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Original Article

Desarrollo de competencias innovadoras entre futuros especialistas en cultura física y deportes a través de la formación digital y orientada a STEAM

Innovative competence development among future physical culture and sports specialists through digital and STEAM-oriented training

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Resumen

El desarrollo de la competencia innovadora entre los futuros especialistas en cultura física y deportes se ha convertido en una prioridad en el contexto de la transformación digital y la modernización de la educación superior. El propósito de este estudio fue evaluar la efectividad de un sistema educativo digital y orientado a STEAM diseñado para fomentar la competencia innovadora en futuros profesionales. Se empleó un diseño de investigación cuasiexperimental con 220 estudiantes de cultura física y deportes, divididos en un grupo experimental (n = 110) y un grupo de control (n = 110). La intervención incluyó la implementación de tecnologías educativas digitales, aprendizaje orientado a STEAM, actividades basadas en proyectos y la creación de un entorno educativo innovador. La competencia innovadora se evaluó según criterios motivacionales, cognitivos y basados en la actividad. Los datos se recopilaron mediante cuestionarios, pruebas, entrevistas, observaciones y análisis del rendimiento académico. La significancia estadística se verificó mediante la prueba χ^2 de Pearson. Los resultados demostraron niveles considerablemente más altos de competencia innovadora entre los estudiantes del grupo experimental. El 58,9 % de los participantes alcanzó un alto nivel de competencia según el criterio motivacional, el 59,9 % según el criterio cognitivo y el 67,9 % según el criterio de actividad, en comparación con el 28,2 %, el 29,2 % y el 29,2 % del grupo de control, respectivamente. La prueba χ^2 de Pearson confirmó diferencias estadísticamente significativas entre los grupos. Los resultados indican que las condiciones pedagógicas propuestas potencian eficazmente la competencia innovadora y apoyan la modernización de la formación profesional de los futuros especialistas en cultura física y deporte.

Palabras clave: Competencia innovadora, futuros especialistas en cultura física y deportes, digitalización, recursos digitales, enfoque STEAM.

Abstract

The development of innovative competence among future specialists in physical culture and sports has become a priority in the context of digital transformation and modernization of higher education. The purpose of this study was to evaluate the effectiveness of a digital and STEAM-oriented educational system designed to foster innovative competence in future professionals. A quasi-experimental research design was employed involving 220 students of physical culture and sports, divided into an experimental group (n = 110) and a control group (n = 110). The intervention included the implementation of digital educational technologies, STEAM-oriented learning, project-based activities, and the creation of an innovative educational environment. Innovative competence was assessed according to motivational, cognitive, and activity-based criteria. Data were collected through questionnaires, testing,

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interviews, observations, and academic performance analysis. Statistical significance was verified using Pearson's χ^2 test. The results demonstrated considerably higher levels of innovative competence among students in the experimental group. High-level competence was achieved by 58.9% of participants according to the motivational criterion, 59.9% according to the cognitive criterion, and 67.9% according to the activity criterion, compared with 28.2%, 29.2%, and 29.2% in the control group, respectively. Pearson's χ^2 test confirmed statistically significant differences between the groups. The findings indicate that the proposed pedagogical conditions effectively enhance innovative competence and support the modernization of professional training for future specialists in physical culture and sports.

Keywords: innovative competence, future specialists in physical culture and sports, digitalization, digital resources, STEAM approach.

Introduction

The rapid digital transformation of contemporary society is substantially changing the requirements for professional training in higher education. Future specialists in physical culture and sports are expected not only to possess advanced disciplinary knowledge and practical skills but also to demonstrate innovative competence, adaptability, creativity, and the ability to effectively apply digital technologies in professional practice. These requirements are reinforced by the increasing integration of digital tools, data-driven decision-making, virtual learning environments, and interdisciplinary educational approaches into physical education and sports training (Jurat et al., 2024).

Recent studies have highlighted the importance of innovative educational practices in developing professional competencies among future physical education specialists. Research has demonstrated the positive effects of competency-based learning, flipped classroom models, active learning strategies, and digital technologies on students' professional development and learning outcomes (Ghorbel et al., 2025; Cáceres & Contreras Mu, 2025). Similarly, studies on adventure education, game-based learning, and immersive technologies have shown their potential to enhance students' engagement, critical thinking, and pedagogical competencies (González-Rivas et al., 2024; Maquera-Maquera et al., 2024). Furthermore, the growing adoption of STEAM-oriented approaches has created new opportunities for integrating interdisciplinary knowledge, creativity, and innovation into professional education.

