Integrating STEAM Education For self-Responsible and Mindful Practices Among students: A scoping Review

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Abstract

The implementation and advancement of technology-based learning pedagogies have made 21st-century classrooms increasingly adaptive to STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. The purpose of this scoping literature review is to explore practical implications for educators, examine how the integration of STEAM concepts influences students' self-responsible and mindfulness practices in the classroom and to identify possible research gaps. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a structured search and selection process was conducted. An initial pool of studies was identified through electronic databases using keywords such as “STEM education,” “STEAM education,” “self-responsible,” “self-regulatory,” and “practicing mindfulness.” Inclusion criteria were journal articles published between 2019 and 2024, written in English, and empirical studies focused on the field of education. A total of 20 relevant journal articles meeting these criteria were selected for analysis. The findings of the review suggest that STEAM approaches foster critical thinking, problem-solving, and independent learning, thereby enhancing students' responsibility for their own learning. Moreover, the collaborative and engaging nature of STEAM-based learning environments supports not only cognitive development but also students’ social and emotional competencies, encouraging mindfulness toward themselves and their peers. Future research is recommended to explore longitudinal effects of STEAM interventions on students' personal and interpersonal development, particularly in diverse cultural and educational contexts.

Keywords: STEAM education, Mindfulness, self-responsible, self-regulation

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1. Introduction

Incorporating STEAM (Science, Technology, Engineering, Arts, and Mathematics) education into modern learning environments offers numerous benefits that align with the demands of a rapidly evolving, technology-driven world. This educational approach fosters interdisciplinary learning, enhances critical thinking, and prepares students for future challenges by providing more comprehensive and practical experience (Delia Voicu et al., 2023). One of the major advantages of STEAM is its influence on the development of students' creativity, critical thinking abilities, and problem-solving skills (Bertrand & Namukasa, 2020; Wannapiroon & Petsangsri, 2020). The integration of knowledge and skills from different fields allows students to synthesize and apply their learning in real-world settings (Li, 2024). Additionally, students make meaningful connections between disciplines, developing a holistic understanding of the learning process (Utaminingsih et al., 2023).

Moreover, STEAM education promotes engagement, intrinsic motivation, and independence among students. Hands-on activities, project-based learning, and immersive technologies such as virtual and augmented reality offer interactive learning opportunities that enhance student participation (Trina et al., 2024). These technologies enable visualization of abstract concepts and experimentation in virtual labs, making learning more captivating and motivating. Consequently, improvements in academic performance are observed, particularly in STEM-related fields (Mengmeng et al., 2019).

Beyond academic development, STEAM education also supports socio-emotional and behavioral growth. The integration of the Arts within STEAM allows students to explore creativity and innovation while cultivating emotional intelligence (Chen & Dong, 2023). By engaging in artistic and interdisciplinary projects, students develop the ability to think outside the box and collaborate with others, which supports teamwork, empathy, and ethical awareness (Konkuş & Topsakal, 2022; Syahmani et al., 2021). These qualities are essential in preparing students for the complexities of future workplaces and society at large.

A significant contribution of STEAM education is its potential to nurture self-responsibility and mindfulness among students. In STEAM-based learning environments, students often engage in project-based tasks where they are required to set goals, manage time, track progress, and reflect on outcomes (López Carrillo et al., 2024). This level of autonomy helps them cultivate accountability, initiative, and self-directed learning skills, thereby strengthening their responsibility for their own educational progress (Lee, 2021). By promoting ownership of learning, STEAM equips students with the tools to navigate academic and life challenges with confidence.

Mindfulness is another emerging component of effective STEAM integration. When mindful practices are embedded into STEAM curricula, students show enhanced focus, emotional regulation, resilience, and interpersonal skills (Rahma et al., 2023). Mindfulness also helps mitigate learning barriers such as anxiety and stress, improving classroom behavior and attention (Jia et al., 2021). Furthermore, the benefits extend to teachers, as mindfulness practices improve their emotional well-being, classroom management, and overall teaching performance (Zhu, 2022). This reciprocal relationship suggests that fostering mindfulness supports a healthier, more productive classroom climate for both students and educators.

1.1 Problem Statement

Despite its interdisciplinary strengths, STEAM education continues to face critical implementation challenges. One of the major concerns is the lack of sufficient professional development and pedagogical training for teachers. Many educators express low confidence in delivering integrated STEAM content due to limited understanding of interdisciplinary teaching methods and student-cantered pedagogies (DeJarnette, 2018). While strategies such as interdisciplinary collaboration (Li, 2024), professional learning communities (Cheung, 2024), and innovative assessment approaches (Budarina et al., 2022) have shown promise, access to consistent and structured teacher training remains inadequate. Furthermore, many schools, especially those in under-resourced regions struggle with budget limitations, lack of instructional materials, and insufficient access to necessary technologies, all of which impede the sustainable implementation of STEAM programs (Boice et al., 2021; Delia Voicu et al., 2023).

