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### STEM-ОСВІТА І МУЗИКА: ПОРІВНЯЛЬНИЙ АНАЛІЗ ПРАКТИК

**Анотація.** STEM-освіта сьогодні стає все більш актуальною через запит суспільства на розвиток критичного мислення й креативності у молоді. Така освіта поєднує науку, технології, інженерію, мистецтво та математику, сприяючи розвитку інноваційних рішень у галузі освіти. Порівняльний аналіз успішних практик упровадження STEM дозволяє виявити ефективні методи, адаптувати їх до локальних умов та покращити освітні програми, базуючись на доказових підходах. Вивчення музики в рамках STEM не є виключенням. Музика стимулює просторове мислення та допомагає вивчати інші дисципліни через міждисциплінарні зв'язки. У статті піднімається проблема покращення музичної освіти через виявлення кращих освітніх практик STEM-освіти та музики. На основі порівняльного аналізу наукових результатів виявлені схожі риси та відмінності в підходах до інтеграції музики в освіту STEAM у різних країнах. Спільним є наголос на міждисциплінарному навчанні, яке сприяє розвитку критичного мислення та креативності. Країни з потужними освітніми програмами з мистецтва, такі як Фінляндія та Канада, демонструють вищу залученість і досягнення студентів, тоді як регіони, де мистецтво є неприоритетним, такі як частини Сполучених Штатів, стикаються з проблемами в успішності студентів. Культурний контекст значно впливає на інтеграцію музики; країни з сильними музичними традиціями часто розглядають музику як фундаментальний аспект освіти, що збагачує досвід навчання. Щоб покращити освіту STEAM за допомогою музики, рекомендується кілька стратегій. Педагоги повинні розробити міждисциплінарні плани уроків, які поєднують музику з математичними та науковими концепціями, використовуючи проєктне навчання для створення цікавого досвіду. Крім того, навчальні заклади повинні прийняти політику підтримки, яка віддає перевагу мистецтву поряд із дисциплінами STEM і надає можливості професійного розвитку для викладачів. Спільні зусилля між викладачами мистецтв і STEM можуть сприяти обміну ресурсами та інноваційними стратегіями навчання, збагачуючи освітній досвід.

**Ключові слова:** STEM-освіта; музична освіта; успішні практики; порівняльний аналіз; міждисциплінарна основа; підготовка вчителів музики; професійна підготовка.

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### STEAM EDUCATION AND MUSIC: A COMPARATIVE ANALYSIS OF PRACTICES

**Abstract.** STEAM education is becoming more and more relevant today due to society's demand for developing critical thinking and creativity in young people. Such education combines science, technology, engineering, art, and mathematics, contributing to developing innovative solutions in education. Studying music within the framework of STEAM is no exception. Music stimulates spatial thinking and helps to learn other disciplines through interdisciplinary connections. A comparative analysis of successful STEAM implementation practices allows us to identify effective methods, adapt them to local conditions, and improve educational programs based on evidence-based approaches. The article raises the problem of enhancing music education by identifying the best educational practices of STEAM education and music. A comparative analysis of scientific results identifies similarities and differences in approaches to integrating music into STEAM education in different countries. What is detected is an emphasis on interdisciplinary learning that promotes critical thinking and creativity. Countries with arts education programs, like Finland and Canada, demonstrate higher student engagement and achievement. Regions where the arts are not a priority, such as parts of the United States, need help in student achievement. The cultural context significantly impacts music integration; countries with solid musical traditions often view music as a fundamental aspect of education that enriches the learning experience. Several strategies are recommended to enhance STEAM education through music. Educators should develop interdisciplinary lesson plans that

*combine music with math and science concepts, using project-based learning to create engaging experiences. In addition, educational institutions should adopt supportive policies that prioritize the arts alongside STEM disciplines and provide professional development opportunities for teachers. Collaborative efforts between arts and STEM teachers can facilitate sharing resources and innovative teaching strategies, enriching the educational experience.*

**Keywords:** *STEM education; music education; successful practices; comparative analysis; interdisciplinary framework; music teacher education; professional training.*

**Statement of the problem.** In recent years, the importance of holistic approaches to learning has been increasingly recognized in the educational environment. STEAM [8; 12] and STEAM [1; 4] education is becoming a prominent paradigm integrating science, technology, engineering, art, and mathematics. Integrating the arts, particularly music, into the Science, Technology, Engineering, Arts, and Mathematics (STEAM) education framework has garnered considerable attention as a pedagogical strategy to increase student engagement and learning outcomes. This strategy is essential when considering the role of music, as it transcends traditional disciplines and fosters a well-rounded educational experience. By researching various practices of STEAM education, scientists strive to identify the best ones for implementing STEAM initiatives.

