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Integrating the Engineering Design Process (EDP) in Stem Classroom: A Systematic Literature Review of Impacts and Challenges

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Abstract

The engineering design process (EDP) represents a systematic and iterative methodology for addressing problems and developing effective solutions. In this regard, the current study explores both the prevailing trends and the challenges encountered in implementing EDP within classroom settings. A systematic literature review (SLR) was guided by the PRISMA protocols with data extracted and analyzed from 27 peer-reviewed publications from 2020 to 2025. Implementation efforts span various educational levels from early childhood to the high school students. Findings from the thematic analysis indicate that integrating EDP into STEM teaching and learning yields five key dimensions: (a) the development of 21st-century competencies, (b) enhanced student engagement and motivation particularly within STEM domains, (c) the implementation of scaffolded teaching approaches, (d) iterative problem-solving processes that explicitly incorporate learning from failure and (e) the contextualization of learning through authentic real-world scenarios, interdisciplinary connections, and inclusive educational environments. In addition, this SLR identified five principal barriers: (a) curriculum constraints, (b) insufficient teacher preparedness, (c) student engagement issues and motivation, (d) resource limitations and learning environment, and (e) task complexity and assessment difficulties. To address these issues, the review recommends that student interests be prioritized during implementation, professional development opportunities for teachers be expanded and continued empirical research on EDP be encouraged to further optimize pedagogical practices.

Keywords: Engineering Design Process, STEM Education, Impacts, Challenges, Systematic Review

Introduction

The Engineering Design Process (EDP) constitutes an educational approach that introduces engineering practices. This methodology develops student design capabilities to guide educational artifact creation. Learners apply scientific knowledge and mathematical principles to analyze and solve authentic real-world problems. Students further develop open-ended design comprehension through collaborative skill-building, innovative idealization, scientific application, prototype testing analysis, and creative pursuit throughout learning. Consistent with this, Tipmontiane and Williams (2021) characterize EDP's iterative steps as creative learning processes integrating science, mathematics, and technology concepts.

The processes encompassed by the EDP involve defining the problem, reviewing relevant literature, generating and evaluating ideas to select the optimal solution, developing and testing prototypes, refining the final design and disseminating the results to others (Hafiz & Ayop, 2019; Fan et., 2020). Moreover, every phase of the EDP cultivates students' critical thinking, creativity and collaboration while simultaneously reinforcing essential competencies such as problem-solving, effective communication and informed decision-making. Similarly, Ngo (2024) asserts that by designing, constructing and evaluating their prototypes, learners directly confront and revise their scientific conceptions. Thus, uncovering and correcting misunderstandings.

Fan et al. (2020) outline a structured framework for implementing an engineering-focused STEM curriculum specifically tailored to secondary technology and engineering educators. Furthermore, Bunprom et al. (2019) reported that tenth-grade students exhibited clear proficiency in engineering design process skills. The instructional activities employed in their study also encouraged learners to integrate science, technology, engineering, and mathematics (STEM) principles to address problems within specified contexts. Šafhalter et al. (2020) similarly found that engineering design–based tasks significantly enhanced middle school students' spatial reasoning abilities. Syukri et al. (2018) investigated the incorporation of the EDP into physics learning modules and observed marked improvements in secondary students' problem-solving skills.

This study is grounded in theoretical frameworks that correspond with constructivist and design-based learning perspectives. In these frameworks, knowledge is not merely transferred or passively acquired; instead, based on Sung et al. (2025), it is actively constructed through genuine inquiry that prompts learners to explore, question, and engage deeply with the subject matter. Active construction of knowledge is amplified through iterative problem-solving, as learners face challenging situations and systematically navigate difficulties (Robert et al., 2022), resulting in a deeper understanding and better retention of information. Furthermore, the focus on collaborative engagement cultivates an environment where learners can exchange ideas, challenge each other (Zhang et al., 2020) and co-create knowledge, enhancing the overall learning experience (Chen & Chen 2025). This conceptual lens serves as a robust foundation for understanding how the Engineering Design Process (EDP) can effectively support the development of higher-order thinking skills and facilitate deep learning in the context of science education.