In addition to structural barriers, challenges in curriculum development and assessment limit the effectiveness of STEAM integration. Teachers often face difficulties aligning STEAM projects with traditional subject goals, leading to fragmented instructional design (Almalki & Faqihi, 2021; Wahono et al., 2020). Moreover, traditional assessment methods are poorly equipped to capture the full spectrum of STEAM outcomes especially competencies such as creativity, collaboration, and mindfulness (Conradty & Bogner, 2020; Mejias et al., 2021). These limitations highlight the need for a broader, more inclusive framework that evaluates both academic and non-academic learning dimensions.

1.2 Research Gaps

Although STEAM education has been extensively researched for its academic, cognitive, and technical benefits, limited attention has been given to its potential role in fostering self-responsibility and mindfulness among students. These attributes, which are essential for nurturing independent, emotionally intelligent learners, remain underexplored in STEAM contexts. Most current studies emphasize content mastery, problem-solving, and technical skill acquisition, but overlook behavioural and emotional capacities such as self-awareness, emotional regulation, and goal-setting (López Carrillo et al., 2024; Rahma et al., 2023). There is a notable lack of empirical research that investigates how STEAM environments can be explicitly structured to promote self-directed learning, personal responsibility, and emotional resilience.

Self-responsibility is a critical yet insufficiently examined component of STEAM education. It plays a pivotal role in promoting student autonomy an essential skill for navigating open-ended, interdisciplinary tasks typical of STEAM-based learning. Developing self-directed learning (SDL) capacities, such as purposeful goal-setting and accountability, supports lifelong learning and adaptability in complex problem-solving contexts (Vintere et al., 2021). Similarly, self-regulated learning strategies reinforce individual responsibility for acquiring and applying knowledge effectively (Abdul Majid & Rochmah, 2018). However, the extent to which STEAM programs intentionally cultivate these skills remains poorly documented.

Parallel to this, mindfulness has emerged as a promising practice for enhancing emotional awareness, stress management, and focus in educational settings. Its integration within STEAM has the potential to support students' capacity for reflection, resilience, and

engagement especially during hands-on and project-based learning experiences. Studies have suggested that mindfulness-based pedagogical models can increase emotional intelligence and civic responsibility, especially when tied to real-world, community-oriented projects (Ng & Man, 2022). Despite such findings, mindfulness remains an underutilized and weakly theorized component of STEAM education. There is a lack of clarity on how mindfulness strategies can be consistently embedded into interdisciplinary curricula or how their outcomes should be assessed.
Moreover, while educators recognize the importance of nurturing these qualities, there is a reported shortage of professional development resources that equip teachers with strategies to implement self-responsibility and mindfulness in STEAM learning (Alghamdi, 2023). Teachers often call for more practical and evidence-based guidance on how to foster emotional intelligence, autonomy, and metacognition alongside academic objectives. Some researchers have pointed to the value of immersive, real-world learning environments that build trust, equity, and collaborative learning factors closely linked to mindfulness and personal responsibility (Shea et al., 2023). Yet, such practices are still emergent and not systematically integrated into mainstream STEAM instruction.

Addressing these research gaps is essential for fully realizing the transformative potential of STEAM education. By overlooking the development of self-responsibility and mindfulness, current educational models risk producing students who may be proficient in technical or academic tasks but lack the emotional and metacognitive competencies necessary for long-term success. In a rapidly evolving world that demands adaptability, resilience, and ethical decision-making, STEAM education must evolve beyond skill acquisition to embrace holistic learner development.

1.3 Research Objectives

1. To examine how the integration of STEAM concepts affects the self-responsible and mindfulness practices of the students in the classroom
2. To explore practical implications for educators from the existing literature
3. To identify methodological trends, gaps, and limitations in current literature related to the evaluation of self-responsibility and mindfulness within STEAM education contexts.

2. Related Research

2.1 STEAM Education and Self-Responsibility

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has shown promise in promoting self-responsibility among students, particularly through the development of self-regulated learning (SRL), critical thinking, and self-efficacy. A growing number of studies have explored how digital learning environments integral to STEAM pedagogy enhance SRL by encouraging student autonomy and ownership over the learning process. For instance, Andrisyah et al. (2021) demonstrated that early childhood teachers in Indonesia effectively implemented SRL strategies within digital learning settings, leading to improved teaching outcomes and student motivation. Similarly, Yang et al. (2023) noted that digital literacy supports EFL students in goal-setting and progress monitoring, suggesting its broader applicability in STEAM contexts.
The role of self-efficacy, a core element of self-responsibility, is also emphasized in the literature. Lee (2021) found that students in STEAM-based physical education settings

who reported higher self-efficacy also exhibited stronger self-directed learning behaviors. This underscores the interdependence between confidence and responsibility in learning environments enriched by STEAM methodologies. Furthermore, the research by López Carrillo et al. (2024) reinforces this connection by showing that a STEAM project grounded in the 5E instructional model significantly enhanced students' self-regulation, metacognitive skills, and engagement.

