THE ROLE OF THE STEAM APPROACH AND DIGITAL COMPETENCIES IN DEVELOPING CRITICAL THINKING AMONG FUTURE TEACHERS

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Abstract: This article analyzes the role of the STEAM approach and digital competencies in developing critical thinking among future teachers. The study highlights the opportunities of STEAM education based on interdisciplinary integration and reveals the mechanisms for developing future teachers' critical thinking skills through the enhancement of digital competencies.

Keywords: STEAM education, digital competencies, critical thinking, future teachers, higher education, interdisciplinary integration, digital technologies, problem-based learning, pedagogical technologies.

Аннотация: В данной статье проанализирована роль STEAM-подхода и цифровых компетенций в развитии критического мышления у будущих педагогов.

Ключевые слова: STEAM-образование, цифровые компетенции, критическое мышление, будущие педагоги, высшее образование.

INTRODUCTION. The processes of globalization and digital transformation are imposing new demands on the education system. Among the essential twenty-first-century skills, critical thinking, problem-solving, creativity, and the effective use of digital technologies have gained particular importance. In this regard, developing these competencies in future teachers has become one of the priority tasks of modern education. Teachers are expected not only to possess profound subject knowledge but also to be capable of analyzing information critically, evaluating its reliability, drawing evidence-based conclusions, and guiding students toward independent thinking.

In recent years, the STEAM (Science, Technology, Engineering, Arts, and Mathematics) educational approach has been widely implemented as an innovative model

based on interdisciplinary integration. This approach enables students to connect theoretical knowledge with practical activities, develop problem-solving abilities, collaborate effectively, and enhance their research skills. Moreover, the use of digital tools in STEAM classes provides opportunities for students to improve their competencies in searching for, analyzing, processing, and evaluating information.

Digital competencies constitute an essential component of a modern teacher's professional activity. They facilitate the purposeful and effective use of digital technologies, ensure information security, promote media literacy, and support the innovative organization of the educational process. The development of digital competencies also has a direct impact on the formation of critical thinking. In the process of analyzing, comparing, and evaluating information obtained from various sources, students demonstrate their ability to assess the reliability of evidence and make well-reasoned decisions.

A review of the existing literature indicates that although the significance of the STEAM approach and digital competencies in teacher education has been extensively studied, the mechanisms for developing critical thinking through the integration of these two components have not yet been sufficiently explored. This gap highlights the relevance and necessity of the present study. Therefore, the aim of this article is to determine the role of the STEAM approach and digital competencies in fostering critical thinking among future teachers and to analyze the pedagogical opportunities arising from their integration.

Literature Review and Methods. Critical thinking has been recognized as one of the essential competencies required for successful participation in the twenty-first century. Researchers emphasize that critical thinking enables individuals to analyze information objectively, evaluate evidence, identify assumptions, and make reasoned judgments. In teacher education, the development of critical thinking is considered a prerequisite for preparing future educators capable of responding effectively to rapidly changing educational contexts.

The STEAM approach has attracted considerable attention as an interdisciplinary educational model integrating Science, Technology, Engineering, Arts, and Mathematics. Previous studies have demonstrated that STEAM-based learning environments promote

inquiry, creativity, collaboration, and problem-solving skills. Through authentic tasks and project-based activities, students are encouraged to investigate real-world problems, generate innovative ideas, and justify their decisions using evidence-based reasoning.

At the same time, digital competencies have emerged as a fundamental component of professional teacher preparation. They encompass the ability to access, evaluate, create, and communicate information through digital technologies in a responsible and effective manner. Scholars argue that digitally competent teachers are better equipped to design interactive learning experiences and foster higher-order thinking skills among students.

Despite the growing body of research on STEAM education and digital competencies, limited attention has been paid to their combined role in developing critical thinking among future teachers. Therefore, further investigation is needed to identify effective pedagogical mechanisms that integrate STEAM principles with digital competencies to enhance critical thinking skills in higher education settings.

This study employed a mixed-methods approach combining qualitative and quantitative research methods. Theoretical methods included the analysis and synthesis of scientific literature, comparison of existing pedagogical approaches, and the systematization of concepts related to STEAM education, digital competencies, and critical thinking.