Despite these advances, existing research primarily focuses on individual instructional methods, digital tools, or specific educational technologies. Much less attention has been devoted to the comprehensive formation of innovative competence as an integrated professional characteristic of future specialists in physical culture and sports. In particular, insufficient evidence exists regarding which pedagogical conditions, educational environments, and instructional mechanisms most effectively contribute to the systematic development of innovative competence within higher education programs.

This gap in the literature reveals an important scientific problem: although innovative competence is increasingly recognized as a key outcome of professional preparation, there remains limited empirical evidence concerning the effectiveness of comprehensive pedagogical systems that combine digital technologies, STEAM-oriented learning, innovative teaching methods, and project-based activities in the training of future specialists in physical culture and sports.

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Accordingly, the study was guided by the following research question:

RQ: To what extent does the implementation of a digital and STEAM-oriented system of pedagogical conditions contribute to the development of innovative competence among future specialists in physical culture and sports compared with traditional educational approaches?

The purpose of this study was to evaluate the effectiveness of a system of pedagogical conditions designed to foster innovative competence among future specialists in physical culture and sports through the integration of digital technologies, STEAM-oriented learning, and innovative educational practices.

The scientific novelty of the study lies in the development and experimental validation of a comprehensive pedagogical system that integrates digital educational technologies, STEAM-oriented learning, project-based activities, and an innovative educational environment for the systematic development of innovative competence among future specialists in physical culture and sports. Unlike previous studies that examined isolated educational innovations, this research evaluates their combined impact within a unified pedagogical framework.

This study contributes to the growing body of research on innovation in higher education by providing empirical evidence regarding effective strategies for developing innovative competence and modernizing professional training in the field of physical culture and sports.

Literature Review

The increasing digitalization of higher education has intensified scholarly interest in innovative approaches to the professional preparation of future specialists in physical culture and sports. Contemporary research consistently demonstrates that educational innovation contributes to the development of professional competencies, learner autonomy, and adaptability in rapidly changing professional environments. However, the concept of innovative competence remains insufficiently theorized and operationalized within the field of physical culture and sports education.

A considerable body of research has examined the effectiveness of active and student-centered learning methodologies. For example, Ghorbel et al. (2025) and Cáceres & Contreras Mu (2025) reported that flipped classroom approaches positively influence students' independence, critical thinking, and professional skills development. González-Rivas et al. (2024) demonstrated the pedagogical value of game-based and adventure-based learning in fostering engagement and competency acquisition. Although these studies provide evidence for the effectiveness of specific instructional strategies, they primarily evaluate isolated pedagogical interventions rather than their contribution to the broader development of innovative competence as an integrated professional characteristic.

Another important research direction concerns the role of digital technologies in professional education. Maquera-Maquera et al. (2024) emphasized the potential of immersive technologies to enrich educational experiences and support competency development. Likewise, Gorozidis et al. (2020) demonstrated that digital collaborative environments can enhance professional learning and knowledge exchange among physical education practitioners. However, the findings also indicate that technological innovation alone does not automatically improve

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educational outcomes. Its effectiveness depends on pedagogically meaningful integration, instructional design, and learner engagement. Consequently, digital competence should be viewed as only one component of a broader innovative competence framework.

Recent studies have increasingly highlighted the importance of interdisciplinary and STEAM-oriented approaches in higher education. According to Leão Pereira et al. (2025), innovative educational practices should promote not only professional knowledge acquisition but also creativity, problem-solving abilities, learner autonomy, and authentic engagement with real-world challenges. This perspective aligns with the growing recognition that innovation competence requires the integration of cognitive, motivational, and behavioral dimensions rather than the mastery of technological tools alone. Nevertheless, empirical investigations rarely examine how these dimensions interact within a unified educational system. Özer et al. (2024) demonstrated the effectiveness of gymnastics activities in improving students' physical development, thereby supporting the integration of innovative, practice-oriented approaches into professional training programs.

The concept of innovative competence itself remains subject to different interpretations in educational research. Existing literature generally associates innovative competence with the ability to generate new ideas, apply creative solutions, adapt to changing professional conditions, effectively use emerging technologies, and engage in continuous professional development. From a competency-based perspective, innovative competence can be understood as an integrated personal and professional quality that combines motivation for innovation, knowledge of innovative practices, and the capacity to implement them in real professional contexts. This multidimensional nature suggests that innovative competence encompasses motivational, cognitive, and activity-related components that function in close interaction.