Moreover, empirical evidence suggests that STEAM education fosters critical thinking a skill closely tied to learner autonomy. Syukri et al. (2022) observed a significant improvement in students' critical thinking abilities through pre- and post-test evaluations following STEAM instruction. Critical thinking naturally demands active participation and reflective thinking, both of which are hallmarks of responsible learning behavior.

While these studies collectively present a strong case for the role of STEAM in promoting self-responsibility, limitations remain. Most studies rely on short-term interventions or self-report data, which may not capture long-term behavioral changes. In addition, the focus often lies on cognitive or motivational gains, with less emphasis on behavioral accountability, time management, or ethical decision-making key dimensions of self-responsibility that remain underexplored. There is also limited research assessing the impact of teacher professional development on fostering self-responsibility in students through STEAM education, though initiatives such as those described by Conradty and Bogner (2020) suggest that long-term teacher training can indirectly enhance student responsibility by boosting creativity and self-efficacy.

2.2 STEAM Education and Mindfulness

Mindfulness in education typically encompasses self-awareness, emotional regulation, and attentional control attributes increasingly seen as vital in 21st-century learning. Although direct research linking mindfulness to STEAM education is limited, several studies offer indirect evidence of its positive influence through variables such as engagement, focus, empathy, and cooperative learning. Nofia Henita et al. (2023) found that students participating in STEAM-based social science lessons exhibited greater focus and engagement behaviors that align with mindfulness practices. In these contexts, students were more present in their learning experiences, showing increased awareness of both content and learning environments. Likewise, Syukri et al. (2022) argued that critical thinking, fostered by STEAM learning, inherently promotes a mindful approach by encouraging students to be fully engaged and reflective.

Collaborative learning is another domain where STEAM education supports mindfulness. (Konkuș and Topsakal, 2022) studied gifted students over a 10-week STEAM intervention and reported improvements in attitudes, cooperative skills, and career awareness. Such collaborative activities necessitate empathy, active listening, and interpersonal regulation all components of mindfulness. Similarly, López Carrillo et al. (2024) highlighted how interdisciplinary, problem-based learning environments encouraged students' enjoyment and metacognition, further suggesting a positive link to mindful engagement.

The relationship between mindfulness and teacher training is also noteworthy. Conradty and Bogner's (2020) study on long-term professional development not only improved students' creativity and self-efficacy but also created classroom environments conducive to emotional awareness and regulation. Although the study did not explicitly measure mindfulness, its findings suggest that emotionally supportive STEAM classrooms foster key aspects of mindful behavior.

3. Method

3.1 Research design

The purpose of this scoping literature review was to examine how the integration of STEAM education can impact student's self-responsibility and mindfulness in the classroom. Scoping literature review is an emerging approach for synthesizing studies by rigorous and transparent analyses of relevant literature (Pham et al., 2014). This was done by following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021).

3.2 Data extraction process by PRISMA

The four steps (identification, screening, eligibility, and inclusion) were followed to review the studies. Since this was a literature review, the search was conducted through electronic databases. Using multiple search sources can minimize the bias when selecting journals (Leavy et al., 2023). The first step of the article selection procedure was to design the key terms to focus on and topics that would be searched to find the relevant studies aligned with the study topic. Thus, "STEM education," "STEAM education," "self-responsibility," "self-regulatory," and "practicing mindfulness" were used as keywords during the search. The journal search was restricted to the years 2019–2024. In addition, all the reviewed studies were checked for full accessibility to ensure the entire article could be read and assessed. To further minimize potential bias in literature selection, two researchers independently screened the articles based on the inclusion and exclusion criteria and worked collaboratively to resolve any discrepancies. This approach ensured consistency and transparency in the screening process and helped reduce subjective judgment. The following table summarizes the inclusion and exclusion criteria that were followed during the literature review and article selection process.

Result in this review were obtained manually through an inductive thematic analysis of the selected studies. Two researchers independently reviewed and coded the full-text articles, identifying recurring patterns related to STEAM education's influence on self-responsibility and mindfulness. Research gaps were identified by comparing the study design, educational stage, and country across studies, revealing limited direct exploration of self-responsibility and mindfulness, minimal use of validated measurement tools, and a lack of longitudinal or mixed-method approaches. This process ensured a comprehensive synthesis of current findings while highlighting areas for future research.

