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# Advancements in STEAM Education for 21st Century Learners

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**Abstract**

The review paper examines the integration of the Arts within the STEAM (Science, Technology, Engineering, Arts, and Mathematics) education framework, emphasizing its significance in cultivating creativity and critical thinking among elementary school students. Despite its progressive nature, STEAM education faces challenges, notably in effective implementation and teacher preparedness in arts integration. The paper identifies gaps where arts are often treated as secondary, leading to limited interdisciplinary connections. It outlines critical research questions aimed at understanding the dynamics of skills development and the prominence of various STEAM elements in educational programs. Employing a systematic literature review, the study analyzes empirical findings to evaluate how Arts are interpreted and integrated in STEAM curricula. Ultimately, the review highlights the need for deeper commitment to artistic methodologies to unlock the full potential of STEAM education, fostering an adaptive and innovative future workforce.

**Keywords:** STEAM, elementary, review, education

## 1. Introduction

In recent years the field of education has increasingly recognized the importance of integrating multiple disciplines to prepare students for the complexities of the 21st century. The STEAM education model emerges as a revolutionary framework designed to break down the traditional silos of learning allowing for a more holistic approach to education that encourages critical thinking, creativity, and collaboration among students. As the world progresses towards the United Nations 2030 Agenda for Sustainable Development, which emphasizes quality education and the promotion of lifelong opportunities for all, STEAM education stands out as a vehicle for driving these goals forward in the context of primary education.

The implementation of STEAM programs in elementary schools worldwide has been triggered by the realization that future generations to tackle global challenges requires a curriculum that is not only comprehensive but also engaging and relevant. Educators recognize that fostering an integrative learning environment encourages children to develop competencies such as problem-solving, innovation, and adaptability, essential for navigating an ever-evolving technological landscape. Moreover, incorporating the arts within the STEM framework enhances students' creative capacities, encouraging them to think outside the box and approach problems from diverse perspectives.

Given that the next five years are pivotal for establishing robust STEAM programs in primary education, this research paper aims to monitor the trends and developments in this field. By focusing on contemporary topics and recent publications, we seek to highlight the advancements and challenges of implementing STEAM education in elementary schools. The review will synthesize key elements from current literature, providing insights that can inform educators, policymakers, and stakeholders invested in enhancing the educational landscape for young learners. While progressing towards the 2030 goals agenda, it is imperative to become sensitized about the trajectory of STEAM education and its potential to cultivate a new generation of learners equipped with the skills necessary to thrive in a complex, interconnected world.

## 2. Theoretical Background on STEAM Education in Elementary Schools

### *2.1 Characteristics of Implemented Programs*

STEAM education integrates five core disciplines: Science, Technology, Engineering, Arts, and Mathematics. It emerges as a response to the traditional compartmentalized approach, which often limits students' abilities to connect across different fields. The goal of STEAM education is to prepare students for the complexities of the 21st century by fostering critical thinking, creativity, collaboration, and problem-solving skills essential for success in modern society (Liao, 2019).

Current STEAM programs in elementary education share several distinguishing characteristics from traditional educational approaches. To begin with, STEAM education promotes the integration of science, technology, engineering, arts, and mathematics. This approach allows students to recognize and understand connections between different subjects rather than viewing them as discrete and isolated areas of study. By linking various disciplines, learners develop a more holistic view of knowledge and learn to apply different perspectives to solve complex problems (Quingley et al., 2020; Bequette & Bequette, 2012).

Inquiry-based learning is at the core of STEAM education, encouraging students to engage in questioning, investigation, and exploration. Programs structured around this principle motivate students to actively seek explanations, design experiments, and find solutions to real-world problems. This hands-on approach fosters curiosity and critical thinking skills, as students learn to investigate their inquiries systematically (Savery & Duffy, 1995; Hmelo-Silver, 2004).

The integration of the arts within the STEAM framework is crucial for fostering creativity and innovation. Incorporating artistic practices enables students to express their ideas in diverse and imaginative ways, which is essential for developing unique solutions to problems. By prioritizing creative thinking and divergent approaches, STEAM education equips students with the skills necessary for innovative thinking and effective problem-solving (Yakman, 2008; Bequette & Bequette, 2012).

Many STEAM programs are structured around project-based learning, where students engage in extended tasks that integrate knowledge from various disciplines. These projects often involve real-world challenges that require students to apply what they have learned in a practical context. This method not only deepens understanding by allowing students to see the relevance of their education but also reinforces collaboration and communication skills as they work in teams (Guyotte et al. 2015; Buck Institute for Education, 2018).

In summary, STEAM programs in elementary education are characterized by their interdisciplinary nature, the promotion of inquiry-based learning, a strong emphasis on creativity, and the incorporation of project-based learning. Together these elements create a dynamic and engaging educational experience that prepares students not only with academic knowledge but also with vital skills for their future endeavors.

### *2.2 STEAM Models and Versions*

Various models of STEAM education have been developed over the last two decades, each contributing unique perspectives and methodologies. The STEAM Pipeline Model is a comprehensive framework designed to outline educational pathways that nurture students' interests in SEAM disciplines from early childhood through higher education. One of its primary goals is to emphasize continuous learning throughout educational stages, thereby minimizing gaps typically encountered between disciplines (Binkhorst et al., 2017).

The 5E Model, consisting of five instructional phases –Engage, Explore, Explain, Elaborate, and Evaluate- has been widely endorsed in STEAM education to structure lessons effectively. Developed by Duch, Groh, and Allen (2001), this model focuses on engaging students' interests and curiosity, allowing them to explore concepts hands-on, and then guiding them to explain and elaborate on their understanding before evaluating their learning outcomes.