Radloff et al. (2019) documented the incorporation of engineering design into undergraduate biology through a life-science design task that employed both quantitative and qualitative methodologies. In their study, participants were tasked with researching and constructing a composting process model aimed at aiding Puerto Rican communities in post-hurricane recovery. Lakose (2015), meanwhile, concentrated on creating engineering-design-oriented learning activities aligned with the United States' Next Generation Science Standards (NGSS) that were driven by a recognized need for more life-science exercises integrating engineering principles. Although STEM applications in particular engineering are widely advocated, Lakose contends that engineering integration within STEM curricula remains nascent. In contrast, English and King (2015) explored how to embed engineering into elementary education by adapting five comprehensive core design-thinking processes specifically for young learners. Collectively, these investigations affirm that engineering design–based pedagogies offer considerable benefits for STEM students and enhance educational outcomes.

Ali and Tse's (2023) bibliometric analysis charted research trends and emerging issues in the engineering design process within STEM education from 2011 to 2021. Their systematic review identified several leading EDP such as employing the process to bolster teachers' professional development, weaving design thinking and computational thinking through the engineering design framework, enhancing students STEM competencies, examining the interplay between scientific inquiry and design methodology and utilizing EDP to mitigate gender gaps in STEM (Winarno et al., 2020). Additionally, they underscored ongoing challenges and future research opportunities which included the need for deeper integration of STEM disciplines, expanded EDP-centred professional training, solutions to computational and design thinking challenges and more nuanced studies of learner behaviour throughout the engineering design process.

Winarno et al. (2020) conducted a systematic review of empirical studies on the engineering design process in science education between 2010 and 2020. Their analysis revealed that engaging students in the engineering design process not only strengthens cognitive and procedural skills but also cultivates positive attitudes toward learning. They further highlighted that EDP represents an emerging trend in science teaching underscoring the need for research-derived evidence to inform policy decisions affecting educators, learners, and other stakeholders. Accordingly, the objective of this study is to evaluate the implications of integrating teaching strategies with the Engineering Design Process (EDP) for school-level students and to identify the key challenges in implementing EDP within STEM education at schools. By clearly delineating this scope, the study contributes both theoretically and practically towards advancing engineering design as a transformative approach in STEM education.

Research Questions

In this study, the formulation of the research questions was guided by the PICo model. An acronym of "P" denotes "Population" or "Problem," "I" represents "Interest," and "Co" refers to "Context" (Shaffril et al., 2021). These three elements collectively informed the development of the research questions for this systematic literature review.

In the context of this study, the "Population" refers to students in schools that are involved in STEM implementation, the "Interest" is the integration of EDP to assess its impacts and challenges, and the "Context" in terms of STEM education at schools. Based on these components, the following two research question (RQ) were developed:

1. Assessing the implication of integrating instructional strategies with the Engineering Design Process (EDP) on students at the school level.
2. Identifying key challenges in the implementation of the Engineering Design Process (EDP) within STEM education in schools.

Methodology

This study constitutes a systematic literature review (SLR) is a rigorous, methodical approach to examining extant research and publications on a specific topic which is the classroom enactment of the engineering design process. The review involves identifying, appraising and synthesizing pertinent studies to provide a comprehensive understanding of the subject matter (Sauer & Seuring, 2023; Snyder, 2023) . Specifically, the inquiry entailed articulating precise research questions, establishing inclusion and exclusion criteria, conducting exhaustive searches across multiple databases, and critically appraising the methodological quality of the selected studies. By systematically organizing and analyzing the findings, the study aims to delineate prevailing trends and challenges in classroom implementation of the engineering design process and to offer actionable insights and directions for future research and practice.