Table 1: Inclusion and exclusion criteria for search selection

Publication type	**Journal article**
Types of studies	Qualitative, Quantitative, Mixed methods
Year	2019-2024
Keywords	"STEM education," "STEAM education," "self-responsibility," "self-regulatory," and "practicing mindfulness"
Language	English

The keywords were incorporated into titles to search relevant articles. For literature review searches, it is recommended to use search strategies that are sensitive to the topic rather than using specific questions (Nightingale, 2009). These topics include a) Effect of STEM education on students' self-responsibility, b) Effect of STEM education on students' self-responsibility, c) How does STEAM education impact students' self-responsibility, d) Impact of STEAM education of student's self-regulatory and e) Impact of STEAM education on students' mindfulness. The search topics resulted with several relevant studies from different journals. During the process of identification, the journal selection was done based on the title and abstract. Hence, all the papers that were relevant was saved in a single folder named as "*Identification*."

The next stage was to screen the articles from the identified articles. The screening of the articles includes to remove all the duplicates that was downloaded from different databases. Once the screening was done, eligibility of the articles was checked by applying the inclusion and exclusion criteria. Any article that does not fit into the criteria was eliminated from the list and the remaining articles were included as reviewed studies.

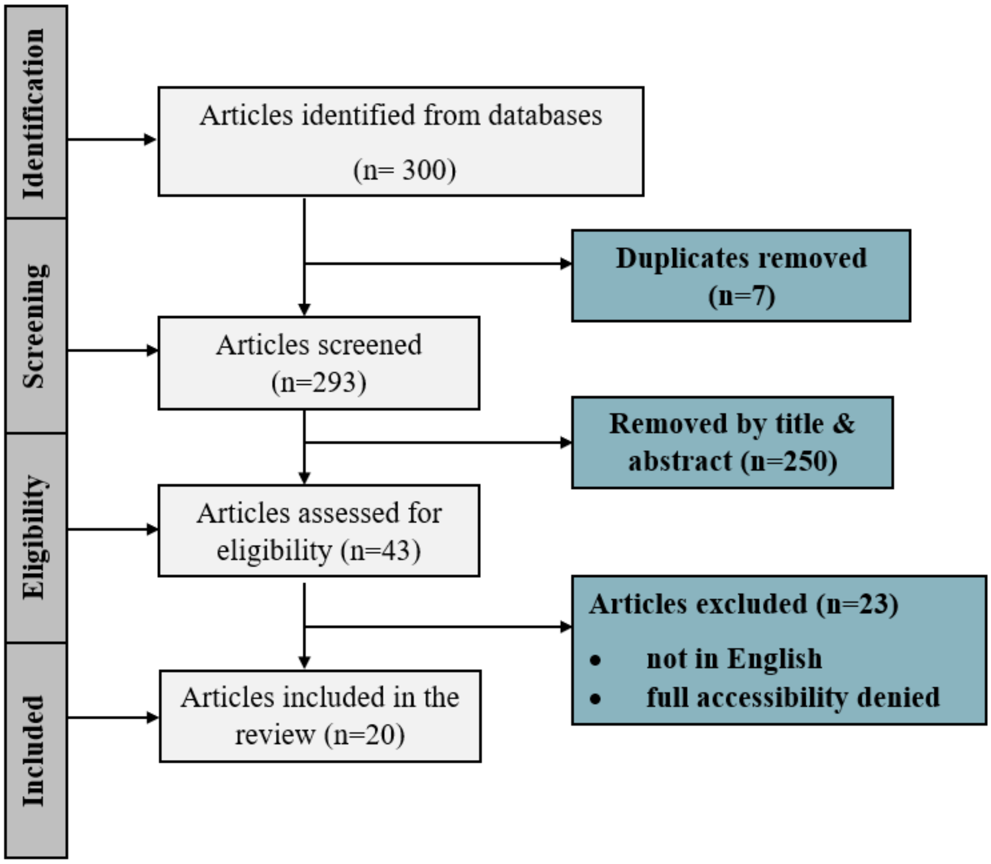

Figure 1: Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flowchart

After selecting relevant journal articles, they were read carefully and summarized in the following Table 2. Basic information like author, year, study design, educational stage, and country where the study was conducted were noted down.

