DEVELOPING CREATIVE PEDAGOGICAL COMPETENCIES THROUGH STEAM-BASED EDUCATION: AN EXPERIMENTAL STUDY

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Annotation. This study explores the development of creative pedagogical competencies among future educators through the implementation of STEAM-based education. The research focuses on how integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) into teacher training programs enhances creativity, problem-solving, and interdisciplinary thinking. An experimental approach was used, involving 60 undergraduate pedagogy students divided into control and experimental groups. The experimental group participated in a semester-long STEAM project designed to foster innovation, teamwork, and reflective teaching practices. Data were collected through observation, creativity assessment scales, and self-reflection journals. Findings revealed that STEAM-based learning significantly improved participants' creative teaching skills, critical thinking abilities, and adaptability in designing interactive lessons. The results suggest that integrating STEAM approaches into teacher education can play a vital role in preparing future educators for the challenges of modern, technology-rich classrooms. The study contributes to the growing body of evidence supporting innovative pedagogical models that combine creativity, collaboration, and scientific inquiry to strengthen teachers' professional competence and educational impact.

Introduction. In the modern era of rapid technological advancement and global transformation, the demand for creative, adaptive, and innovative educators has become one of the most essential priorities in educational

development. Traditional teaching methods, which primarily emphasize memorization and theoretical understanding, are no longer sufficient to prepare learners for the complex challenges of the 21st century. As education systems worldwide move toward interdisciplinary and technology-integrated learning environments, the need to develop creative pedagogical competencies among future educators has gained significant importance. One of the most effective approaches for achieving this goal is the implementation of STEAM-based education, which integrates Science, Technology, Engineering, Arts, and Mathematics into a cohesive learning framework. This model not only encourages the acquisition of technical knowledge but also nurtures imagination, problem-solving, and collaboration—skills that are fundamental for effective teaching and lifelong learning. In teacher education, the STEAM approach serves as a dynamic platform where theory and practice merge to create an environment that promotes critical thinking and creativity. Through project-based learning, design thinking, and experimentation, prospective teachers learn to design lessons that inspire curiosity and innovation among students. Moreover, the inclusion of arts in the STEAM framework provides a balance between analytical reasoning and emotional expression, allowing future educators to cultivate both cognitive and affective dimensions of learning. As countries aim to modernize their education systems, integrating STEAM principles into teacher preparation programs becomes a strategic necessity rather than an option. This approach aligns with the global emphasis on fostering 21st-century skills such as creativity, communication, collaboration, and digital literacy.

Literature review. Creative pedagogical competencies are widely recognized as essential for effective teaching in the 21st century because they enable educators to create engaging, inquiry-based learning environments that promote curiosity and innovation. Researchers emphasize that teachers who possess creative competencies are more capable of linking theory to practice, using flexible teaching strategies, and integrating technology and art into learning to enhance student motivation and performance [1]. STEAM education, which combines Science, Technology, Engineering, Arts, and Mathematics, has emerged as a key framework for fostering such competencies among future educators. It encourages holistic thinking, collaboration, and problem-solving through interdisciplinary integration, making learning more relevant and dynamic [2]. The inclusion of arts in STEAM not only strengthens cognitive skills but also nurtures emotional intelligence, communication, and imagination, which are critical for developing empathy and creativity in the classroom [3]. Several studies have shown that when teachers engage in STEAM-based professional training, they demonstrate higher levels of innovation in lesson planning, adaptability in digital environments, and confidence in designing cross-curricular activities that reflect real-world challenges [4]. Furthermore, recent research highlights the transformative potential of technology-enhanced STEAM

education in promoting design thinking and creative reflection among educators. By merging analytical and artistic thinking, STEAM allows teachers to become facilitators of creativity, capable of inspiring students to think critically, collaborate effectively, and express themselves imaginatively [5].

Research methodology. This study employed an experimental research design to investigate the effectiveness of STEAM-based education in developing creative pedagogical competencies among future educators. The research was conducted at the Faculty of Pedagogical Sciences of the International Nordic University during the 2024–2025 academic year. A total of 60 undergraduate students majoring in pedagogy participated in the study, divided into two groups: an experimental group (30 students) exposed to STEAM-based learning and a control group (30 students) taught using traditional methods. The experimental design included pre-tests and post-tests to measure changes in creative pedagogical competencies over one academic semester. The research process was divided into three main phases: diagnostic, formative, and evaluative. In the diagnostic phase, baseline data were collected to determine participants' initial levels of creativity, problem-solving ability, and pedagogical flexibility using a Creative Pedagogical Competence Scale and a Reflective Teaching Inventory. This helped establish the comparative framework for both groups before the intervention. During the formative phase, the experimental group participated in a series of STEAM-integrated learning modules that combined scientific reasoning, technological tools, engineering design, artistic expression, and mathematical modeling. These modules were designed to engage students in real-world problem-solving and creative project work. Activities included designing interdisciplinary lesson plans, building prototypes, using digital design platforms such as Canva and Tinkercad, and integrating artistic elements into STEM-based tasks. In contrast, the control group continued with conventional lecture-based learning focused on theoretical pedagogy. The evaluative phase assessed the outcomes of the intervention. Both groups completed post-tests measuring growth in creativity, collaboration, and instructional innovation. In addition, qualitative data were collected through classroom observations, reflective journals, and semi-structured interviews with participants. The data analysis process combined quantitative and qualitative methods. Quantitative data were analyzed using paired sample t-tests to determine statistically significant differences between pre- and post-test scores of both groups, while qualitative data were coded thematically to identify emerging patterns related to creativity, engagement, and teaching confidence. Ethical considerations were fully observed: participants were informed about the study's objectives, participation was voluntary, and all personal data remained confidential. Reliability was ensured by using validated research instruments, and triangulation strengthened the credibility of the results.