Identification

According to Mohamed Shaffril et al. (2020), the identification stage requires the careful selection of keywords including synonyms, related terms, and variations. This to ensure that search results capture relevant studies. In this study, the keywords “engineering design process” and “engineering design” were employed by additional search terms such as science education or STEM education to retrieve pertinent articles from the Scopus and Web of Science (Table 1). The combinations of these keywords were processed using search functions such as field code functions, phrases searching, wildcards, truncation and Boolean operators in two databases. Initially, a total of 43,812 potential articles related to the engineering design process were identified from the selected databases.

Table 1
Search string used in the selected database

Database	String
Scopus	TITLE-ABS-KEY = ((“engineering design process*” OR “EDP*” AND *) AND (“STEM education*" OR "science education*”) AND (“secondary school*" OR "middle school*" OR "secondary education*"))
Web of Science (WOS)	TS = = ((“engineering design process*” OR “EDP*” AND *) AND (“STEM education*" OR "science education*”) AND (“secondary school*" OR "middle school*" OR "secondary education*"))

Screening

Screening was the second procedure carried out where articles were either included or excluded. It has been done with the assistance of the database and manually screened by the author from the study based on a specific set of criteria (see Table 2). Considering the concept of ‘research field maturity’ emphasised by Kraus et al. (2020), this review limited the screening process to only include the articles published between 2020 and 2025.

Table 2
Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Timeline	2020 - 2025	2019 and earlier
Document type	Articles (with empirical data)	Review article, chapter in a book, book, conference proceeding, etc
Languages	English	Non- English
Subject area	Social science	Environmental science, engineering, geography, other non-social science research
Access to full text	All open access	Limited or no access

This timeline was chosen given that the number of published studies was sufficient to perform a representative review. Notably, to avoid confusion, only those written in English were considered. Since the SLR objective related to schools' level, choosing educational research studies as one of the criteria was believed to increase the possibility of acquiring more articles related to schools. A total of 43,558 articles were excluded from the review during this stage since they were not in line with the inclusion requirement. This resulted in 254 remaining articles for evaluation in the subsequent stage.

Eligibility

The authors manually screened all remaining articles against additional criteria including verification of 'final publication stage' and 'journal' source type in Scopus alongside Web of Science indexing in the specific 'Education and Educational Research' category. This determined eligibility against predefined inclusion criteria. Thus, 192 articles were excluded. A further seven additional duplicates were identified and excluded. Therefore, 62 articles remain with full text for next evaluation in the subsequent stage.

Exclusion

Twenty-eight articles were excluded due to title and abstract mismatch. Although these publications technically satisfied all predefined eligibility criteria, subsequent full-text assessment revealed substantive non-conformity with the study's scope parameters (see Figure 1). Specifically, they addressed educational contexts beyond the authors' selection framework: non-school educational levels, samples restricted to teachers and policymakers, higher education student cohorts, or university level instructional subjects. Consequently, this selection yielded 27 studies fulfilling all eligibility criteria for access and analysis. Table 3 shows that all the articles provide the foundational evidence required to address the research questions.