Table 2: A summary of examined studies

	Author	Study design	Educational stage	Country
1	(Meral & Altun Yalçin, 2022)	Quantitative method	Secondary school	Turkey
2	(Hasibuan et al., 2022)	Quantitative descriptive study	High School	Indonesia
3	(Mohd Hawari & Mohd Noor, 2020)	Case study	Primary School	Malaysia
4	(Zheng et al., 2020)	Mixed method approach	High School	United States
5	(SARI, DUYGU, ŞEN, & KIRINDI, 2020)	Mixed method approach	University	Turkey
6	(García-Senín et al., 2022)	Mixed method approach	Secondary School	Spain
7	(Stehle & Peters-Burton, 2019)	Conversion mixed methods approach	High School	-
8	(López Carrillo et al., 2024)	Mixed method approach	Primary School	-
9	(Izzati & Dewi, 2023)	Research and Development (R&D) method	Primary School	Indonesia
10	(Kryshko et al., 2022)	Quantitative method	University	Germany
11	(Conradty & Bogner, 2020)	Quantitative method	Primary School	Germany
12	(Ardianti et al., 2020)	Quantitative method	High School	Indonesia
13	(Kim et al., 2022)	Qualitative method	College	South Korea
14	(Li et al., 2022)	Design Based Research	Primary School	China
15	(Bedar & Al-Shboul, 2020)	Quasi-experimental method	Secondary School	Jordan

16	(Nyaaba et al., 2024)	Qualitative Approach	Primary School	Ghana
17	(García-Senín et al., 2022)	Mixed method design	Secondary School	Spain
18	(Ozkan & Umdu Topsakal, 2021)	Mixed method design	Primary School	Turkey
19	(Amirinejad & Rahimi, 2023)	Quantitative method	Primary School	Iran
20	(Konkuş & Topsakal, 2022)	Mixed method design	Secondary School	Turkey

4. Results and Discussions

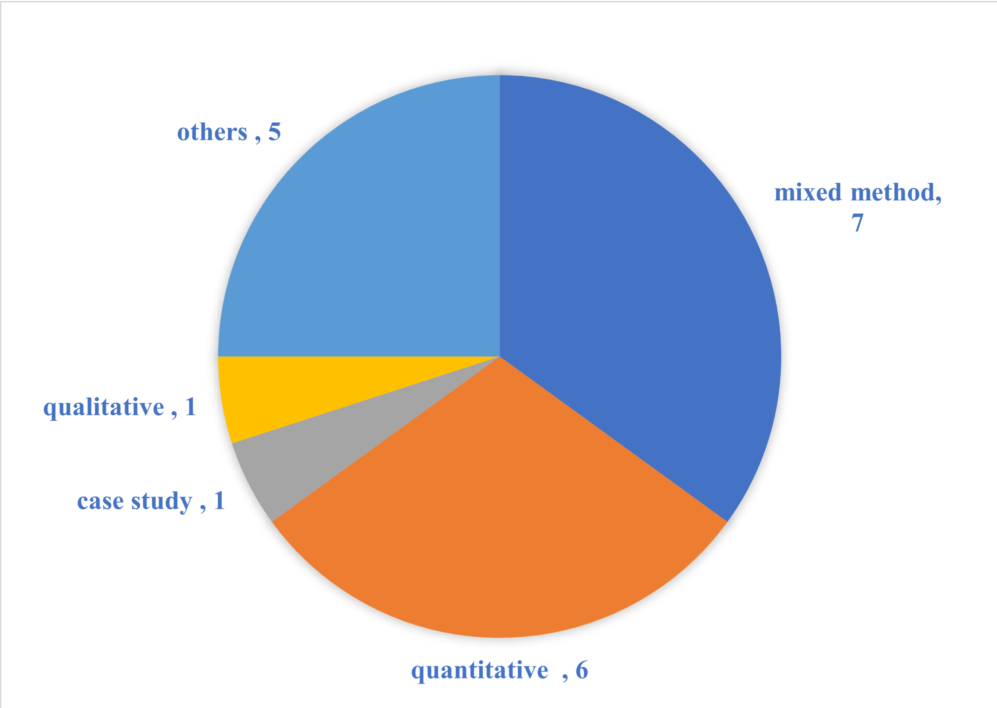

Figure 2: Study design used in the reviewed studies

The above pie chart in Figure 2 shows study designs used in the examined studies. while 6 studies have used quantitative studies, only 1 study used a qualitative design. In addition, 7 studies have opted mixed methods and 1 study used case study. Hence, majority of the studies used mixed method for their research. There is a need for qualitative methodologies, such as in-depth interviews, ethnographic studies, and case studies, that explore students' personal reflections, emotions, and behaviors as they engage with STEAM activities and gap in conducting longitudinal studies that track students' development over extended periods (Portillo-Blanco et al., 2024).