Despite the growing number of studies addressing innovative teaching methods, digital technologies, and competency-based education, several limitations remain evident. First, most investigations focus on individual educational innovations rather than comprehensive pedagogical systems. Second, the relationship between digitalization, STEAM-oriented learning, and innovative competence development remains insufficiently explored. Third, there is limited empirical evidence regarding the pedagogical conditions that facilitate the systematic formation of innovative competence among future specialists in physical culture and sports.

Therefore, the current literature demonstrates a clear research gap. While previous studies have confirmed the educational value of specific innovative methodologies and technologies, insufficient attention has been paid to the comprehensive development of innovative competence as an integrated outcome of professional training. In particular, there is a lack of empirical research examining the effectiveness of pedagogical systems that combine digital technologies, STEAM-oriented learning, project-based activities, and an innovative educational environment within a unified framework.

Addressing this gap, the present study investigates the effectiveness of a comprehensive system of pedagogical conditions designed to foster innovative competence among future specialists in physical culture and sports. Unlike previous studies that analyzed separate educational innovations, this research evaluates their combined influence on the motivational, cognitive, and activity-related dimensions of innovative competence.

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Methodology

Research Design

This study employed a quasi-experimental research design to evaluate the effectiveness of a system of pedagogical conditions aimed at developing innovative competence among future specialists in physical culture and sports. The research was conducted in three consecutive stages: ascertaining, formative, and evaluative. At the ascertaining stage, the initial levels of innovative competence were identified and compared between groups. During the formative stage, the proposed pedagogical system was implemented in the Experimental Group, while the Control Group continued learning according to traditional educational approaches. At the evaluative stage, repeated measurements were conducted to assess changes in competence levels and determine the effectiveness of the intervention.

Participants

The study involved 220 undergraduate students enrolled in physical culture and sports programmes at higher education institutions. Participants were assigned to an Experimental Group (EG, n = 110) and a Control Group (CG, n = 110). The groups were comparable in terms of educational background and initial levels of innovative competence, which was confirmed during the ascertaining stage of the experiment.

Participation in the study was voluntary. All respondents were informed about the objectives of the research and agreed to participate anonymously. Confidentiality and ethical standards of educational research were strictly maintained throughout the study.

Assessment Framework

Innovative competence was considered an integrated professional characteristic comprising three interrelated dimensions: motivational, cognitive, and activity-based.

The motivational criterion reflected students' interest in innovation, willingness to engage in professional self-development, readiness to implement innovative approaches, and positive attitudes toward educational change.

The cognitive criterion assessed knowledge of innovative educational technologies, digital tools, STEAM-oriented learning approaches, pedagogical innovations, and contemporary professional practices in physical culture and sports.

The activity-based criterion evaluated the ability to apply innovative methods in practical situations, participate in project activities, use digital technologies effectively, solve professional problems creatively, and implement innovative solutions in educational and sports contexts.

Based on the assessment results, participants were classified into three levels of innovative competence formation: high, average, and low.

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Research Instruments

To ensure a comprehensive assessment of innovative competence, multiple data collection methods were employed.

The quantitative component included structured questionnaires and diagnostic surveys designed to evaluate students' motivational orientation toward innovation and their readiness to engage in innovative professional activities. Knowledge tests were used to assess the cognitive dimension of innovative competence.

The qualitative component included pedagogical observations, individual and group interviews, and analyses of students' academic and project-based performance. These methods enabled the researchers to identify behavioural manifestations of innovative competence and obtain additional evidence regarding students' engagement in innovative activities.

The use of methodological triangulation enhanced the credibility of the findings by combining quantitative and qualitative sources of evidence.

Educational Intervention

The formative intervention was based on a comprehensive system of pedagogical conditions designed to foster innovative competence among future specialists in physical culture and sports.

The intervention incorporated the following components:

- Integration of digital educational technologies into the learning process.
- Implementation of STEAM-oriented educational activities.
- Project-based learning focused on authentic professional challenges.
- Interactive learning methods promoting collaboration and critical thinking.
- Interdisciplinary tasks aimed at developing creativity and innovation.
- Creation of an innovative digital educational environment supporting independent and collaborative learning.

Particular attention was devoted to developing students' innovative thinking, professional reflection, creativity, and readiness to use digital resources in future professional practice. The educational activities included digital learning platforms, multimedia resources, online collaboration tools, project assignments, discussions, workshops, and reflective exercises.

Students in the Control Group studied according to the traditional curriculum without the implementation of the proposed pedagogical conditions.

Data Analysis

The collected data were analysed using descriptive and inferential statistical methods. Frequency distributions and percentages were calculated to determine the distribution of respondents across the identified competence levels.

