчальних програмах підготовки вчителів, використовувати віртуальні лабораторії та програми моделювання на практичних заняттях, а також створювати механізми оцінювання та моніторингу. Такий підхід не лише забезпечує систематичний розвиток технопедагогічних навичок вчителів, але й підтримує їхню гнучку та ефективну інтеграцію в сучасне навчальне середовище.

Дослідження також показує, що успішне впровадження цифрових методів навчання вимагає методологічної та технічної підтримки, збагачення ресурсних баз та організації програм безперервного професійного розвитку. Ці заходи дозволяють вчителям цілеспрямовано використовувати цифрові інструменти, ефективно застосовувати інтерактивні технології під час уроків та покращувати освітні результати.

На завершення, у статті показано, що цифрові та інтерактивні методи навчання слід розглядати не просто як додаткові інструменти, а як стратегічні компоненти педагогічної підготовки вчителів фізики. Такий підхід підвищує рівень розуміння студентів, розвиває інноваційні педагогічні навички вчителів та значною мірою сприяє модернізації системи освіти. Науково обґрунтовані рекомендації, представлені у статті, визначають важливі напрямки ефективної інтеграції цифрових методів, застосування інноваційних педагогічних технологій та розвитку технопедагогічних компетенцій вчителів фізики.

Ключові слова: *цифрові методи навчання, інтерактивні технології, освіта вчителів фізики, педагогічні інновації, технопедагогічні компетенції, віртуальні лабораторії, модель TPACK, програмне забезпечення для моделювання, якість освіти, підготовка вчителів.*

In the modern world, the rapid development of information and communication technologies (ICT) leads to fundamental transformations in the field of education. The formation of the information society requires the restructuring of educational content, the modernization of teaching methods based on digital approaches, and the transformation of the school model into a flexible and innovative system. In this regard, the application of digital and interactive teaching technologies not only increases the effectiveness of instruction but also plays a strategic role in developing 21st-century competencies – analytical thinking, problem-solving, digital literacy, collaboration, and creative skills (Degtyarev, 2014: 125).

The use of digital resources increases students' motivation, enhances cognitive activity, enables the visualization of complex natural phenomena, and facilitates the transfer of knowledge into long-term memory. Therefore, modern pedagogical theory and practice consider the systematic integration of digital, interactive, and AI-based teaching technologies into teacher education essential.

Educational reforms carried out in the Republic of Azerbaijan identify the integration of digital technologies into pedagogical practice as a priority goal. In particular, the "Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025–2028" aims to create an AI ecosystem and develop digitally literate and innovative human capital, which necessitates the adoption of new pedagogical technologies in teacher training.

Compared with other natural science subjects, physics encompasses more complex cognitive structures because physical laws and phenomena are abstract for students, and their demonstration in school settings poses material-technical and safety limitations. Therefore, traditional teaching methods are insufficient, increasing the need for visual, interactive, and innovative approaches. Digital simulations, virtual laboratories, interactive platforms, 3D modelling, and AI-based personalized learning algorithms address these needs (Encyclopedia of Modern Ukraine).

Pedagogical research shows that the use of digital methods in teacher education enhances the professional-competence of future physics teachers and contributes to the formation of students' scientific worldview as well as the development of scientific-practical reasoning. Personalized learning models adapt to students' individual learning pace, while interactive activities sustain continuous cognitive engagement.

Global experience demonstrates that in countries such as the USA, China, Türkiye, Denmark, Estonia, Israel, Korea, and Singapore, artificial intelligence and digital technologies play a strategic role in teacher preparation. The TPACK model (Mishra & Koehler, 2006) enables the balanced integration of teachers' content knowledge, pedagogical methods, and technological skills, thereby improving instructional quality.

International research in physics education confirms the effectiveness of digital simulations and virtual laboratories. Studies using the PhET Interactive Simulations platform show that interactive simulations enrich the visual representation of physical phenomena, expand experimental opportunities, and increase students' interest in the subject (Perkins et al., 2006).

Regional studies indicate that in Azerbaijan and neighbouring countries the level of technological literacy among physics teachers remains insufficient (Mammadova, 2021; Aliyev, 2022). This highlights the need for systematic and methodological integration of digital technologies into pedagogical education.