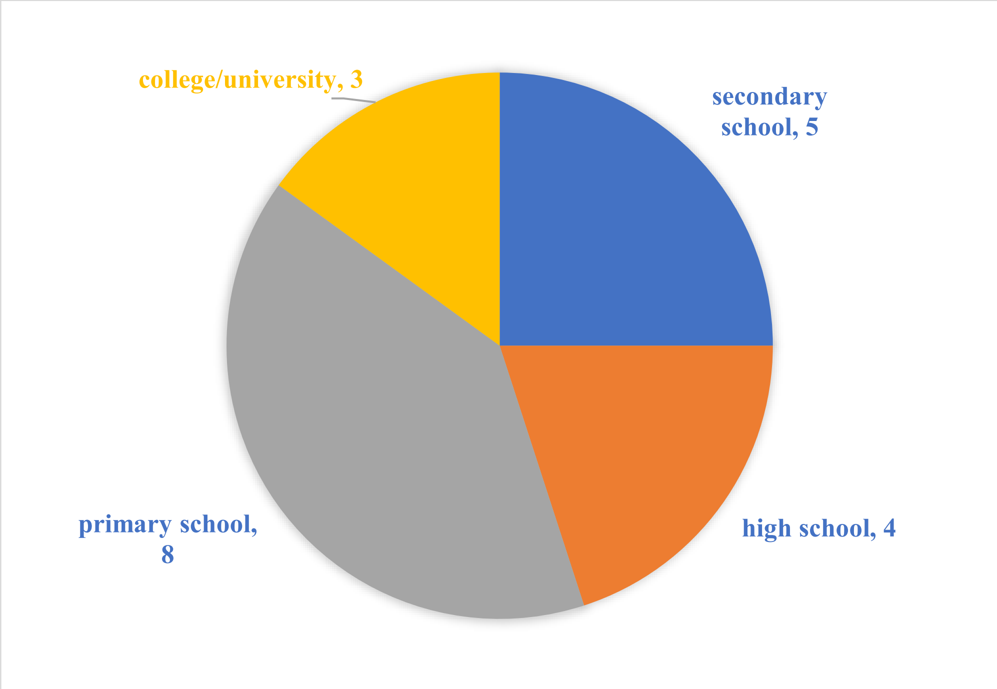

Figure 3: Educational stages of reviewed studies

The above Figure 3 summarizes educational stages of examined studies. It shows 8 studies were conducted in primary schools, 5 stdueis in secondary schools, 4 stduies in high schools and 3 studies in college/universities. From the literature it is believed Conducting studies simultaneously at different levels can contribute to attaining more generalizable results (Meral & Altun Yalçin, 2022). At the same time, it is important to find the effect of STEAM education on conceptual understanding by applying different numbers and age groups (Ozkan & Umdu Topsakal, 2021).

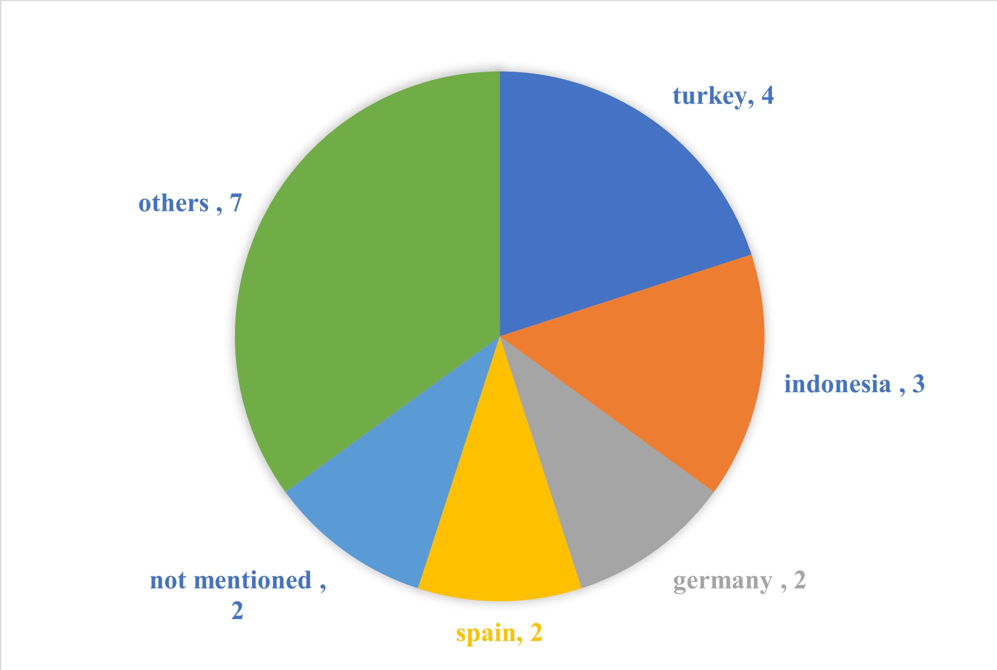

Figure 4: Countries where reviewed studies were done

Figure 4 shows geographical data about the examined studies. 4 studies were conducted in Turkey, 3 studies in Indonesia, 2 in Germany and in Spain. These countries were repeated in the examined studies while there were 7 other countries as well. 2 papers have not mentioned their selected country.