To assess the statistical significance of differences between the Experimental Group and the Control Group, Pearson's chi-square (χ^2) test was applied. The analysis compared the distributions of respondents according to motivational, cognitive, and activity-based criteria at the formative stage of the experiment.

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The motivational criterion revealed statistically significant differences between the groups, $\chi^2(2, N = 220) = 34.33$, $p < .001$, Cramer's $V = .40$.

For the cognitive criterion, the analysis also demonstrated statistically significant differences, $\chi^2(2, N = 220) = 33.16$, $p < .001$, Cramer's $V = .39$.

The strongest differences were identified for the activity-based criterion, $\chi^2(2, N = 220) = 41.05$, $p < .001$, Cramer's $V = .43$.

The obtained effect sizes indicate moderate to relatively strong practical effects, confirming the effectiveness of the implemented pedagogical conditions in developing innovative competence among future specialists in physical culture and sports.

Ethical Considerations

The study was conducted in accordance with the ethical principles governing educational research. Participation was voluntary, and respondents were informed about the purpose and procedures of the study prior to data collection. All data were collected anonymously and processed confidentially. Participants had the right to withdraw from the study at any stage without negative consequences. The research procedures complied with institutional ethical standards for studies involving human participants.

Results and Discussion

Content and necessary innovations in the professional training of physical culture and sports specialists in order to form innovative competence in them.

Contemporary physical culture and sports education is increasingly influenced by digital transformation and the growing demand for innovation in professional practice. Consequently, the training of future specialists requires not only the acquisition of disciplinary knowledge and practical skills but also the development of innovative competence, adaptability, and the ability to effectively use digital technologies (Lin, 2018).

Current research highlights the need to modernize professional training through the integration of innovative teaching methods, digital resources, and technology-enhanced learning environments that stimulate students' cognitive and professional development. The transition from traditional educational models to innovation-oriented approaches necessitates corresponding changes in higher education curricula and instructional practices.

In this context, innovative competence represents an integrated professional characteristic that combines pedagogical thinking, professional orientation, creativity, and the ability to implement innovative solutions in practice. Therefore, the primary objective of professional training is not only to provide students with theoretical knowledge and practical skills but also to foster their readiness for continuous learning, adaptation to changing professional conditions, and application of progressive educational technologies.

The integration of innovative technologies into the educational process promotes personalized learning, supports the differentiation of training, enhances professional thinking, and contributes to the development of competencies required for

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successful professional activity in the field of physical culture and sports (Belmonte et al., 2020).

The main requirements that a modern professional specialist in physical culture and sports must meet. The role of digitalization in the formation of innovative competence of future specialists in physical culture and sports.

The field of Physical Culture and Sports requires the preparation of competitive professionals capable of continuously developing their competencies and adapting to evolving professional demands. From this perspective, professional training should be grounded in a synergistic approach, which emphasizes learner autonomy, creativity, initiative, self-regulation, and active engagement in educational and professional development processes (Mohr & Townsend, 2026).

Accordingly, modern specialists in physical culture and sports are expected to demonstrate professional flexibility, innovative competence, creativity, and the ability to solve complex professional challenges. In this context, digitalization plays a crucial role in competence development, as contemporary educational technologies create new opportunities for communication, collaboration, individualized learning, and professional growth.

The integration of digital technologies into higher education enhances the quality of professional training by supporting competency-based, project-based, adaptive, and lifelong learning approaches. However, the effective use of digital tools depends on students' readiness to develop both digital competence and professional expertise, enabling them to respond successfully to the challenges of modern educational and sports environments (Gorozidis et al., 2020; Longakit et al., 2024).

The most common digital resources and the role of the STEAM approach in the educational process of training future physical education and sports specialists to form innovative competence.

The digitalization of professional training in physical culture and sports involves the use of diverse educational resources, including cloud-based applications, online learning platforms, synchronous and asynchronous communication tools, mobile health and fitness applications, interactive assessment systems, multimedia content creation tools, and digital movement-analysis technologies. These resources expand opportunities for personalized learning, collaboration, self-directed study, and professional skill development.

The effective integration of digital technologies supports students' adaptation to innovation-oriented educational environments and enhances their readiness for professional practice. An important complementary approach is STEAM-oriented learning, which promotes interdisciplinary thinking, creativity, problem-solving, and the application of knowledge in authentic contexts. In physical education and sports training, STEAM education facilitates the integration of scientific knowledge, technology, design, and physical activity, thereby contributing to the development of innovative competence among future specialists. The growing importance of interdisciplinary STEAM approaches in higher education has been emphasized in recent research (Leão Pereira & Lorente-Catalán, 2024).