**Analysis of current research.** The STEAM framework suggests incorporating the arts into curricula fosters creativity, critical thinking, and interdisciplinary learning. Research shows that music education can significantly enhance cognitive development, especially in areas related to STEM disciplines, such as pattern recognition and spatiotemporal thinking [2]. This study showed that integrating music promotes the growth of emotional intelligence and cooperation between students, which are essential skills in today's learning environment. The arts, including music, serve as a conduit for exploring complex scientific and mathematical concepts, thus creating a more holistic educational experience [2]. According to Kaplan (2017), the inclusion of music in educational programs enhances student engagement and fosters deeper learning through experience [6].

The inclusion of music in STEAM curricula is a multifaceted tool that fosters artistic expression while enhancing the critical cognitive skills required for all disciplines. The collaborative nature of music-making encourages teamwork and communication, consistent with Simpson's assertion that creative expression leads to transformative educational experiences [9]. For example, the principles of acoustics in physics can be explored in the study of musical instruments, allowing students to apply theoretical concepts in a practical context [10].

Several educational programs have successfully integrated music into their STEAM curricula, achieving notable results in engaging and educating students. The "Mind Over Music" program exemplifies this, significantly improving teachers' knowledge and student achievement by effectively integrating live music into lessons [6]. Similarly, the STEMITL project, which engaged high school students in interdisciplinary lessons on water pollution through music and art, demonstrated the ability of music to motivate students and deepen their understanding of complex subjects [10].

The benefits of incorporating music into STEAM education are numerous, encompassing improvements in cognitive abilities such as memory, attention, and problem-solving skills. Research shows that students who learn music tend to outperform their peers academically, especially in math and reading [3]. In addition, music promotes emotional and social development, creating a more engaging atmosphere for students to express themselves and engage.

**Purpose.** To conduct a comparative analysis of the practice of implementing STEAM education related to music.

**Methods:** comparative analysis and comparison of scientific results.

**Results.** The integration of music into STEAM education manifests itself differently in different cultural and educational contexts, reflecting different pedagogical philosophies. For example, in the United States, programs such as Phoenix Symphony's "Mind Over Music" initiative exemplify a collaborative model where professional musicians work with educators to develop curricula incorporating live music into academic lessons. This partnership aims to improve student engagement and create a sustainable model for integrating the arts in public schools [7]. The emphasis on community engagement and professional partnerships emphasizes a proactive approach to incorporating music into the educational framework.

In contrast, Finland has developed a more holistic approach to STEAM education, where music education is intertwined with different disciplines, fostering a deeper understanding of scientific and mathematical concepts. The Finnish model is an example of pedagogical change that values emotional and social learning alongside cognitive development, thus creating a comprehensive educational experience [11]. Music in Finland is a supplement to academic subjects and an important component that enriches the overall learning experience.

In Asia, particularly in Japan, there is a growing trend towards incorporating traditional arts, particularly music, into the STEM framework. Programs that explore the physics of sound using traditional musical instruments combine cultural appreciation with scientific research, thereby enriching students' understanding of scientific principles and cultural heritage [9]. This integration of local traditions into the curriculum not only enhances students' learning experience but also fosters a sense of cultural identity.

Latin American countries present another perspective where music and dance are deeply rooted in culture. Educators use these elements to improve interaction and understanding of scientific and mathematical concepts. Educators promote culturally responsive pedagogical activities that resonate with student backgrounds by engaging students in creating music or performing artistic statements related to scientific topics [5].

A comparative analysis of STEAM educational practices reveals several key similarities and differences between countries, as summarized in the table (Table 1).

Table 1.

**Characteristics of STEAM Educational Practices in Different Countries of the World**

Aspect	USA	Finland	Japan	Latin America
Emphasis on music integration	Strong partnership with the community	A holistic, integrated approach	The Cultural Significance of Music	Cultural Expressions as Teaching Tools
Pedagogical focus	Engagement Through Collaboration	Creativity and critical thinking	Historical context and research	Compliance with local traditions
Curriculum development	STEAM-Focused Project-Based Learning	Interdisciplinary, flexible curricula	Traditional arts integrated with STEM	Music and Dance as Teaching Methods
Community and cultural context	Strong emphasis on local cooperation	National Education Policy	Local Heritage and Community Values	Community-Based Learning

A comparison of scientific results shows similarities and differences in approaches to integrating music into STEAM education in different countries. A common theme is the emphasis on interdisciplinary learning, which fosters critical thinking and creativity. Countries with vital arts education programs, like Finland and Canada, show higher student engagement and achievement. In contrast, regions where the arts are not a priority, such as parts of the United States, face challenges in student performance. The cultural context has a significant impact on the integration of music. Countries with strong musical traditions often view music as a fundamental aspect of education, enriching the learning experience.