The research gaps identified from the demined studies are summarized as conceptual, methodological, empirical, and contextual gaps in the following paragraphs.

4.1 Conceptual Gaps

Limited understanding of the relationship between motivational regulation and academic satisfaction was noticed by (Kryshko et al., 2022; Meral & Altun Yalçin, 2022). While research has established a link between motivational regulation and academic performance, the relationship with academic satisfaction, a critical indicator of academic success, needs more investigation. Specifically, research should examine the role of expectancy, value, and cost as mediators in this relationship. In addition, there is lack of understanding of the interplay between different self-regulated learning process, learning context and outcomes (Hasibuan et al., 2022; Ozkan & Umdu Topsakal, 2021). Existing research predominantly focuses on variable-oriented approaches, neglecting the complex interactions between different regulatory processes, learning contents, tools, strategies, and learning outcomes. Underdeveloped theoretical frameworks for examining the impact of STEAM education on conceptual learning is another gap found through this literature review (Mohd Hawari & Mohd Noor, 2020; Zheng et al., 2020). Despite the growing popularity of STEAM education, there is a lack of robust theoretical frameworks to guide research on its effects on conceptual learning. More research is needed to clarify how integrating arts into STEM education can enhance understanding and address misconceptions in STEM concepts.

4.2 Methodological Gaps

The heavy reliance on variable-oriented approaches limits understanding of the diverse profiles and behavioural patterns of self-regulated learners in specific contexts. The adoption of person-oriented approaches, such as cluster analysis, can offer richer insights into individual differences in self-regulated learning (Hasibuan et al., 2022; Sari, Duygu, Şen, & Kirindi, 2020). There is a need to move beyond self-reported data and utilize behavioural trace data collected from computer-based learning environments, widely used in engineering design, to objectively capture and analyse students' SRL processes and strategies (Hasibuan et al., 2022). In addition, studies have highlighted need for more experimental research designs in studies on STEAM education.

Existing research on STEAM education predominantly relies on correlational or descriptive designs, limiting causal inferences about its effectiveness. The implementation of randomized controlled trials or quasi-experimental designs with control groups would enable researchers to establish causal relationships between STEAM interventions and learning outcomes (Izzati & Dewi, 2023; Mohd Hawari & Mohd Noor, 2020; Zheng et al., 2020). The examined studies showed there is limited studies using mixed method research design which is an essential paradigm to capture the complex nature of STEAM education. A greater integration of qualitative and quantitative data would provide a more holistic and comprehensive understanding of complex learning phenomena (Bedar & Al-Shboul, 2020; López Carrillo et al., 2024).

4.3 Empirical Gaps

Due to the small sample size and focus on specific STEAM discipline, the findings cannot be generalized (Amirinejad & Rahimi, 2023; Nyaaba et al., 2024). To improve generalizability, future research needs to incorporate larger samples and investigate the applicability of findings across various STEM disciplines and other fields, such as humanities. Apart from this, there is a lack of longitudinal studies exploring the development of 21st Century skills in students over time. Longitudinal research is needed to examine how inclusive STEAM high schools promote the development of 21st Century skills, such as collaboration, problem-solving, and self-regulation, in students over an extended period.

4.4 Contextual Gaps

More research is needed to understand how the unique characteristics of specific STEM disciplines and learning environments shape SRL processes and strategies (Conradty & Bogner, 2020; Ozkan & Umdu Topsakal, 2021). Future research should investigate the influence of factors such as cultural background, gender, age, socioeconomic status, and prior knowledge on the effectiveness of self-regulated learning interventions and STEAM education programs (Ardianti et al., 2020; Stehle & Peters-Burton, 2019). Despite the growing interest in learning analytics, there is a need for more research in the context of secondary school education, particularly on how learning analytics data can be used to support students' self-regulated learning and academic achievement. The studies emphasize that addressing these research gaps is critical to advancing the field and informing the development of effective interventions and pedagogical practices that support student learning and success in STEAM.