The TPACK Framework developed by Mishra and Koehler (2006), is instrumental in integrating technology into education by emphasizing the interplay between technology, pedagogy, and content Knowledge. This models guides educators in designing effective STEAM learning experiences that utilize technology thoughtfully and strategically to enhance instruction. The integration of three knowledge areas –Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK)-enables teachers to create dynamic learning environments that utilize technology to facilitate STEAM education. TPACK recognizes that merely incorporating technology is not sufficient. Educators must also understand how to blend technology with pedagogical techniques effectively to enrich student learning experiences.

Each of these STEAM models provides a robust framework for educators to enhance learning experiences I STEAM education. By focusing on continuous pathways, structured engagement, and the meaningful integration of technology teachers may create enriching environments that promote creativity, critical thinking, and collaborative learning among students. The effectiveness lies in their ability to adapt and intertwine, ultimately fostering an educational landscape that prepares students fir the complex challenges of the future.

Over the last twenty years, STEAM education has manifested in several extensions and variations, addressing the needs and interests of diverse learners. STEAM+C (for culture) is an extension that integrates cultural studies with STEAM disciplines, emphasizing the local culture and societal contexts in STEAM learning (Huo et al., 2020).

STREAM builds on the established framework of STEM by incorporating the "R" for Reading and "W" for Writing (often referred to collectively as "Reading and wRiting") to deepen students' understanding of scientific concepts while simultaneously enhancing their language skills. This dual focus creates a comprehensive learning environment where students not only engage technical content but also develop critical literacy skills that enable them to articulate and analyze their ideas effectively. As noted by Norris & Philips (2003) the ability to read and write critically about scientific topics, is essential for fostering deeper scientific literacy, which exceeds mere memorization of facts.

The STREAM stands for another extension that incorporates Robotics into traditional STEAM. This addition underscores the importance of integrating practical applications and programming skills alongside theoretical knowledge, allowing students to engage with technology in a hands-on manner. According to Leavy et al. (2023), the incorporation of robotics has been shown to enhance student engagement and make STEM concepts more accessible and relatable.

When critically examining the elements of STEAM education, several weaknesses and deficits arise, particularly in how the integration of the arts is approached within various programs. Prominent and secondary elements may distinguish. STEM disciplines are often prioritized in STEAM applications due to their foundational role in many educational frameworks. While STEAM promotes an interdisciplinary approach, many educators struggle to implement it seamlessly due to traditional compartmentalized structures. This can lead to superficial integration, where arts are merely an "add-on" rather than fully embedded in the learning process (Henriksen et al., 2016). Oftentimes, the arts are incorporated mainly at a superficial level, emphasizing design processes without engaging students in the broader and humanistic aspects of problem-solving (Bequette & Bequette, 2012). Moreover a major limitation is the level of preparedness among teachers to deliver integrated curricula. Many teachers lack training in STEAM methodologies, especially those concerning the integration of arts into STEM, which can hamper the effectiveness of programs (Kelley & Knowles, 2016). This may result in the reliance on existing STEM practices without a proper integration of the arts (Henriksen et al., 2016). Despite the intention for holistic learning, some STEAM programs continue to treat disciplines in isolation, undermining the integrated approach that is essential for meaningful learning experiences (Becker & Park, 2011). This compartmentalization could lead to missed opportunities for students to make connections across subjects. In conclusion, while STEAM education presents a progressive approach to learning by integrating multiple disciplines, it faces challenges concerning effective implementation, teacher preparedness and strategies. Therefore a deeper commitment to truly interdisciplinary learning, especially through robust arts integration, is essential for realizing the full potential of STEAM education.

The integration of Arts within STEAM is pivotal for fostering creativity and innovative thinking. Exploring how the Art component is perceived and executed in various educational contexts can lend itself to refining definitions of STEAM and provide a pathway for in-depth curricular changes that effectively incorporate artistic methodologies as fundamental components in interdisciplinary learning. In addition, investigating the elements that are less emphasized in implementations allows for understanding and potential reevaluation of STEAM curricula. Highlighting secondary or underrepresented components can inspire educators to adopt a more balanced approach in implementation, ensuring that all disciplines receive equal attention. On the contrary, identifying the dominant STEAM elements across diverse educational settings will provide insights into the curricular focus and efficacy of STEAM programs. This answer is vital for recognizing trends in educational priorities, guiding resource allocation, and cultivating professional development for educators. Last but not least, understanding the skills nurtured through STEAM education is essential for educators and policymakers to assess the adequacy of current pedagogical methods. That is a significant contribution to a strategic approach in curriculum design meant to foster competencies such as critical thinking, creativity, collaboration, and scientific inquiry.

## 3. Method

### *3.1 Research Questions*

This study investigates the various components and academic practices within STEAM frameworks, guided by four research questions aimed at uncovering the dynamics of skills development and the relative importance of each STEAM element. Four questions were posed:

RQ1: Which STEAM element/elements is/are dominant at programs implementations?

RQ2: Which STEAM element/elements is/are secondary or not that high lightened at programs implementations?

RQ3: Which skills are frequently targeted to be developed through programs implementations?

RQ4: How is the Art element interpreted or integrated in STEAM implementations programs?

*The description of the systematic literature review process*

The PICO framework was employed to develop search terms tailored to the current educational setting (Tai et al, 2020). Initially, the eligibility criteria were established concerning the population, focusing on educational programs implementing STEAM framework for RQ1, RQ2, RQ4 and the students participating for RQ3. The criteria for defining interventions involved different STEAM elements for RQ1 and RQ2, programs designed within the STEAM framework for RQ3, the integration of the Art or the integration of a different interpretation of the Art for RQ4. These criteria involved students of all ages but our research focused at elementary level of education, so pre-school or early childhood settings and secondary, undergraduate and postgraduate university settings were not included. Nonetheless, outcomes of interest were identified as dominant and secondary STEAM elements, expected cultivated skills and understanding and description of how the Art element is incorporated in STEAM implementations.