**Discussion.** According to the results of the study [2], we note:

– in the United States, the implementation of STEAM education faces significant challenges, primarily due to budget constraints and the prevailing emphasis on standardized testing. While initiatives such as the Common Core State Standards advocate for integrated learning approaches incorporating creativity and critical thinking, arts education, including music, often remains marginalized. Research shows that students engaged in music education perform better in math and standardized grades, emphasizing the need for a balanced approach that values both the arts and STEM disciplines;

– In stark contrast, Finland's educational system exemplifies a holistic approach to STEAM education, where music is integrated into various subjects. Finnish policies prioritize the arts as a vital component of cognitive development, with studies indicating that students exposed to music education show enhanced mathematical skills, as the mental abilities fostered through music are transferable to STEM learning. This integration promotes creativity and problem-solving, aligning with the principles of STEAM education;

– Japan employs an integrated studies approach that effectively combines music with STEM disciplines, cultivating a deeper understanding of both areas. The Japanese educational system's emphasis on arts education enhances students' problem-solving skills and creativity, with musical training linked to improved mathematical abilities. This methodology reflects a broader recognition of the importance of arts integration in enriching educational experiences;

– Across Europe, countries like the United Kingdom, Sweden, and Norway have implemented innovative policies encouraging interdisciplinary learning. Initiatives like the Arts Council's Creative Partnerships program in the UK promote collaboration between artists and educators, enhancing student engagement through creative learning environments. Similarly, Scandinavian countries demonstrate that integrating the arts into scientific education fosters problem-solving abilities and increases interest in STEM subjects. These examples underscore the potential benefits of a holistic educational framework that embraces creativity;

– In developing nations, integrating music into STEAM education faces unique challenges, but innovative practices have emerged. For instance, in Kenya and India, grassroots initiatives have successfully incorporated music into STEM curricula, enhancing student engagement and understanding. These examples illustrate that arts integration can improve educational outcomes and foster creativity even in resource-constrained environments.

Despite promising results related to integrating music into STEAM education, several challenges still need to be addressed. A common problem is the fragmentation of the curriculum across disciplines, which

hinders the creation of cohesive learning experiences. In addition, different levels of teacher preparedness may limit practical interdisciplinary approaches to teaching, as teachers may feel they need to be more adequately equipped to combine the arts with STEM subjects [10]. Systemic obstacles, such as limited funding for arts programs and a focus on standardized testing, further contribute to the marginalization of music in STEAM curricula [5].

However, there is significant scope for improving the integration of music into STEAM education. The growing recognition of creativity and critical thinking in education has positioned music as essential to a holistic learning experience. The rise of IT in schooling offers innovative ways to integrate music, allowing students to create music using coding languages and digital tools. Partnerships between educational institutions and local arts organizations can provide access to professional musicians, enriching the learning environment and fostering experiential learning opportunities [6].

Several strategies are recommended to enhance STEAM education through music. Educators should develop interdisciplinary lesson plans that combine music with mathematical and scientific concepts, using project-based learning to create engaging experiences. In addition, educational institutions must adopt supportive policies prioritizing the arts alongside STEM disciplines and provide professional development opportunities for educators. Collaborative efforts between arts and STEM educators can facilitate the exchange of resources and innovative learning strategies, enriching the educational experience.

Future research should focus on assessing the impact of music integration on student engagement and academic achievement, mainly through empirical research exploring the long-term benefits of such curricula. Comparative analysis of international models can provide best practices that inform local educational contexts and promote effective integration strategies.

**Conclusions.** Several vital ideas emerge from the comparative analysis of STEAM educational practices related to music integration. The practices in different countries underscore the potential of music to enrich learning in STEM disciplines. They also emphasize the significance of collaboration between the arts and educational institutions, thereby highlighting the role of music as a fundamental component of interdisciplinary learning and promoting its inclusion in STEAM curricula.

Integrating music into STEAM education fosters student engagement and develops the essential skills needed to succeed in today's world. The comparative analysis's results underscore the importance of recognizing music as a critical component of a comprehensive educational framework, promoting its inclusion in STEAM education.

Future STEAM education trends will likely emphasize project-based learning and technology integration, aligning academic content with students' experiences. International conferences and online communities dedicated to music in STEAM education can facilitate knowledge sharing among educators, fostering the creation of innovative curricula that reflect diverse cultural contexts.

As scholars continue to explore the integration of music into STEAM curricula, problem-solving through purposeful professional development is essential. Ongoing dialogue around these practices will contribute to developing educational approaches worldwide, ensuring that music remains a vital and enriching component of STEAM education.

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