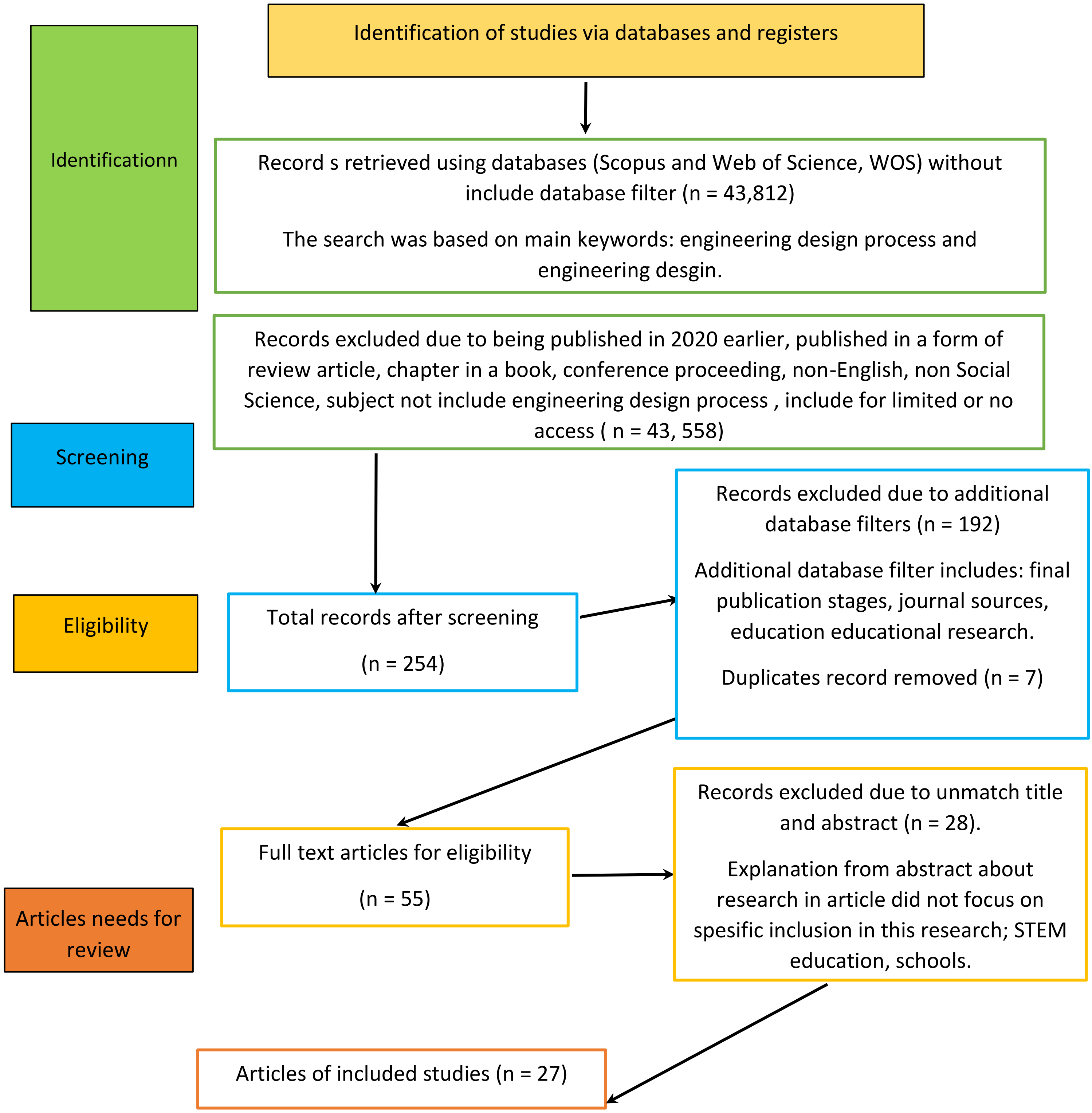

Figure 1: PRISMA Model Flow Chart
Source: Adapted from PRISMA Model by Page et al. (2021)