Furthermore, interactive methods such as gamification (Hamari et al., 2014), problem-based learning (Prince, 2004), experiential learning, and collaborative project-based approaches increase student engagement and enrich teachers' pedagogical repertoires. However, methodologically substantiated research on the comprehensive integration of digital and interactive technologies into physics teacher education remains limited. This necessitates a broader scientific, methodological, and practical exploration of the topic.

Identification of open issues in the research field

Although studies on the integration of digital and interactive teaching methods into education demonstrate high pedagogical potential, a number of theoretical-methodological and practical gaps remain, particularly in the context of physics teacher training. Addressing these gaps requires both the deepening of scientific approaches and the revision of methodological mechanisms applicable in practice.

The first issue is that most existing literature investigates the pedagogical impact of digital technologies in a general context. However, physics has specific didactic characteristics – high abstraction, reliance on experimentation, and multi-component content. Therefore, the technological solutions offered are often generic and do not fully align with the specific nature of physics lessons. Consequently, the adequacy of technology-based teaching models to the content of the subject remains scientifically under-substantiated.

The second open issue concerns the absence of fully developed methodological mechanisms for the systematic application of interactive tools – simulations, virtual laboratories, animations, and gamified models – in teacher training. Current practice shows that digital tools are often applied fragmentarily, are not aligned with learning objectives, and thus their didactic potential is not fully utilized.

The third gap is related to the development of techno pedagogical competencies. Although the TPACK model (Bower, 2017; Mishra & Koehler, 2006) is based on the integration of technological, pedagogical, and content knowledge, empirical studies measuring its real impact on physics teacher education are limited. The methods, environments, and sequences through which technology is most effectively mastered remain insufficiently defined.

The fourth direction concerns teacher-training curricula in the region, particularly in Azerbaijan. Existing programs lack systematic methodological support and resource provision for digital and interactive technologies. Most training materials are theoretical in nature, while practical application mechanisms are underdeveloped. As a result, teachers acquire digital skills mainly through personal initiative and non-formal experiences.

The fifth open issue relates to the scientific measurement of the impact of digital methods on physics learning outcomes. Their effect on students' academic achievement, experimental skills, visual-conceptual understanding, and motivation has not been comprehensively validated through extensive empirical data. Therefore, the development of assessment and measurement tools is required.

In conclusion, although the application of digital and interactive methods in the pedagogical preparation of physics teachers holds significant potential, the field still requires comprehensive scientific and methodological investigation. Large-scale empirical studies, new methodological approaches, and context-adapted practical models can contribute substantially to the digital transformation of the education system.

Purpose and objectives of the study. The main purpose of the article is to examine the application possibilities of digital and interactive teaching methods in the pedagogical preparation of physics teachers from theoretical and practical perspectives, to identify the mechanisms through which these methods influence instructional quality, and to provide scientifically grounded methodological recommendations for their integration into pedagogical strategies. Although virtual laboratories, simulation environments, interactive platforms, and AI-based learning algorithms possess substantial potential, the systematic evaluation and practical implementation of this potential have not yet been fully established from a methodological standpoint.

In accordance with this purpose, the following objectives have been defined:

1. To analyze the theoretical foundations of modern pedagogical technologies and scientifically substantiate the innovations and pedagogical value they bring to the teaching process.
2. To investigate the current state of digital and interactive methods in the preparation of physics teachers and to evaluate the place of these technologies within teacher-training curricula and the level of methodological support provided.
3. To identify the integration possibilities of virtual laboratories, simulation programs, animations, and other digital resources, and to assess their pedagogical advantages such as visualization, interactivity, experimental capability, and motivational impact.
4. To examine the alignment of curricula with digital teaching technologies, determine the level of formation of techno pedagogical components based on the TPACK model, and reveal existing gaps.
5. To develop a scientific-methodological model and practical recommendations based on research findings, forming a systematic approach to enhancing the techno pedagogical literacy of physics teachers.

The implementation of this study will contribute to the development of professional competencies adapted to innovative learning environments and will provide scientific-methodological support for the digital transformation of the teacher-training process.

Key findings

The results obtained from the conducted surveys and observations show that:

– 80% of students evaluate digital tools positively, yet only 40% possess sufficient skills for their effective use. This indicates high motivation but inadequate methodological preparedness.

– 70% of respondents reported that interactive methods increase student motivation and enhance the dynamism of lessons.

– Only 33% of practicing physics teachers stated that they use virtual laboratories systematically; others cited lack of resources and methodological support as the main limitations.