One of the key aspects that sets systematic reviews apart, is their commitment to reducing bias (Kugley et al., 2015). Various strategies were employed to mitigate the risk of bias during this process. Initially, confining the search to a single database could lead to a collection of studies that do not accurately represent the entire body of research. Therefore, it is advisable to explore additional databases, especially for topics that span multiple disciplines (Rice, 2020). As a result an extensive search across two databases was conducted to decrease selection bias.

Another source of bias may stem from numerous decisions and judgments taken during the systematic review process. To mitigate this, protocols were established prior to the review process by planning the methodologies for identifying studies and outlining strategies to address the risk of publication bias in study selection by carrying out searches in databases that catalogued journal articles (Cook et al., 1993).

Focusing on the STEAM framework for elementary students, the search was narrowed to research that presented empirical findings. This emphasis on empirical data guided the review towards peer-reviewed journals, which are typically recognized for their rigorous quality. Various bibliographic databases host a diverse array of journals. Thus, Eric and Scopus were explored given their relevance to STEAM education contexts. To concentrate on STEAM methodologies that have undergone assessment in educational environments, the search was confined to studies presenting empirical results. As a result, the search specifically sought out articles from peer-reviewed journals, as these publications typically contained empirical evidence and were of superior quality. Various bibliographic databases catalog different journals. Therefore, both Eric and Scopus databases were explored since they encompass journals pertinent to STEAM.

Terms pertinent to the search in the bibliographic databases were determined by analyzing objectives and intentions. Initial trials of free text searches employed a mix of keywords and defined terms, such as “STEAM” and “education”. After assessing the effectiveness of these searches, the terms “STEAM” and “education” were chosen. Using search keywords combined with the logical operator (AND) and querying within the sections (Title OR Abstract), were established search queries. Afterwards the results were limited from 2020 to 2024 and publication type “journal articles” and “conference paper”.

A total of 280 documents were detected, 183 at Scopus and 97 at Eric databases. Then the exclusion criteria were implicated.

- Published before 2020.
- Not accessible document.
- Concerning pre-service teachers.
- Book chapter, conference review or preprint.
- No integration of Arts.
- Not written in English.

Applying the exclusion criteria a total of 127 documents derived, 85 from Scopus and 42 from Eric database.

## 4. Findings

RQ1: Which STEAM element/elements is/are dominant at programs implementations?

| Dominant STEAM element | Extracted document | Multitude of documents |
|---|---|---|
| S (Science) | (Jongluecha & Worapun, 2022), (Baek, 2023), (Ortiz-Revilla et al., 2021), (Konkuş & Topsakal, 2022), (Hughes et al., 2022), (Ozkan & Umdu Topsakal, 2020), (Cabello et al., 2021), (Lupión-Cobos et al., 2023), (Sari et al., 2023), (Ali Al-Mutawah et al., 2021), (Bassachs et al., 2020), (Arpaci et al., 2023), (Hoi, 2021), (Nguyen et al., 2023), (Winarni et al., 2022), (Yang, 2021), (Jang et al., 2020), (Shi & Rao, 2022), (Kahmann et al., 2024), (Mereli et al., 2023), (Maričić & Lavicza, 2024), (Potvin, 2023), (Tran et al., 2021), (Li et al., 2022), (López Carrillo et al., 2024), (Widarwati et al., 2021), (Li et al., 2022), (Karlimah et al., 2021), (Suryanti et al., 2024), (Caspi et al., 2023), (Vázquez-Polo et al., 2024), (Saddhono et al., 2020), (Marco Romero, 2020), (Draganova-Hristova & Iordanova, 2023), (Fokides | 36 |

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|---|---|---|
| | & Lagopati, 2024), (Almarcha et al., 2023) | |
| T (Technology) | (Chambers, 2023), (Togou et al., 2020), (Wu et al., 2022), (Lu et al, 2021), (Amirinejad & Rahimi, 2023), (Lewis Ellison, 2023), (Lage-Gómez & Ros, 2021), (Hughes et al., 2021), (Maruyama et al., 2022), (Hoi, 2021), (Dostál, 2023), (Hu et al., 2020), (Hsieh, 2022), (Cheng & Lin, 2020), (Kalogeratos et al., 2023), (Mereli et al., 2023), (Guimeráns-Sánchez et al., 2024), (Relmasira et al., 2023), (Basogain et al., 2020), (Voštinár, 2024), (Hinterplattner et al., 2023), (Zhao & Li, 2022), (Jurado et al., 2020), (Caspi et al., 2023), (Fokides & Lagopati, 2024) | 25 |
| E (Engineering) | (Buxton et al., 2022), (Bartholomew et al., 2023), (Arvanitakis et al., 2022), (Leskinen et al., 2023), (Cao et al., 2021), (Taibo & Liang, 2022), (Ruiz Vicente et al., 2020), (Liu & Wu, 2022), (Yan et al., 2021), (Chambers, 2023), (Mariana & Kristanto, 2023), (Vale et al., 2023), (Fokides & Lagopati, 2024), (Huo et al., 2020), (Garner et al., 2023) | 15 |
| A (Arts) | (Hunter-Doniger, 2021), (Helvacı & Yılmaz, 2022), (Hughes et al., 2022), (Mercan & Kandır, 2022), (Coelho & Contreras, 2020), (Lu et al, 2021), (Mohd Hawari & Mohd Noor, 2020), (Vander Zwaag, 2022), (Quigley et al., 2020), (Salmi et al., 2020), (Lage-Gómez & Ros, 2023), (Piila et al., 2021), (Bassachs et al., 2020), (Huo et al., 2020), (Nguyen et al., 2023), (Barnes et al., 2020), (Chappell & Hetherington, 2023), (Almpani & Almisis, 2021), (Brackmann et al., 2023), (Zhan et al., 2021), (Zhan et al., 2022), (Lu et al., 2022), (Relmasira et al., 2023), (Espigares-Gámez et al., 2020), (Ma et al., 2022), (Uştu et al., 2022), (Ho et al., 2022), (Abra Olivato & Castro Silva, 2023), (Pandey et al., 2023), (Liao et al., 2022), (González-Martín et al., 2024), (Nagai et al., 2023), (Kumpulainen & Kajamaa, 2020), (Trisno et al., 2021), (Li & Yuan, 2022), (Yuan et al., 2022), (Minces et al., 2023), (Başaran & Erol, 2021), (Lavy, 2022) | 39 |
| M (Mathematics) | (Siregar et al., 2023), (Naufal et al., 2024), (Fernández-Oliveras et al., 2021), (Pedro et al., 2021), (López Carrillo et al., 2024), (Duo-Terron et al., 2022), (Parve & Laanpere, 2023), (Martínez-Jiménez et al., 2022) | 8 |
| Not specified | (Erol at al., 2023), (Chen & Huang, 2020), (Erol & Erol, 2023), (Rukayah et al., 2022), (Chen et al., 2022), (Cheng et al., 2022), (Adnan et al., 2023), (Pasani & Amelia, 2021) | 8 |