Table 3
List of Selected Articles

No	Author and year	Title of Article
1.	Martin et al. (2020)	Promoting Science, Technology, and Engineering Self-Efficacy and Knowledge for All with an Autism Inclusion Maker Program
2.	Aranda et al. (2020)	Productive thinking in middle school science students' design
3.	Hite et al. (2020)	STEM challenge: two years of community-engaged engineering
4.	Gencer et al. (2020)	Developing biomimicry STEM activity by querying the relationship between structure and function in organisms
5.	Dedetürk et al. (2021)	The effects of STEM activities on 6th grade students' conceptual development of sound
6.	Zhou et al. (2021)	Examining Middle School Students' Engineering Design Processes in a Design Workshop
7.	Guzey et al. (2021)	Productive Thinking and Science Learning in Design Teams
8.	Ergül & Çalış (2021)	Examination of High School Students' Engineering Design Skills: Example of Electromagnetism
9.	Anggoro et al. (2021)	Developing an Observation Tool to Measure Preschool Children's Problem-Solving Skills
10.	Gök & Sürmeli (2022)	The Effect of Scientific Toy Design Activities Based on the Engineering Design Process on Secondary School Students' Scientific Creativity
11.	Duong et al. (2022)	Applying STEM Engineering Design Process through Designing and Making of Electrostatic Painting Equipment in Two Rural Schools in Vietnam
12.	Kocaman (2023)	Investigation of the effects of STEM activities on STEM attitude in gifted students
13.	Xue et al. (2023)	The Development and Validation of an EDP-STEM Module—Taking Heat Transfer, Mechanics, and Buoyancy as Examples
14.	Baze et al. (2023)	Understanding student use of epistemic criteria in engineering design contexts
15.	Putra et al. (2023)	Development of the Engineering Design Process (EDP) on the Ability to Design Prototypes to Increase Natural Disaster Mitigation for Elementary Schools in Indonesia
16.	Precharattana et al. (2023)	Blended Engineering Design Process Learning Activities for Secondary School Students during COVID-19 Epidemic: Students' Learning Activities and Perception
17.	Simpson et al. (2023)	Children's engineering identities-in-practice: An exploration of child-adult interactions in an out-of-school contect.
18.	McNair & Hayward (2023)	How do engineers do that? —An interactive introduction to the engineering design process for secondary age school pupils
19.	Putra et al. (2023)	Exploring Students' Critical Thinking Skills Using the Engineering Design Process in a Physics Classroom
20.	Putra et al. (2023)	Gender roles in engineering design process activity: A small group exploration through collaborative argumentation
21.	Kim & Park (2023)	Elementary Students' Management of Conflicts in an Engineering Design Process and Its Effects on Their Group Interaction Progress
22.	Thomason & Hsu (2024)	The effect of a STEM integrated curriculum on design thinking dispositions in middle school students

23.	Ioannou et al. (2024)	Condensation and precipitation of water vapor: The emergence of a Precursor Model through the Engineering Design Process
24.	Barajas-Salazar et al. (2025)	Culturally relevant informal STEM learning for underserved students: effects of repeated exposure to the engineering design process
25.	Pramasdyahsari et al. (2025)	Developing engaging STEAM-geometry activities: Fostering mathematical creativity through the engineering design process using Indonesian cuisine context
26.	Thammaariyasaakun et al. (2025)	Development of a Virtual Learning Environment with the Engineering Design Process to Enhance Students' Creative Thinking Skills
27.	Hewitt an & Forcino (2025)	The influence of a STEM unit on the interest in and understanding of science and engineering between elementary school girls and boys

Findings and Discussion

Background of Studies

The earliest publications start in 2020, four featuring works by Marttin et al. (2020), Aranda et al. (2020), Hite et al. (2020), and Gencer et al. (2020). Continuing into 2021, there is five steady contributions with studies by Dedetürk et al. (2021), Zhou et al. (2021), Guzey et al. (2021), Ergül and Çalış (2021), and Anggoro et al. (2021). The year 2022 marks the involvement of two authors such as Gök and Sürmeli (2022) and Duong et al. (2022). The year 2023 shows a ten of relatively denser publication activity including Kocaman (2023), Xue et al. (2023), Baze et al. (2023), Putra, P et al. (2023), Precharattana et al. (2023), Simpson et al. (2023), McNair and Hayward (2023), Kim and Park (2023). The author in this articel identified that in 2023, a single lead author published two distinct articles with co-authors, both addressing different aspects of the EDP namely Putra et al. (2023) within the same calendar year. Advancing into 2024, two studies by Thomason and Hsu (2024) and Ioannou et al. (2024) are noted and there were four studies recorded by Barajas-Salazar et al. (2025), Pramasdyahsari et al. (2025), Thammaariyasaakun et al. (2025) and Hewitt and Forcino (2025) as shown in Figure 2.