1-Table. Comparison of creative pedagogical competencies between control and experimental groups

Indicators of Creative Competence	Control Group (Mean Score)	Experimental Group (Mean Score)	Percentage Difference (%)
Originality in Lesson Design	65.2	86.7	33.0
Flexibility in Teaching Methods	62.8	84.3	34.2
Problem-Solving Skills	64.1	87.9	37.1
Integration of Technology	60.3	89.2	47.9
Reflective Thinking Ability	66.5	88.1	32.4

The table presents the results comparing the creative pedagogical competencies of control and experimental groups after implementing STEAM-based education. It shows that the experimental group demonstrated significantly higher scores in all key indicators, particularly in technology integration and problem-solving. These findings confirm that STEAM-based learning environments effectively enhance creativity, adaptability, and reflective teaching among future educators.

Research discussion. The results of the study clearly demonstrated that the integration of STEAM-based education had a significant impact on the development of creative pedagogical competencies among future educators. The experimental group, which participated in interdisciplinary STEAM activities, showed remarkable improvement in creativity, problem-solving, and reflective teaching skills compared to the control group. Quantitative data from the pre- and post-tests revealed substantial increases in indicators such as originality, flexibility, and instructional innovation. Participants in the experimental group demonstrated greater ability to design creative lesson plans, integrate technology into teaching, and connect theoretical knowledge with practical classroom applications. This aligns with previous research emphasizing that STEAM education encourages students and educators to think beyond traditional subject boundaries and engage in deeper cognitive and emotional learning processes. Qualitative findings from interviews and reflective journals further confirmed the transformative effect of STEAM-based learning. Many participants reported that working on interdisciplinary projects helped them overcome fear of failure, enhanced their self-confidence, and motivated them to approach teaching with a more experimental mindset. They described the process as engaging, inspiring, and challenging—encouraging them to explore multiple solutions rather than

relying on one correct answer. Teachers and students collaborated closely during the creative tasks, which fostered teamwork, communication, and mutual respect. These aspects reflect the social and emotional dimensions of creative pedagogy, where learning becomes a shared process rather than an individual activity. The inclusion of art and design elements within STEAM modules played a crucial role in stimulating imagination and aesthetic awareness, providing balance between analytical and intuitive thinking. Participants learned how to apply visual and artistic methods in teaching scientific and mathematical concepts, thereby transforming abstract ideas into tangible and relatable experiences. Moreover, the use of technological tools such as digital design software, simulation programs, and AI-based applications enhanced digital literacy and encouraged participants to incorporate modern educational technologies into their pedagogical practices. This combination of creativity and technology not only developed participants' innovative potential but also prepared them for teaching in technologically advanced classrooms. Another significant observation was the improvement in reflective practice.

Conclusion The findings of this experimental study confirm that STEAM-based education is a powerful and effective approach for developing creative pedagogical competencies among future educators. By integrating Science, Technology, Engineering, Arts, and Mathematics into a cohesive learning model, future teachers were able to cultivate creativity, innovation, and interdisciplinary thinking—skills that are essential for success in 21st-century education. Participants who engaged in STEAM-based learning demonstrated higher levels of originality, flexibility, and reflective teaching compared to those taught through traditional methods. The results revealed that the inclusion of artistic and design elements within the STEAM framework enhanced participants' ability to express ideas creatively and link theoretical knowledge with real-life applications. Moreover, the use of digital technologies and project-based learning activities encouraged collaboration, problem-solving, and critical analysis, fostering a deeper understanding of pedagogical creativity. The research also highlighted the importance of reflection and experimentation in professional growth, as future educators learned to analyze their teaching approaches and continuously adapt to innovative methods. Overall, this study concludes that the STEAM-based educational model not only strengthens the creative potential of teacher candidates but also prepares them to become dynamic, adaptive, and forward-thinking professionals capable of inspiring creativity in their students. Therefore, incorporating STEAM principles into teacher training curricula is recommended as a key strategy for building a modern, innovative, and globally competitive education system.

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