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Substantiation and experimental verification of the effectiveness of the proposed system and pedagogical conditions for the formation of innovative competence in future specialists in physical education and sports.

In the content of the innovative competence of the future specialist, we invested an integrated quality of personality, characterized by the ability to implement innovative technologies, cultivate creativity, and focus on the individual needs of students, their characteristics, and interests.

The study determined the structure of the innovative competence of students, which consists of components: motivational, professional, and innovative-activity, which are interdependent and interconnected, have a conditional nature, are determined by the specifics, and are formed comprehensively.

Innovations, creativity, and the development of creative thinking characterize the motivational component.

The professional component provides the student's professional sphere of activity in the field of pedagogical innovations, includes basic theoretical knowledge, focuses on the ability to organize their own innovative activities independently, and develops innovative skills.

The innovative-activity component covers creative and creative activities, the ability to make non-standard decisions, demonstrates the possibilities of the future specialist's emotional-volitional work, and forms an individual innovative style.

To assess the level of formation of innovative competence in future specialists, a diagnostic tool was developed, and the following criteria were characterized: motivational, cognitive, and activity.

The levels of formation of innovative competence were characterized as high, average, and low.

During the ascertaining experiment, the generalization of the obtained data according to all criteria allowed us to establish that at this stage of the experiment, no significant differences were established between the experimental and control groups (from 0.2% to 2.2%); a low level of formation of innovative competence was recorded in the vast majority of respondents in the control and experimental groups:

- A low level of formation of innovative competence is observed in the control group (64.6%) and the experimental group (62.6%).
- An average level of formation of innovative competence is observed in the control group (30.7%) and the experimental group (30.5%).
- A high level of development of innovative competence among higher education applicants is observed in the control group (4.7%) and the experimental group (6.9%).

The results of the ascertaining stage of the experiment showed that innovative competence among future specialists in physical culture and sports is insufficiently developed and requires the implementation of the developed system and the theoretically substantiated pedagogical conditions.

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Experimental verification of the effectiveness of the developed system and pedagogical conditions for the formation of innovative competence in future specialists in physical culture and sports.

To foster innovative competence among future specialists in physical culture and sports, a comprehensive pedagogical system was implemented in the Experimental Group. The system was structured around several developmental stages, including motivation, professional training, adaptation, professionalization, and professional mastery, reflecting the progressive formation of professional identity and innovative competence throughout the educational process.

The intervention aimed to develop students' understanding of professional roles and responsibilities, innovative competence, self-improvement strategies, reflective practice, pedagogical creativity, and contemporary sports training technologies. Particular attention was given to strengthening professional orientation and preparing students for innovative activity in educational and sports contexts.

The expected outcomes included improving the quality of professional training, increasing students' innovative competence, enhancing readiness to use modern technologies, fostering innovative thinking, and promoting lifelong professional development.

The pedagogical system was based on four key conditions: the creation of an innovative digital educational environment, the development of readiness for innovative activity, the integration of innovation-oriented content into academic disciplines, and the enhancement of students' motivation for professional innovation. Methodologically, the intervention combined systemic, competence-based, subject-activity, axiological, contextual, and project-based approaches. Project activities played a particularly important role by engaging students in interdisciplinary tasks, problem-solving, communication, and analytical work, thereby promoting critical thinking and innovative competence development.

Innovative teaching practices included the use of digital educational technologies, interactive platforms, virtual simulations, online courses, and multimedia resources. These tools enhanced the flexibility of the learning process, supported individualized learning pathways, and increased students' motivation for independent work. In addition, STEAM-oriented learning emphasized the practical solution of real-world problems through interdisciplinary collaboration, experimentation, and creative inquiry.

The implementation of the pedagogical system also incorporated reflective activities, collaborative learning, discussions, workshops, debates, master classes, and project-based tasks. The formation of innovative competence was evaluated throughout a formative experiment comprising orientation, implementation, and assessment stages, designed to verify the effectiveness of the proposed pedagogical conditions.

Evaluation of the results of the experimental test of the developed system and pedagogical conditions for the formation of innovative competence.

At the formative stage of the experimental study, we conducted, using the same diagnostic methodology as at the ascertaining stage of the experiment, a re-diagnosis of the levels of formation of innovative competence of respondents: questionnaires, testing, analysis of the results of knowledge control, interviews (individual, collective), quantitative and qualitative analysis of the behavior of

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students and their activities, as well as the results of these actions carried out through observation.