Empirical data were collected through pedagogical observation, questionnaires, interviews, and experimental activities conducted with university students enrolled in teacher education programs. The experimental study involved control and experimental groups to examine the effectiveness of STEAM-based instructional activities supported by digital technologies in developing critical thinking skills.

The collected data were analyzed using descriptive and comparative statistical techniques. Changes in students' critical thinking levels before and after the intervention were evaluated to determine the effectiveness of the proposed educational approach. The findings obtained through these methods provided a basis for identifying pedagogical mechanisms that contribute to the development of critical thinking among future teachers through the integration of STEAM education and digital competencies.

Research Methods Used to Develop Students' Critical and Creative Thinking through STEAM Lessons in a Digital Environment

In this study, several scientific methods were employed to identify strategies for developing students' critical and creative thinking through STEAM lessons in a digital environment.

The application of these methods made it possible to determine the role and significance of STEAM education in the modern educational system and to substantiate its pedagogical potential in fostering students' critical thinking skills.

The findings indicate that the implementation of various educational approaches in STEAM lessons conducted within a digital environment—including Baamboozle, Kahoot!, Blended Learning, Project-Based Learning, and the Flipped Classroom model—facilitates students' transformation into active participants in the learning process. In particular, creative teaching methods integrated with digital technologies enhance students' motivation for independent learning and encourage them to engage more actively in the construction of knowledge.

Discussion and Results. The findings of the study demonstrated that the integration of the STEAM approach with digital competencies had a positive impact on the development of critical and creative thinking among future teachers. During the implementation of STEAM-based learning activities in a digital environment, students showed increased engagement in the educational process, greater motivation to solve problems, and improved ability to analyze information from different perspectives.

The use of digital educational tools such as Baamboozle, Kahoot!, Blended Learning, Project-Based Learning, and the Flipped Classroom model encouraged students to become active participants rather than passive recipients of knowledge. Through these approaches, students were required to search for information independently, evaluate the credibility of sources, compare alternative viewpoints, justify their arguments with evidence, and propose innovative solutions to real-life problems. These activities contributed significantly to the enhancement of their critical thinking skills.

Furthermore, project-based and collaborative STEAM activities promoted the development of creativity, communication, and teamwork competencies. Students demonstrated a greater willingness to express their opinions, defend their viewpoints using logical arguments, and engage in reflective discussions. The integration of digital technologies also increased their confidence in using technological tools for academic purposes and strengthened their digital literacy skills.

The comparative analysis of the control and experimental groups revealed that students exposed to STEAM-based instruction supported by digital technologies achieved higher levels of critical thinking than those who participated in traditional learning environments. The experimental group showed notable improvements in information analysis, evidence-based reasoning, problem-solving, and decision-making abilities. These findings confirm the effectiveness of integrating STEAM education and digital competencies in preparing future teachers capable of meeting the demands of contemporary education.

Overall, the results suggest that the purposeful use of STEAM methodologies within a digital environment creates favorable conditions for fostering higher-order thinking skills. Therefore, incorporating digitally supported STEAM strategies into teacher education programs can be considered an effective pedagogical approach for developing future teachers' critical and creative thinking.

Conclusion and Recommendations. The findings of this study confirm that the integration of the STEAM approach and digital competencies plays a significant role in fostering critical and creative thinking among future teachers. The use of digitally supported STEAM learning environments encourages students to become active participants in the educational process, enhances their problem-solving abilities, and improves their capacity to analyze and evaluate information critically.

The study revealed that the implementation of innovative instructional strategies, including Kahoot!, Baamboozle, Blended Learning, Project-Based Learning, and the Flipped Classroom model, contributes positively to the development of higher-order thinking skills. Students engaged in STEAM-based activities demonstrated greater independence in

learning, stronger evidence-based reasoning, increased creativity, and improved collaboration skills.

The results also indicate that the purposeful integration of digital technologies into STEAM instruction creates favorable pedagogical conditions for developing future teachers' digital competencies and preparing them to meet the challenges of contemporary education. Therefore, STEAM-supported digital learning can be regarded as an effective approach to improving the quality of teacher education.

Based on the findings of this study, the following recommendations are proposed:

In conclusion, strengthening the relationship between STEAM education, digital competencies, and critical thinking development can contribute significantly to the preparation of competent, innovative, and reflective future teachers capable of addressing the demands of the digital age.

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