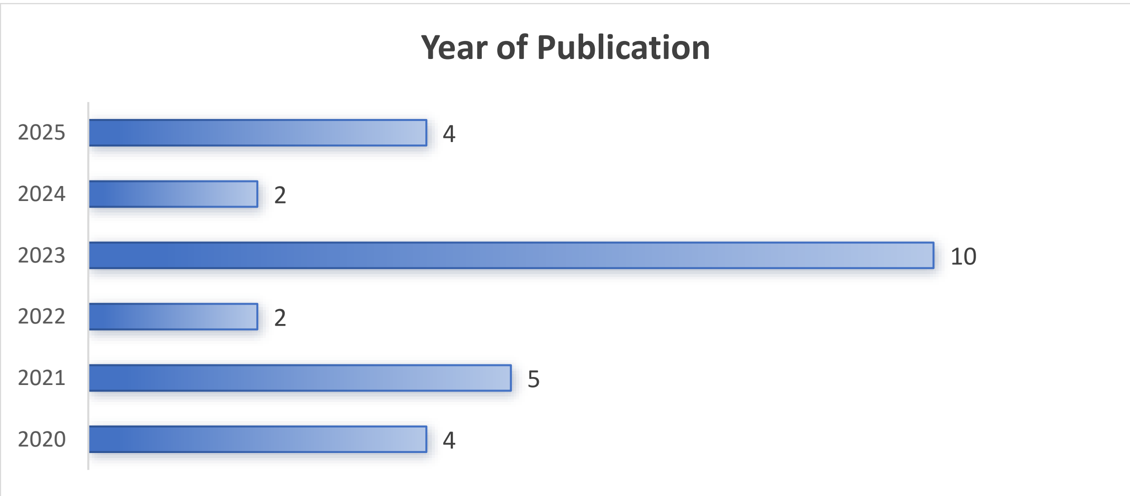

Figure 2: Number of articles published between 2020 and 2025

The United States emerges as the principal contributor to the study as distinguished by the highest number of publications (Marttin et al., 2020; Aranda et al., 2020; Hite et al., 2020; Zhou et al., 2021; Guzey et al., 2021; Anggoro et al., 2021; Baze et al., 2023; Simpson et al., 2023; Thomason & Hsu, 2024; Barajas-Salazar et al., 2025; Hewitt & Forcino, 2025). This predominance likely reflects greater resource allocation and established research infrastructures that facilitate continuous scholarly production. Turkey constitutes the second major locus of activity with repeated contributions between 2020 and 2022 (Gencer et al., 2020; Dedetürk et al., 2021; Ergül & Çalış, 2021; Gök & Sürmeli, 2022; Kocaman, 2023) signalling growing engagement and emergent prominence. Indonesia also appears as a vigorous centre marked by recurrent author clusters (Putra et al., 2023; Putra et al., 2023; Putra et al., 2023; Pramasdyahsari et al., 2025) which emphasize its rising regional and international visibility. Smaller but geographically diverse contributions from the UK (McNair & Hayward, 2023), Republic of Korea (Kim & Park, 2023), Greece (Ioannou et al., 2024), China (Xue et al., 2023), Thailand (Thammaariyasaasakun et al., 2025; Precharattana et al., 2023) and Vietnam (Duong et al., 2022; Anggoro et al., 2021) underscore the field's expanding global reach. Collectively, these patterns (see Figure 3) indicate concentration in specific research hubs alongside an ongoing international diversification.