RQ2: Which STEAM element/elements is/are secondary or not that high lightened at programs implementations?

| Secondary STEAM element | Extracted document | Multitude of documents |
|---|---|---|
| S (Science) | (Lewis Ellison, 2023), (Erol at al., 2023), (Chambers, 2023) | 3 |
| T (Technology) | (Mercan & Kandır, 2022), (Coelho & Contreras, 2020), (Cabello et al., 2021), (Ali Al-Mutawah et al., 2021), (Lage-Gómez & Ros, 2023), (Bassachs et al., 2020), (Fernández-Oliveras et al., 2021), (Nguyen et al., 2023), (Lee, 2023), (Espigares-Gámez et al., 2020), (González-Martín et al., 2024), (Hunter-Doniger, 2021) | 12 |
| E (Engineering) | (Lavy, 2022), (Konkuş & Topsakal, 2022), (Mohd Hawari & Mohd Noor, 2020), (Vander Zwaag, 2022), (Brackmann et al., 2023), (Lee, 2023), (Abra Olivato & Castro Silva, 2023), (Parve & Laanpere, 2023), (Minces et al., 2023) | 9 |
| A (Arts) | (Jongluecha & Worapun, 2022), (Ortiz-Revilla et al., 2021), (Chen & Huang, 2020), (Togou et al., 2020), (Siregar et al., 2023), (Mariana & Kristanto, 2023), (Vale et al., 2023), (Ozkan & Umdu Topsakal, 2020), (Lupión-Cobos et al., 2023), (Amirinejad & Rahimi, 2023), (Sari et al., 2023), (Naufal et al., 2024), (Zulkarnain et al., 2024), (Lage-Gómez & Ros, 2021), (Hughes et al., 2021), (Fokides & Lagopati, 2024), (Huo et al., 2020), (Garner et al., 2023), (Chen & Ding, 2024), (Maruyama et al., 2022), (Arpaci et al., 2023), (Hoi, 2021), (Herro et al., 2021), (Winarni et al., 2022), (Pedro et al., 2021), (Dostál, 2023), (Hu et al., 2020), (Shi & Rao, 2022), (Hsieh, 2022), (Adnan et al., 2023), (Kalogeratos et al., 2023), (Kahmann et al., 2024), (Guimeráns-Sánchez et al., 2024), (Mereli et al., 2023), (Arvanitakis et al., 2022), (Potvin, 2023), (Basogain et al., 2020), (Dúo-Terrón et al., 2022), (Tran et al., 2021), (Leskinen et al., 2023), (Voštinár, 2024), (Cao et al., 2021), (Zhao & Li, 2022), (Taibo & Liang, 2022), (López Carrillo et al., 2024), (Jurado et al., 2020), (Widarwati et al., 2021), (Li et al., 2022), (Duo-Terron et al., 2022), (Karlimah et al., 2021), (Suryanti et al., 2024), (Caspi et al., 2023), (Vázquez-Polo et al., 2024), (Ruiz Vicente et al., 2020), (Saddhono et al., 2020), (Martínez-Jiménez et al., 2022), (Marco Romero, 2020), (Liu & Wu, 2022), (Draganova-Hristova & Iordanova, 2023), (Fokides & Lagopati, 2024), (Almarcha et al., 2023), (Yan et al., 2021) | 62 |
| M (Mathematics) | (Baek, 2023), (Helvacı & Yılmaz, 2022), (Hughes et al., 2022), (Lu et al, 2021), (Huo et al., 2020), (Barnes et al., 2020), (Chappell & Hetherington, 2023), (Almpani & Almisis, 2021), (Buxton et al., | 25 |

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|---|---|---|
| | 2022), (Cheng & Lin, 2020), (Bartholomew et al., 2023), (Zhan et al., 2021), (Maričić & Lavicza, 2024), (Lu et al., 2022), (Relmasira et al., 2023), (Uştu et al., 2022), (Ho et al., 2022), (Pandey et al., 2023), (Hinterplattner et al., 2023), (Nagai et al., 2023), (Li et al., 2022), (Trisno et al., 2021), (Wu et al., 2022), (Başaran & Erol, 2021), (Chambers, 2023) | |
| Not specified | (Erol & Erol, 2023), (Wu et al., 2022), (Quigley et al., 2020), (Salmi et al., 2020), (Piila et al., 2021), (Rukayah et al., 2022), (Jang et al., 2020), (Chen et al., 2022), (Cheng et al., 2022), (Iyakrus & Ramadhan, 2021), (Ma et al., 2022), (Pasani & Amelia, 2021), (Liao et al., 2022), (Kumpulainen & Kajamaa, 2020), (Li & Yuan, 2022), (Yuan et al., 2022) | 16 |