4.5 Practical implications for educators

Educators play a pivotal role in enhancing student learning and well-being by implementing integrated pedagogical strategies such as STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. This interdisciplinary approach fosters essential 21st-century skills including critical thinking, creativity, collaboration, problem-solving, and self-management (Nyaaba et al., 2024; Ozkan & Umdu Topsakal, 2021). Central to its effectiveness is the emphasis on hands-on, exploratory, and student-cantered activities that reflect real-world challenges and encourage diverse solutions (Mohd Hawari & Mohd Noor, 2020). Promoting self-regulated learning (SRL) within these environments is crucial, as it enables students to actively monitor and manage their motivation and learning progress (Kryshko et al., 2022). Developing students' self-efficacy for motivational regulation, especially among those with low confidence can lead to more independent and resilient learners. Creating safe, supportive learning environments where mistakes are viewed as opportunities is critical in this regard (Ozkan & Umdu Topsakal, 2021).
Integrating the arts into STEM enhances conceptual understanding by making learning more relatable, engaging, and accessible. However, effective STEAM implementation requires addressing systemic challenges such as teacher shortages and insufficient interdisciplinary collaboration. Cooperative teaching models, where subject specialists co-plan and co-teach, offer a promising solution (Li et al., 2022). Additionally, sustained professional development focused on practical STEAM methodologies not merely theoretical instruction is essential for equipping teachers (Mohd Hawari & Mohd Noor, 2020). To maximize STEAM's impact, varied assessment methods should be used across all domains, and curriculum adjustments, including extended instruction time, may be necessary to ensure student engagement and holistic development (Li et al., 2022; Zheng et al., 2020).

Integrating STEAM education for self-responsible and mindful practices among students presents a complex picture, revealing both promising outcomes and significant limitations or contradictory findings across many studies. While many studies highlight the benefits of STEAM in fostering self-regulated learning (SRL) and motivation, others show limited or inconsistent effects. For example, Hasibuan et al. (2022) reported that digital storytelling and STEAM-based e-learning tools enhanced students' self-regulation, including academic self-regulation and both introjected and external regulation. However, other studies present less optimistic results. Meral and Altun Yalçin (2022) conducted an 8-week entrepreneurship-based STEM program and found no significant change in students' overall self-regulation skills, although there were improvements in sub-dimensions like "openness" and "seeking," as well as increased self-efficacy. Similarly, Bedar and Al-Shboul (2020) found that a STEAM intervention did not significantly impact motivation, self-efficacy, or career interest, though it did help reduce class-related anxiety. Conradty and Bogner (2020) also noted that while a professional development initiative improved students' creativity and self-efficacy, it had no effect on career motivation. Notably, their findings suggested that pre-existing levels of motivation and creativity influenced outcomes more strongly than the STEAM intervention itself, indicating that learner characteristics may moderate the effectiveness of STEAM programs.

5. Conclusion

The integration of STEAM education holds strong potential for developing students' self-responsibility and mindfulness by promoting critical thinking, problem-solving, and independent learning. Its collaborative nature also fosters social-emotional skills, encouraging students to be more mindful of themselves and others. However, several gaps remain. Methodologically, studies often rely on self-reported data and lack experimental or mixed-method approaches. Empirical limitations include small sample sizes and the absence of longitudinal research to track long-term effects. Contextual factors such as diverse learning environments and student backgrounds also remain underexplored. To strengthen the field, future research should adopt more rigorous designs, use validated tools to measure mindfulness and self-responsibility, and incorporate these constructs explicitly into teacher training and curricula. This approach will help ensure that STEAM education supports not only academic success but also the holistic growth of responsible, mindful learners.

6. Recommendations

The recommendations are as follows;

1. Educator Training and Support: Efficiency in teacher training and Investment in professional development programs for educators to equip them with the necessary skills and knowledge to effectively deliver STEAM education. This includes workshops, seminars, and collaborative learning opportunities that focus on interdisciplinary teaching methods.

2. Resource Allocation: It is vital to ensure equitable access to STEAM resources, including technology, laboratory equipment, and creative materials, across all schools. Precise focus is needed for peripheral communities. This will enable to bridge the gap and provide all students with equal learning opportunities.

3. Curriculum Development: Develop a comprehensive and balanced STEAM curriculum that integrates the arts with science, technology, engineering, and mathematics in a blended and meaningful manner. Clear emphasis should be on both theoretical knowledge and practical applications for fostering a well-rounded educational experience hence prepare students for life.

4. Research and Evaluation: Further research needs to be conducted to identify effective strategies for integrating STEAM education in the current teaching models. This is vital to assess its impact on the students' self-responsible and mindful practices. Furthermore, longitudinal studies are highly recommended to track students' progress and the long-term benefits of STEAM education.

5. Collaborative Learning Environments: Create collaborative learning spaces that encourage teamwork, creativity, and innovation. These environments should facilitate hands-on projects, experiential learning, and interdisciplinary collaboration among students.

6. Community and Industry Partnerships: Partnership with community and social responsibility of the local communities and industries need to be flourished. This will provide students with real-world experiences and mentorship opportunities. These partnerships can enhance the relevance of STEAM education and prepare students for a better carrier guidance.

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