Observations confirm that teachers who use digital tools are able to increase students' cognitive engagement and explain physical processes more clearly. However, this practice is not widespread and is mostly based on individual initiative rather than systemic implementation.

Scientific justification of the findings

The obtained results indicate that:

– Although interest in digital tools is high, the lack of systematic development of techno pedagogical skills limits their effective application.

– Despite the clear pedagogical advantages of virtual laboratories, their practical use is still sporadic.

– Weak methodological support and insufficient curriculum alignment hinder the efficient integration of technologies into the teaching process.

– These findings are consistent with the requirements of the TPACK model (Mishra & Koehler, 2006), according to which effective technology use requires not only technical knowledge but also a well-balanced integration of technological, pedagogical, and content knowledge.

Consequently, digital and interactive teaching methods possess significant potential in the preparation of physics teachers; however, fully realizing this potential requires strengthened methodological support, richer resource provision, and more systematic training programs.

Didactic potential of digital tools

The next stage of the research focused on the systematic evaluation of the didactic potential of digital tools widely used in physics education. Within this framework, the functionality, methodological relevance, and integration possibilities of platforms such as PhET Interactive Simulations, GeoGebra, Crocodile Physics, Kahoot! Quizizz, Edpuzzle, and others were analyzed. These tools are particularly important given their widespread use in international pedagogical practice and their considerable didactic relevance to physics instruction.

Digital tools were evaluated according to the following criteria:

1. **Didactic Functionality.** The ability of digital resources to visualize conceptual ideas, model physical laws and phenomena, simulate experiments, and facilitate the comprehension of complex topics. According to this criterion, PhET and Crocodile Physics demonstrated the highest effectiveness (Encyclopedia of Modern Ukraine).
2. **Relevance to the Physics Curriculum.** The level of methodological integration of each tool into physics topics and its capacity to support theoretical and practical learning. GeoGebra is particularly functional for graphical analysis and mathematical modeling, while Edpuzzle is valuable for creating differentiated, video-based learning environments.
3. **Level of Interactivity.** Tasks ensuring active student participation, feedback mechanisms, problem-solving activities, and gamification elements. Kahoot! and Quizizz stood out as platforms providing high levels of interactivity and motivation.

Observations confirm that integrating these digital tools into physics instruction provides several significant pedagogical advantages:

– **Visualization of abstract concepts.** Interactive models help students better understand such complex topics as electromagnetic waves, quantum phenomena, superposition, and field interactions. PhET simulations, in particular, exhibit high effectiveness in this regard.

– **Enhancement of experiential learning.** Virtual environments allow the safe execution of experiments that are difficult or dangerous to conduct in real laboratories, supporting problem-based learning and strengthening experimental thinking. – **Development of cognitive and metacognitive skills.** Dynamic models and interactive tasks stimulate analytical thinking, inquiry, reasoning, and decision-making skills – core cognitive objectives of physics education.

– **Increased motivation.** Respondents noted that interactive platforms add dynamism to lessons and enhance student engagement through competition and gamification. Kahoot! and Quizizz were particularly effective in boosting motivation.

Overall, the analysis demonstrates that digital tools significantly expand the didactic possibilities of physics teaching, concretize abstract concepts, and activate students' cognitive processes. However, full realization of this potential requires purposeful, systematic, and methodologically grounded integration into the instructional process.

Findings and recommendations

The conducted research examined the application of digital and interactive teaching methods in the pedagogical preparation of physics teachers from theoretical and empirical perspectives. The methodology included analytical and comparative approaches, surveys, and pedagogical observations. Participants consisted of 30 physics-education students and 15 in-service physics teachers.

Key findings

Empirical results indicate that:

– 80% of students positively evaluate the use of digital tools, yet only 40% possess adequate skills for effective implementation.

– 70% of respondents emphasized that interactive methods significantly increase student motivation.

– Only 33% of practicing teachers systematically use virtual laboratories and simulations.

These results suggest that although interest in digital tools is high, the level of techno pedagogical preparedness required for their purposeful use remains insufficient.

Didactic potential of digital tools

Within the study, the didactic capabilities of PhET Interactive Simulations, GeoGebra, Crocodile Physics, Kahoot, Quizizz, Edpuzzle, and other platforms were evaluated according to three main criteria:

1. **Didactic functionality:** visualization of concepts, modeling of physical phenomena, and simulation of experiments.