In accordance with the developed criteria, indicators, and levels of students' innovative competence formation at the ascertaining stage of the experiment, the data obtained were analyzed. The main task of the formative experiment was to identify changes in the levels of formation of innovative competence and compare the results of respondents in the EG and CG.

The data obtained during the re-diagnosis were statistically analyzed using the Pearson χ^2 test. Data analysis allowed us to track changes in the levels of formation of innovative competence among respondents in higher education, reflecting their advancement.

Table 1.
Results of diagnostics of the levels of formation of innovative competence of respondents by motivational criterion at the formative stage of the experiment

Level	Experimental Group	Control Group
Low	10	45
Average	35	34
High	65	31

Results:

- $\chi^2(2) = 34.33$
- $p < .001$
- *Cramer's V = 0.40*

The results presented in Table 1 indicate substantial differences between the Experimental Group and the Control Group regarding the motivational component of innovative competence. In the Experimental Group, 65 students (58.9%) demonstrated a high level of motivational readiness for innovative activity, whereas only 31 students (28.2%) in the Control Group reached this level. Simultaneously, the proportion of respondents with a low level of motivation was considerably smaller in the Experimental Group (9.1%) than in the Control Group (40.9%).

The Pearson chi-square test revealed statistically significant differences between the groups, $\chi^2(2) = 34.33$, $p < .001$. The obtained effect size (Cramer's V = .40) indicates a moderate-to-large practical effect. These findings suggest that the implemented pedagogical system positively influenced students' motivation toward innovation, professional self-development, and the adoption of digital and STEAM-oriented educational practices.

Table 2.
Results of diagnostics of the levels of formation of innovative competence of respondents by the cognitive criterion at the formative stage of the experiment

Level	Experimental Group	Control Group
Low	*9*	*42*
Average	*35*	*36*
High	*66*	*32*

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Results:

- *$\chi^2(2) = 33.16$*
- *$p < .001$*
- *Cramer's V = 0.39*

The results shown in Table 2 demonstrate significant advantages of the Experimental Group in the cognitive dimension of innovative competence. A high level of cognitive competence was identified in 66 students (59.9%) of the Experimental Group compared with only 32 students (29.2%) in the Control Group. At the same time, the proportion of respondents with a low level of cognitive competence was markedly lower in the Experimental Group (8.3%) than in the Control Group (37.9%).

Statistical analysis confirmed the significance of these differences, $\chi^2(2) = 33.16$, $p < .001$. The effect size was moderate-to-large (Cramer's V = .39), indicating that the intervention had a meaningful impact on students' acquisition of knowledge related to innovative technologies, pedagogical innovations, and digital educational tools. The findings provide evidence that the proposed educational system effectively enhanced the cognitive foundations of innovative competence.

Table 3.
Results of diagnostics of the levels of innovative competence formation of respondents according to the activity criterion at the formative stage of the experiment

Level	Experimental Group	Control Group
Low	*7*	*39*
Average	*28*	*38*
High	*75*	*32*

Results:

- *$\chi^2(2) = 41.05$*
- *$p < .001$*
- *Cramer's V = 0.43*

The activity-based criterion produced the most pronounced differences between the groups. As shown in Table 3, a high level of innovative competence was achieved by 75 students (67.9%) in the Experimental Group, whereas only 32 students (29.2%) in the Control Group demonstrated comparable results. Moreover, the percentage of respondents with a low level of activity-based competence was substantially lower in the Experimental Group (6.5%) than in the Control Group (35.5%).

The Pearson chi-square test confirmed statistically significant differences between the groups, $\chi^2(2) = 41.05$, $p < .001$. The obtained effect size (Cramer's V = .43) represents the strongest effect among all assessed criteria. These results indicate that participation in digital, project-based, and STEAM-oriented activities significantly improved students' ability to apply innovative approaches in practical educational and professional contexts. Consequently, the implemented pedagogical conditions proved particularly effective in developing the behavioral and practical dimensions of innovative competence.

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Pearson's chi-square test revealed statistically significant differences between the Experimental Group and the Control Group across all assessed criteria. For the motivational criterion, the difference was significant, $\chi^2(2, N = 220) = 34.33$, $p < .001$, with a moderate-to-large effect size (Cramer's V = .40). Similar results were obtained for the cognitive criterion, $\chi^2(2, N = 220) = 33.16$, $p < .001$, Cramer's V = .39, and for the activity-based criterion, $\chi^2(2, N = 220) = 41.05$, $p < .001$, Cramer's V = .43. These findings indicate that the implemented pedagogical system had a statistically significant and practically meaningful effect on the development of innovative competence among future specialists in physical culture and sports.

