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THEORETICAL AND METHODOLOGICAL FOUNDATIONS FOR IMPROVING INTERDISCIPLINARY INTEGRATION IN PHYSICS EDUCATION

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Abstract

In the context of rapid scientific, technological, and socio-economic development of the twenty-first century, the transformation of educational paradigms has become an inevitable requirement for ensuring the quality and sustainability of learning outcomes. In this regard, interdisciplinary integration is increasingly recognized as a key methodological strategy that enables the formation of holistic scientific thinking, the development of higher-order cognitive skills, and the meaningful transfer of knowledge across disciplinary boundaries. Physics education, due to its fundamental nature and close conceptual connections with mathematics, chemistry, biology, and information technologies, occupies a central position in the implementation of interdisciplinary approaches. This study examines the theoretical and methodological foundations of improving interdisciplinary integration in physics education, with a particular focus on academic lyceums as institutions providing advanced and pre-professional training. The research analyzes contemporary pedagogical theories, methodological models, and experimental practices aimed at enhancing interdisciplinary coherence in physics instruction. The findings demonstrate that interdisciplinary-integrated physics teaching significantly improves students' conceptual understanding, problem-solving abilities, and learning motivation, thereby contributing to the development of scientifically literate and professionally oriented graduates.

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Keywords: Physics education, interdisciplinary integration, academic lyceum, competency-based approach, STEAM education, educational methodology, didactics.

INTRODUCTION

The accelerating pace of scientific and technological progress, combined with the increasing complexity of real-world problems, has fundamentally altered the demands placed upon modern education systems, requiring a shift from fragmented disciplinary instruction toward integrated, competency-oriented learning models [1]. Traditional approaches to physics education, which often emphasize isolated theoretical knowledge and algorithmic problem-solving, have proven insufficient for preparing learners to address interdisciplinary challenges that characterize contemporary scientific and professional practice [2].

Within this context, interdisciplinary integration has emerged as a powerful pedagogical concept that enables learners to perceive scientific knowledge as an interconnected system rather than a collection of discrete facts and formulas. Physics, as a core natural science discipline, provides a conceptual and methodological bridge linking mathematics, chemistry, biology, engineering, and information technologies, thereby creating favorable conditions for integrative learning experiences [3].

Academic lyceums, which serve as advanced secondary educational institutions designed to prepare students for higher education and professional specialization, offer a particularly relevant environment for the implementation of interdisciplinary physics education. The cognitive readiness and academic orientation of lyceum students allow for the systematic incorporation of complex integrative tasks, modeling activities, and research-based learning approaches that reflect authentic scientific inquiry [4]. Therefore, the primary objective of this study is to identify and substantiate the theoretical and methodological foundations for improving interdisciplinary integration in physics education within academic lyceums.

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METHODS

The methodological framework of this study is grounded in systems theory, the competency-based educational paradigm, constructivist learning theory, and activity-oriented didactics, which collectively emphasize the active role of learners in constructing knowledge through meaningful engagement with interdisciplinary contexts [5].

The research employed a mixed-methods approach, combining theoretical analysis and empirical investigation. At the theoretical stage, an extensive review of national and international literature on interdisciplinary education, physics didactics, and integrative pedagogical models was conducted, alongside an analysis of relevant educational standards and curriculum frameworks [6].

The empirical stage involved the implementation of an experimental instructional model in selected academic lyceums, where interdisciplinary integration was operationalized through project-based learning, mathematical modeling, virtual laboratory simulations, and contextual problem-solving tasks that incorporated concepts from chemistry, biology, and information technologies. Data collection methods included classroom observations, diagnostic assessments, student questionnaires, and comparative pedagogical experiments [7].

RESULTS

The results of the pedagogical experiment indicate that physics instruction based on interdisciplinary integration yields significantly higher educational outcomes compared to traditional subject-centered teaching approaches. Students exposed to integrative instructional strategies demonstrated a deeper conceptual understanding of physical phenomena, an enhanced ability to apply mathematical and computational tools, and greater proficiency in analyzing complex, real-world problems [8].

Quantitative analysis of diagnostic assessment results revealed statistically significant improvements in academic performance among students in the experimental groups, while qualitative data from surveys and observations highlighted increased learner engagement, intrinsic motivation, and positive attitudes toward physics as a meaningful and applicable discipline [9].

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Furthermore, interdisciplinary tasks facilitated the development of transferable competencies, including critical thinking, scientific reasoning, and collaborative problem-solving, which are essential for success in higher education and professional environments [10].

DISCUSSION

The findings of this study are consistent with international research emphasizing the effectiveness of interdisciplinary and active learning approaches in science education [11]. The observed improvements in student learning outcomes support the theoretical assumption that interdisciplinary integration enhances cognitive coherence by enabling learners to establish meaningful connections between concepts across disciplinary domains.

In the context of academic lyceums, interdisciplinary physics education not only enriches subject-specific knowledge but also contributes to the formation of professional orientation and scientific worldview, aligning educational outcomes with contemporary societal and labor market demands [12]. These results underscore the necessity of rethinking curriculum design, teacher training, and assessment practices to support sustainable interdisciplinary integration in physics education.

CONCLUSION

The study demonstrates that interdisciplinary integration represents a scientifically grounded and pedagogically effective strategy for improving physics education in academic lyceums. By aligning theoretical knowledge with interdisciplinary applications and real-world contexts, integrative physics instruction fosters deeper learning, higher motivation, and the development of essential competencies required for lifelong learning and professional success. Future research should focus on refining interdisciplinary instructional models, developing teacher professional development programs, and exploring digital technologies as enablers of integrative learning environments.

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