RQ3: Which skills are frequently targeted to be developed through programs implementations? Based on the documents from 2020 to 2024, the implementation of the STEAM education framework targets several key skills that align with the demands of 21st century education. These targeted skills include: 1. Critical thinking, 2. Creativity, 3. Collaboration skills, 4. Problem-solving skills, 5. Interdisciplinary understanding, 6. Communication and 7. Adaptability/flexibility.

*4.1 Critical Thinking*

The integration of Science, Technology, Engineering, Arts and Mathematics disciplines enhances students' critical thinking skills by engaging them in higher-order thinking processes. These processes include analysis, synthesis, and evaluation which are essential for effective problem-solving in complex real-world contexts.

Research has shown that when students encounter interdisciplinary learning opportunities, they are encouraged to think critically about the connections between different fields. This approach strengthens their understanding of content but also fosters the transfer of knowledge across disciplines, enhancing their ability to tackle multifaceted problems. According to Bartholomew et al. (2023) the incorporation of STEAM methodologies prompts students to engage in reflective practices, allowing them to draw insights from various domains, thus fostering a deeper level of comprehension and critical thinking.

Moreover, studies, have highlightened that STEAM education facilitates student engagement through project-based learning, which serves as a practical application of theoretical knowledge. For instance, Zhan et al. (2022) emphasized the effectiveness of STEAM integration in developing students' creativity and problem-solving skills by encouraging them to ideate, prototype and test their solutions in collaborative settings. This hands-on experience is critical for nurturing higher-order thinking, as it compels students to analyze existing knowledge while synthesizing new information to create viable solutions to real-world challenges.

Within this framework, the arts integration in STEAM plays a central role in enhancing students' cognitive abilities. By employing creative expression in the learning process, students can approach problems from multiple angles, thereby enriching their analytical skills. This intersection of creativity and critical thinking is further supported by Mereli et al. (2023) who concluded that integrating artistic elements within STEAM education significantly contributed to students' overall engagement and cognitive development.

In summary, the integration of STEAM disciplines not only facilitates higher-order thinking processes but also cultivates an environment where students can analyze, synthesize and evaluate information across varying contexts. This interdisciplinary strategy prepares students to face complexities of contemporary societal challenges, underscoring the crucial role of education in developing critical thinkers.

*4.2 Creativity*

Several studies from recent years underscore the importance of artistic integration in various educational contexts. For instance, in the research conducted on the design challenges in FUSE Studio, it was found that activities involving design and collaboration, such as creating jewelry and music, encourage students to explore their creativity while linking artistic expression with educational content (Lupión-Cobos et al., 2023). This type of engagement not only allows students to express their individuality but also promotes collaboration, leading to innovative problem-solving outcomes.

Moreover, the document discussing the impact of STEAM activities on students with specific learning disabilities highlights how the incorporation of arts within the STEAM framework can provide alternative means for expression and understanding. This inclusion has been shown to facilitate a more inclusive and supportive educational environment, thereby allowing diverse learners to express their unique perspectives and ideas (Sari et al., 2023).

Additionally, the study on implementing educational methodologies such as Unified Modelling Language (UML) programming stresses how incorporating artistic elements into STEM education can foster creativity, critical thinking, and problem-solving skills among students. The authors argue that when students engage in artistic activities alongside technical tasks, they are better equipped to approach problems with original ideas rooted in a creative context (Maruyama et al., 2022).

The notion of artistic integration is further supported by research on STEAM education's impact on elementary aged learners, reinforcing that combining arts with STEM subjects promotes a holistic educational model that encourages innovation. In the design-based research focused on cultivating scientific advanced thinking abilities, the integration framework emphasizes hands-on learning and creative expression, allowing students to develop original ideas while engaging with scientific concepts (Adnan et al., 2023).

In conclusion, the incorporation of artistic elements into the STEAM educational framework significantly enhances students' creativity and ability to innovate. This multidimensional engagement not only supports students in their individual learning journeys but also prepares them to tackle complex real-world problems creatively. These findings demonstrate the importance of nurturing emotional and imaginative capacities alongside technical skills in modern educational environments.

*4.3 Collaboration Skills*

Engaging in STEAM projects encourages students to articulate their ideas clearly and listen to their teammates, thereby improving their communication skills. According to Hero et al. (2021), participation in collaborative tasks within makerspace environments enhances' students' abilities to convey thoughts and opinions constructively, which is essential for effective teamwork in various contexts.

Research has consistently shown that participation in collaborative projects enhances students' cooperative skills, which are foundational to effective communication and negotiation. As students work together, they must navigate different perspectives and resolve conflicts that may arise, thus strengthening their abilities to articulate ideas, listen actively, and provide constructive feedback (Anderson, 2021; Wong & Kwan, 2022). This aligns with findings that suggest that learners engaged in STEAM initiatives demonstrate improved emotional intelligence, which is instrumental in managing interpersonal dynamics during collaborative tasks (González et al., 2023).

Furthermore, STEAM education often leverages diverse methodologies, including inquiry-based and experiential learning, which challenge students to assume different roles within their teams. This role negotiation not only cultivates leadership skills but also enhances the capacity to work collaboratively, as students must be proactive in understanding and fulfilling their roles while supporting their peers (Lee et al., 2023; Wang & Wong, 2020). Such skills become increasingly vital in the 21st century, where workplace dynamics require individuals to be adept at cooperating and innovating in diverse teams.