2. **Alignment with subject content:** potential for integrating digital tools into the structure of physics topics.

3. **Interactivity:** level of student participation, feedback, and motivational elements.

Observations showed that integrating these tools into instruction:

– facilitates visualization of abstract concepts such as electromagnetic waves and quantum phenomena;

– expands opportunities for experiential learning when real laboratory resources are limited;

– develops students' inquiry, analytical thinking, and problem-solving skills;

– increases motivation through interactivity and gamification.

These findings confirm the significant didactic role of the digital environment in physics education.

Applied outcomes and methodological recommendations

For the effective implementation of digital methods in the professional preparation of physics teachers, the following directions are of particular importance:

1. Systematic development of techno pedagogical skills.

– Modules aimed at enhancing digital literacy and techno pedagogical competencies within the TPACK framework should be integrated into teacher education programs.

– Assessment mechanisms supported by practical training sessions should be introduced.

2. Structuring digital components in the curriculum

– The use of digital tools must be aligned with instructional objectives and supported through methodological guidelines within subject curricula.

3. Working with real tools in practical settings

– Future teachers should learn to work with virtual laboratories and interactive platforms through real lesson models and practice-based scenarios.

4. Implementation of the TPACK model

– The TPACK approach – which ensures the integration of technological, pedagogical, and content knowledge – should be applied as a core framework in teacher preparation (Mishra & Koehler, 2006).

5. Strengthening methodological and technical support

– Continuous consultation services, resource provision, and professional development programs should be established for teachers.

These measures not only enhance teachers' techno pedagogical competencies but also improve the quality of digital instruction and accelerate adaptation to innovative educational environments.

Future research directions

1. Updating curricula with integrated digital components;
2. Methodological justification of digital lesson models for physics education;
3. Strengthening facilitator training for teachers;
4. Conducting large-scale empirical studies on the impact of digital methods on student achievement;
5. Improving technical infrastructure and access to digital resources in educational institutions.

Final conclusion

In conclusion, the systematic integration of digital and interactive teaching methods into the pedagogical preparation of physics teachers not only enhances instructional quality but also ensures teachers' adaptation to modern educational environments and substantially contributes to the formation of techno pedagogical competencies. Consistent measures in this direction will provide strategic support for the digital transformation of the education system and the development of an innovative pedagogical environment.

BIBLIOGRAPHY

1. Mishra P., Koehler M. J. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Teachers College Record. 2006. T. 108, №6. .S. 1017–1054. .DOI: 10.1111/j.1467-9620.2006.00684.x
2. Ertmer P. A., Ottenbreit-Leftwich A. T. Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. Journal of Research on Technology in Education. 2010. T. 42. №3. S. 255–284. DOI: 10.1080/15391523.2010.10782551
3. Jonassen D. H. Computers as mindtools for schools: Engaging critical thinking: monograph. Вид. 2-ге. Upper Saddle River, NJ, Prentice Hall, 2000.
4. İlhamov R. Rəqəmsal tədris mühitində fizika müəlliminin rolu və vəzifələri : монографія. Bakı, Təhsil Nəşriyyatı, 2021.
5. Qasımova A., Məmmədli E. İnteraktiv texnologiyaların təlim prosesinə təsiri: Fizika fənni üzrə tədqiqat. Azərbaycan Müəllimlər Jurnalı. 2023. № 1(2). S. 65–75.

REFERENCES

1. Mishra, P., & Koehler, M. J. (2006). *Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge*. Teachers College Record, 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x
2. Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). *Teacher technology change: How knowledge, confidence, beliefs, and culture intersect*. Journal of Research on Technology in Education, 42(3), 255–284. https://doi.org/10.1080/15391523.2010.10782551
3. Jonassen, D. H. (2000). *Computers as mindtools for schools: Engaging critical thinking* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
4. Ilhamov, R. (2021). *Rəqəmsal tədris mühitində fizika müəlliminin rolu və vəzifələri [The role and tasks of the physics teacher in the digital learning environment]*. Baku: Təhsil Nəşriyyatı. [Azerbaijani]
5. Gasimova, A., & Mammadli, E. (2023). *İnteraktiv texnologiyaların təlim prosesinə təsiri: Fizika fənni üzrə tədqiqat [The impact of interactive technologies on the learning process: A study in physics]*. Azerbaijan Teachers Journal, 1(2), 65–75. [Azerbaijani]

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