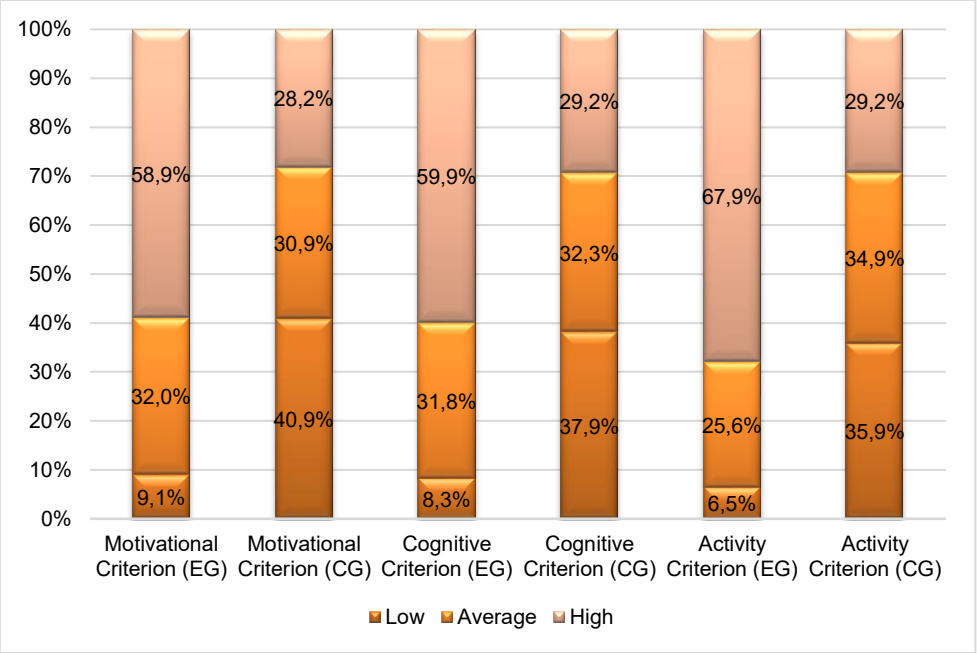

Figure 1. Levels of innovative competence formation among respondents according to motivational, cognitive, and activity criteria at the formative stage of the experiment.

The results demonstrated substantial differences between the Experimental Group (EG) and the Control Group (CG) across all assessed dimensions of innovative competence. According to the motivational criterion, 58.9% of students in the EG achieved a high level compared with 28.2% in the CG, while the proportion of students with a low level was considerably smaller in the EG (9.1%) than in the CG (40.9%). Pearson's chi-square test confirmed the statistical significance of these differences, $\chi^2(2, N = 220) = 34.33$, $p < .001$. The obtained effect size (Cramer's V = .40) indicates a moderate-to-large practical effect.

Similar tendencies were observed for the cognitive criterion. A high level of competence was recorded in 59.9% of EG participants and 29.2% of CG participants, whereas low-level indicators were found in 8.3% and 37.9% of students, respectively. The differences were statistically significant, $\chi^2(2, N = 220) = 33.16$, $p < .001$, with a moderate effect size (Cramer's V = .39).

The strongest differences were identified for the activity-based criterion. High-level competence was demonstrated by 67.9% of students in the EG compared with 29.2% in the CG. At the same time, only 6.5% of students in the EG remained at the low level, compared with 35.5% in the CG. Statistical analysis confirmed a significant

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association between group membership and competence level, $\chi^2(2, N = 220) = 41.05$, $p < .001$. The effect size (Cramer's V = .43) indicates a relatively strong practical impact of the intervention.

Overall, the Pearson χ^2 analyses revealed statistically significant differences between the Experimental and Control Groups across all three criteria. The effect sizes ranged from .39 to .43, suggesting that the observed improvements were not only statistically significant but also educationally meaningful. These findings provide robust empirical support for the effectiveness of the proposed pedagogical system integrating digital technologies, STEAM-oriented learning, project-based activities, and innovation-focused educational practices in fostering innovative competence among future specialists in physical culture and sports.

The findings of this study demonstrate that the implementation of a comprehensive system of pedagogical conditions integrating digital technologies, STEAM-oriented learning, project-based activities, and an innovative educational environment contributed to significantly higher levels of innovative competence among students in the Experimental Group compared with those in the Control Group.

These results are consistent with the findings of Ghorbel et al. (2025) and Cáceres & Contreras Mu (2025), who reported that innovative student-centered approaches, particularly flipped-classroom models, positively influence learners' autonomy, critical thinking, and professional readiness. Similarly, the substantial improvements observed in the Experimental Group support the conclusions of González-Rivas et al. (2024), who demonstrated that active and experiential learning strategies contribute to higher levels of student engagement and competence development in physical education teacher training.