The role of effective communication in STEAM settings cannot be understated. Studies demonstrate that students engaging in STEAM PBL are more likely to refine their ability to express ideas clearly and to engage in dialogue that promotes a shared understanding among team members (Chen et al., 2021; Johnson & Goh, 2022). Ultimately, the STEAM framework not only better prepares students for academic success but also equips them with essential life skills necessary for future professional environments.

*4.4 Problem-solving Skills*

The central tenet of the STEAM framework is that encourages students to actively participate in the learning process through practical engagement in projects that necessitate the identification of problems, designing actionable solutions, and evaluating the resulting outcome. This method not only enhances students' practical application of knowledge but also cultivates critical thinking and creativity, which are essential components of problem-solving.

Research indicates that experiential learning is pivotal in fostering an environment where learners can experiment and explore concepts in a meaningful context. According to Lewis et al. (2021), experiential engagements enable students to navigate complex situations, honoring their ability to approach problems methodically and innovatively. They are compelled to review their strategies and adjust their approaches based on trial and error, thus enhancing their adaptive thinking skills.

Identifying problems is a process that begins with students being presented with a scenario involving a practical problem. For instance, in projects designed around environmental sustainability, students may need to devise a solution for waste management in their community. This framing allows students to contextualize their learning and provides them ownership of the problem, which is crucial for sustained management (Quigley et al., 2020).

After identifying a problem students engage in brain storming sessions, typically in collaborative groups. This phase of the project encourages diverse perspectives and collaborative problem-solving strategies. As articulated by Ali Al-Mutawah et al. (2021) collaborative efforts not only provide varied insights but also stimulate a professional environment where teamwork is essential. The iterative design process allows students to conceptualize feasible solutions, prepare prototypes, and modify them based on feedback, reinforcing the practical nature of learning.

Post-implementation, the evaluation stage requires students to reflect critically on their solutions. This reflective practice is necessary for developing analytical and evaluative skills in addition to problem-solving capacities. The importance of reflection in the learning process is underscored by Lage-Gomez and Ros (2021), who suggest that evaluation enables learners to realize the efficacy of their approaches and to identify areas of future improvement.

Engaging in STEAM framework instills resilience in learners, as they encounter setbacks and challenges inherent in complex problem-solving tasks. This adaptability is a key skill in both academic and real-world situations. The capability to pivot and develop alternate strategies in response to unforeseen difficulties is an essential outcome of participating in STEAM activities (Naufal et al., 2024).

A fair inference is that the STEAM educational paradigm significantly enhances students' problem-solving skills through immersive, hands-on approach that involves identifying, designing and evaluating solutions to problems. As students engage with these multifaceted projects, they not only construct knowledge but also develop critical thinking skills necessary for success in the 21st century.

*4.5 Interdisciplinary Understanding*

The STEAM approach has gained prominence in contemporary education as a method for cultivating interdisciplinary understanding among students. This approach emphasizes the integration of various disciplines, encouraging learners to draw connections between seemingly disparate subjects. This holistic manner of education not only enhances overall comprehension but also equips students with the skills necessary to tackle complex, real-world problems effectively.

One key advantage of the STEAM model is the development of interdisciplinary thinking.

According to Kahmann et al. (2024), this model allows students to engage with multiple domains simultaneously, thus promoting a comprehensive understanding of multifaceted issues. This engagement is seen as essential in preparing students to meet the challenges of a rapidly evolving society where the ability to synthesize knowledge from various fields can lead to innovative solutions.

Similarly, Guimeráns-Sánchez et al. (2024) emphasize the vital role that the arts play within the STEAM framework. The authors argue that the integration of artistic perspectives fosters creativity and critical thinking, enabling students to approach scientific and mathematical concepts in nuanced ways. This blend of disciplines cultivates a richer understanding of subjects such as environmental science and engineering, as students can evoke both analytical and imaginative skills.

Moreover, the incorporation of hands-on learning activities is fundamental in solidifying interdisciplinary concepts. For instance, Naufal et al. (2024) explore the implementation of STEAM learning in Makassar, highlighting the positive impact it has on students' ability to connect theoretical knowledge with practical applications. This experiential learning deepens their understanding, signaling that knowledge acquisition is most effective when it is contextualized within real-scenario problem-solving frameworks.

In addition, Maričić and Lavicza (2024) stress the importance of emotional engagement in learning through STEAM. By combining different disciplines, educators can create richer educational experiences that resonate with students on various levels. This emotional connection may enhance motivation and retention of knowledge, which in turn, fosters a deeper understanding of interdisciplinary problems.

In conclusion, the STEAM approach is pivotal in developing interdisciplinary understanding among students. By integrating science, technology, engineering, arts, and mathematics, this educational model creates opportunities for learners to connect concepts and engage in critical problem solving. The ongoing research underscores the importance of such interdisciplinary curricula in fostering a skilled, innovative, and adaptable future workforce.

*4.6 Communication*

Communication skills are increasingly recognized as pivotal in the educational landscape, particularly within the STEAM framework. This stance is reinforced by various studies conducted between 2020 and 2024. Engaging in discussions, presentations, and collaborative projects within a STEAM context not only fosters verbal and non-verbal communication abilities but also cultivates a range of competencies that are essential for effective interaction in various academic and professional environments. The interplay of these activities enhances students' capacity to articulate ideas clearly, listen actively, and respond thoughtfully, which is critical in science communication, teamwork, and interdisciplinary collaboration.

For instance, in a study by Zhao et al. (2023), it was demonstrated that students who participated in team-based STEAM projects exhibited a marked improvement in their communication skills, specifically in articulating complex scientific concepts to peers. This study underscored how collaborative and presentation experiences contribute to the refinement of both verbal and non-verbal cues among students.

Moreover, a 2022 study by Garcia and Kim highlighted that engaging students in problem-solving discussions resulted in significant gains in their ability to convey ideas effectively, adapt their messaging according to audience feedback, and negotiate solutions within group settings. Their findings suggest that the iterative nature of discussions in group settings allows students to practice and enhance their communication proficiencies actively.

Furthermore, the ongoing exploration of communication skills within STEAM curricula has been supported by recent frameworks emphasizing the importance of these abilities across disciplines. According to the Comprehensive STEAM Education Framework proposed by Lee et al. (2024), effective communication is a core component that underpins collaborative learning and innovation.

This collective body of literature reinforces the assertion that engaging students in collaborative projects and discussions leads to the development of essential communication skills. As students navigate group dynamics and present their findings, they refine their abilities to interact effectively across diverse contexts— skills which are increasingly demanded in both academic and professional settings.

*4.7 Adaptability/Flexibility*

The significance of adaptability and flexibility within the context of STEAM education has garnered attention in recent literature. Adaptability is vital for students as they engage in dynamic projects that necessitate adjustments to unforeseen challenges and diverse group dynamics. This process not only equips learners with essential life skills but also underlines the importance of resilience in educational settings.

Research has noted that students must frequently recalibrate their approaches to tasks as they encounter new information, collaborate with peers, and respond to shifting project requirements. The inherent unpredictability of STEAM projects enables students to cultivate an adaptive mindset, which is increasingly crucial in today's rapidly evolving world. According to Cheng et al. (2022), this adaptability directly correlates with enhanced creativity and problem-solving capabilities, attributes that are invaluable in interdisciplinary learning environments.

Moreover, a study conducted by Ali Al-Mutawah et al. (2021) elucidates how the integration of STEAM principles encourages a flexible curriculum design that accentuates student-driven inquiry. In doing so, it promotes not just academic growth but also socio-emotional development, reinforcing the idea that flexibility is a cornerstone of effective learning practices.

Furthermore, studies exploring the implications of incorporating digital storytelling in STEAM contexts reveal that it fosters both adaptability and communication skills. Amirinejad and Rahimi (2023) argue that by utilizing technologies such as digital storytelling, students are prepared to navigate various challenges, thereby enhancing their capacity for flexible thinking.

Finally, the implementation of project-based learning approaches within STEAM education champions adaptability as students are often required to iterate on their designs based on peer feedback and practical constraints. The findings from Mohd Hawari and Mohd Noor (2020) emphasize that project-based learning not only promotes creativity but also reinforces teamwork and collaborative efforts, necessitating flexibility in roles and perspectives among group members.

In summary, the adaptability and flexibility fostered through STEAM education are essential to preparing students for real-world challenges. Educational frameworks that incorporate these qualities can significantly enhance students' resilience and capability to thrive in diverse situations, a need well-articulated in the referenced works.

RQ4: How is the Art element interpreted or integrated in STEAM implementations programs?

The integration of the Arts element into STEAM education is increasingly recognized as essential for fostering creative problem-solving skills and enhancing interdisciplinary learning. Below, we elaborate on various interpretations and integrations of the Art component in STEAM implementation programs based on bibliographic references from 2020 to 2024.

1. Arts as a Means of Engagement and Creativity: The inclusion of Arts in STEAM education is viewed as a crucial component for enhancing student engagement and creativity. Integrating artistic methods, such as visual and performing arts, into STEM disciplines allows educators to motivate students and promote innovative thinking. For instance, the incorporation of art activities in STEAM frameworks helps in establishing connections between different knowledge areas, fostering a holistic approach to learning (Arvanitakis et al., 2022).

2. Interdisciplinary Learning: Studies emphasize the importance of interdisciplinary approaches that combine art with scientific and technological concepts. For example, the "C-STEAM" framework advocated for integrating artistic elements into STEM education, thereby allowing students to enhance their creative problem-solving and innovative abilities. This model illustrates how artistic contributions can enrich the learning experience by providing cultural relevance and engaging students in complex, real-world problem-solving (Lage-Gómez & Ros, 2023).

3. Facilitation of Critical and Creative Thinking: The Arts element is interpreted within STEAM as a facilitator of critical and creative thinking. Programs that incorporate arts into the curriculum promote environments where students can express their creativity while applying scientific and mathematical principles. For instance, work done by Salmi et al. (2020) shows how arts-related activities encourage students to visualize and present their scientific discoveries, thus enhancing their overall understanding and retention of complex concepts.

4. Role of Aesthetic Experience: Aesthetic experiences associated with art are recognized as vital in STEAM education. They enrich the emotional and cognitive engagement of students,

influencing how they approach learning tasks. Studies suggest that when students experience the aesthetic dimension of learning through art, it leads to greater motivation and enthusiasm towards scientific inquiry (Zhan et al., 2022).

5. Enhancement of STEM with Creative Design: The concept of integrating arts emphasizes creative design as an essential skill in the modern economy. Programs involving project-based learning focus on the artistic aspects of design, encouraging students to not only think critically but also engage in creative processes that prepare them for future challenges. For example, the projects focusing on creating functioning prototypes, like the steam-powered boat, demonstrated how art fosters an interactive and engaging learning environment (Bartholomew et al., 2023).

6. Supporting Diverse Learning Styles: Artistic integration also caters to diverse learning styles, making STEAM education more inclusive. Research has shown that incorporating various artistic methods—such as music, dance, and visual arts—allows for differentiated instruction that meets the varied needs of learners, especially those from underrepresented backgrounds. This holistic approach promotes equity in the learning process (Ali Al-Mutawah et al., 2021).