The present study also corroborates previous evidence regarding the educational potential of digital technologies. Maquera-Maquera et al. (2024) emphasized that immersive and technology-enhanced learning environments create favorable conditions for competency development, while Gorozidis et al. (2020) highlighted the role of digital collaborative environments in supporting professional learning and knowledge exchange. However, unlike these studies, which primarily focused on individual technological tools, the present research suggests that digitalization produces stronger educational outcomes when integrated within a broader pedagogical framework combining technological, methodological, and motivational components.

The findings further support the interdisciplinary perspective proposed by Leão Pereira & Lorente-Catalán (2024) and Leão Pereira et al. (2025), who argued that contemporary professional education should promote creativity, problem-solving, learner autonomy, and authentic engagement with real-world challenges. The higher competence levels demonstrated by students in the Experimental Group may be explained by the synergistic interaction of STEAM-oriented learning, project-based activities, and digital educational technologies, which provided multiple opportunities for active participation, interdisciplinary collaboration, and reflective practice.

The observed differences between the Experimental and Control Groups may also be explained by the cumulative effect of the pedagogical conditions implemented during the intervention. While previous studies, such as those conducted by Ghorbel et al. (2025), González-Rivas et al. (2024), and Maquera-Maquera et al. (2024), investigated the impact of individual educational innovations, the present study evaluated their combined implementation within a unified pedagogical system.

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Consequently, students in the Experimental Group benefited simultaneously from digital resources, innovative teaching methods, project-based learning, and STEAM-oriented activities, which may have strengthened both motivational and behavioral dimensions of innovative competence.

Despite these positive outcomes, several methodological limitations should be acknowledged. First, the study was conducted within a specific disciplinary context involving future specialists in physical culture and sports, which may limit the generalizability of the findings to other academic fields. Second, although multiple assessment methods were employed, the measurement of innovative competence relied primarily on diagnostic instruments developed specifically for this study rather than internationally standardized scales. Third, the intervention was evaluated within a single implementation period; therefore, the long-term sustainability of competence development remains unclear. Fourth, the quasi-experimental design did not allow for random assignment of participants, which limits the strength of causal inferences regarding the effectiveness of the pedagogical intervention.

Conclusions

The findings of this study provide empirical evidence that the integration of digital educational technologies, STEAM-oriented learning, project-based activities, and an innovative educational environment contributes significantly to the development of innovative competence among future specialists in physical culture and sports. The implementation of the proposed system of pedagogical conditions resulted in substantially higher levels of innovative competence in the Experimental Group compared with the Control Group across motivational, cognitive, and activity-based dimensions. Statistical analysis confirmed the significance of these differences, demonstrating the effectiveness of the developed educational intervention.

The scientific contribution of the study lies in the conceptualization of innovative competence as a multidimensional construct comprising motivational, cognitive, and activity-based components and in the empirical validation of a comprehensive pedagogical system designed to foster its development. Unlike previous studies that primarily examined isolated educational technologies or teaching methods, this research evaluated the combined influence of digitalization, STEAM-oriented learning, and innovation-focused pedagogical conditions within a unified educational framework.

The results extend current knowledge regarding competency-based professional training in physical culture and sports by demonstrating that innovative competence can be systematically developed through intentionally designed educational environments rather than through the isolated use of technological tools. The findings support contemporary theoretical perspectives emphasizing the importance of integrating digital literacy, interdisciplinary learning, creativity, and active student engagement in higher education.

From a practical perspective, the proposed pedagogical system may be used by higher education institutions to modernize curricula for physical culture and sports programs. The incorporation of digital technologies, interdisciplinary projects, reflective learning activities, and innovation-oriented instructional strategies can enhance students' readiness for professional practice in rapidly changing educational and sports environments.

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Several limitations should be acknowledged. First, the study involved participants from a limited educational context, which may restrict the generalizability of the findings. Second, innovative competence was assessed within the timeframe of a single academic intervention; therefore, long-term effects were not examined. Third, although multiple assessment methods were employed, future studies should further strengthen measurement procedures through the use of standardized and internationally validated instruments.

Future research should investigate the long-term sustainability of innovative competence development, compare the effectiveness of different digital and STEAM-oriented educational models, and examine the influence of individual pedagogical conditions on specific dimensions of innovative competence. Further studies may also explore the applicability of the proposed framework across different academic disciplines and educational contexts.

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