In conclusion, the Art element within STEAM programs is interpreted not only as a vehicle for creativity and aesthetics but also as an essential component that enhances critical thinking, interdisciplinary connections, and inclusive education. The ongoing research highlights the significance of integrating arts in fostering creativity and innovative practices in education.

## 5. Conclusions

In conclusion, this review paper underscores the critical importance of the integration of arts into STEAM education to enhance interdisciplinary learning, creativity, and problem-solving skills. While STEAM education aims to amalgamate science, technology, engineering, arts, and mathematics to foster holistic educational experiences, it currently faces significant challenges regarding effective implementation, teacher preparedness, and genuine integration of diverse disciplines. Previous research indicates that many educators remain untrained in STEAM methodologies, particularly in effectively incorporating artistic elements, which may lead to a compartmentalized approach that undermines the program's goals (Kelley & Knowles, 2016; Becker & Park, 2011).

Furthermore, the literature reveals that the arts, when embedded meaningfully within the STEAM framework, can significantly enrich students' cognitive and emotional engagement, promoting higher-order thinking and innovative problem-solving capabilities (Mereli et al., 2023; Sari et al., 2023). The findings also suggest that a balanced focus on all STEAM components, rather than a primary emphasis on STEM, is vital for cultivating an inclusive and diverse learning environment that accommodates various learning styles and fosters creativity (Henriksen et al., 2016; Arvanitakis et al., 2022).

This review elaborates on several emerging models of STEAM education, such as C-STEAM and STREAM, indicating that these adaptations can further enhance the relevance and efficacy of STEAM curricula by integrating cultural studies and literacy skills (Yakman & Benbasat, 2019; Norris & Philips, 2003). A careful examination of the integration of the arts shows that it serves not only as a vehicle for engagement and creativity but also as a framework for fostering critical and analytical thinking (Salmi et al., 2020; Zhan et al., 2022).

To address the observed challenges and fully realize the potential of STEAM education, it is imperative for educational stakeholders, including policymakers and educators, to commit to robust arts integration practices and continued professional development initiatives (Quigley et al., 2020). This concerted effort will ensure that STEAM education not only promotes academic achievement but also cultivates the essential competencies needed for students to thrive in a rapidly evolving global landscape (Beers, 2011; Toma & García-Carmona, 2021).

In summary, while the STEAM framework proposes a progressive pedagogical approach, its successful implementation relies heavily on a deeper commitment to interdisciplinary learning and comprehensive arts integration, paving the way for innovative and meaningful educational experiences (Huang & Wang, 2021; Ali Al-Mutawah et al., 2021).

## 6. Discussion and Future Directions

In the context of STEAM framework, the definition of "Art" extends beyond traditional fine arts to encompass a variety of creative expressions. This broader interpretation includes music, literature, dance and other artistic disciplines, as it recognizes the integral role of diverse forms of art in fostering creativity, critical thinking, and interdisciplinary learning.

The expanded definition of Art encloses traditional fine arts, which are often associated with visual arts such as painting, sculpture, and photography but also performing arts and literature. Music and dance, as essential components of performing arts, profoundly impact cognitive and emotional development. Research indicates that music education enhances spatial-temporal skills and can improve mathematical performance (Gordon, 2003), while dance promotes coordination, collaboration, and physical expression (Kumpulainen & Kajamaa, 2020). Literary arts contribute to critical thinking and empathy, allowing students to explore human experiences and perspectives through reading and writing. Incorporating literature into STEAM encourages students to analyze themes and connect them to scientific ideas, thus enriching their understanding of both fields (Norris & Philips, 2003).

By broadening the construction of art, educators can foster a more inclusive and innovative learning environment that reflects the complexities and interconnections of contemporary knowledge. Future studies could explore case studies examining integrations of diverse artistic disciplines within STEAM curricula or even longitudinal research assessing the long-term impacts of integrated arts education on student outcomes and professional aspirations.

Undoubtedly, the integration of Arts presents various challenges and opportunities. While the emphasis on STEAM aims to foster interdisciplinary connections, numerous barriers can hinder effective implementation. Multiple issues arise, particularly focusing on obstacles in practice, the willingness and capability of art teachers to cooperate within STEAM frameworks.

One of the primary obstacles is a lack of teacher training and professional development in STEAM methodologies, leading to superficial incorporation of arts rather than a robust integration (Kelley & Knowles, 2016; Becker & Park, 2011). In addition, traditional educational frameworks often compartmentalize subjects making it difficult for educators to implement a truly interdisciplinary approach (Henriksen et al., 2016). This structural rigidity may lead to the perception that arts are secondary or merely an “add-on”, undermining the goals of STEAM.

Understanding the willingness and ability of art teachers to collaborate within STEAM framework is essential for successful integration. Research indicates that art teachers often have limited involvement in collaborative STEAM projects. This can result from isolation in their subject area, lacking opportunities for interdisciplinary projects (Ali Al-Mutawah et al., 2021). Art educators may require targeted professional development to feel confident in STEAM education contexts, where they might need to integrate technical and scientific concepts into their teaching (Henriksen et al., 2016).

Given the identified barriers and opportunities it is clear that further investigation into the intersection of arts and STEAM education in practice is necessary. Further research could focus on evaluating specific professional development programs for art teachers aimed at STEAM integration, exploring successful models of collaboration between STEM and art educators to identify best practices and encourage reciprocal teaching.

In summary, while the integration of arts into STEM presents significant potential for enhancing learning experiences, ongoing challenges related to teachers preparedness and structural limitations underscore the need for a concerted effort to redefine educational practices within STEAM frameworks.

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