The analysis of educational levels (see Figure 4) reveals that the majority of studies focus on junior or middle school students (n=16) followed by elementary school (n=5), secondary or high school (n=4) and early childhood or preschool (n=2). Research in early childhood education targeting children aged 3–5 years Anggoro et al., (2021) and Ioannou et al., (2024) that offering foundational insights into developmental and pedagogical considerations for the youngest learners. Elementary-level investigations address two cohorts, third grade (8–9 years) examined by Hewitt & Forcino (2025), Simpson et al., (2023), and Kim & Park (2023), and fifth grade (10–11 years) studied by Gencer et al., (2020) and Putra, P et al., (2023) that highlighting instructional strategies and learning pathways. The predominance of middle school research underscores the developmental significance of ages 11–14 which is a period of expanding academic demands and subject diversification. Within this category, studies focus on sixth graders (Marttin et al., 2020; Aranda et al., 2020; Hite et al., 2020; Dedetürk et al., 2021; Guzey et al., 2021), seventh graders (Thomason & Hsu, 2024; Zhou et al., 2021; Gök & Sürmeli, 2022; Precharattana et al., 2023; Kocaman) and eighth graders (Putra, M et al., 2023; Xue et al., 2023; Baze et al., 2023; McNair & Hayward, 2023). Broader grade-range studies (Barajas-Salazar et al., 2025; Pramasdyahsari et al., 2025) further reinforce the centrality of this stage. Secondary or high school research (ages 14–17) addresses the transition to specialized curricula and preparation for post-secondary pathways. Thammaariyasakun et al., (2025) investigate ninth graders, Putra, M et al., (2023) examine tenth graders, while Ergül & Çalış (2021) and Duong et al., (2022) focus on eleventh-grade cohorts. Collectively, these distributions highlight a concentration of scholarly attention at the middle school level, complemented by targeted inquiries across earlier and later stages of formal education.

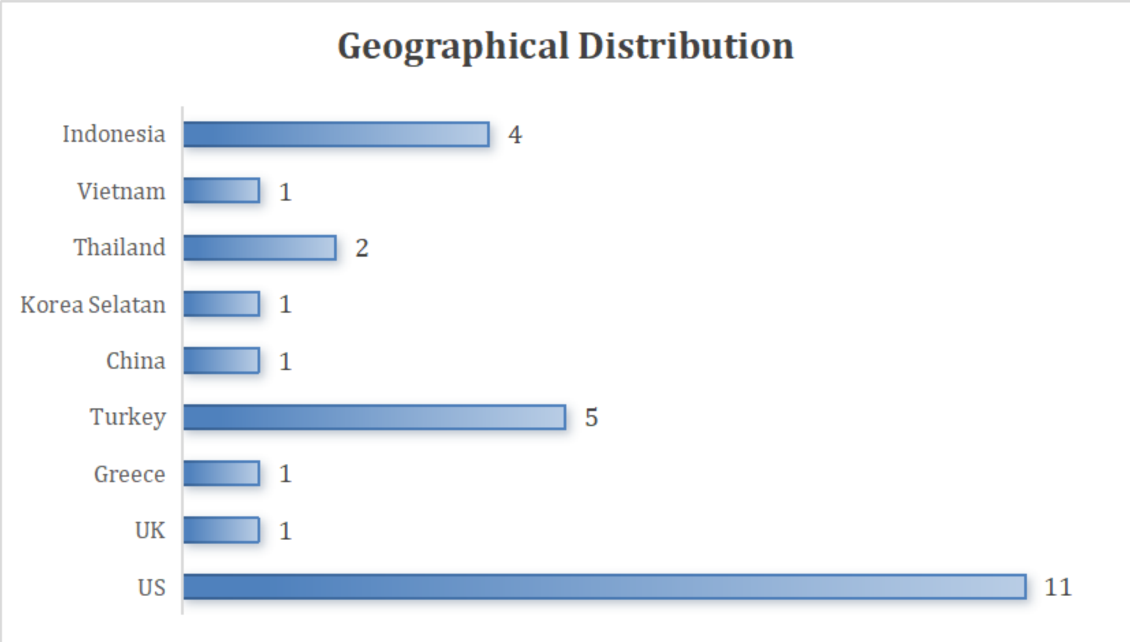

Figure 3: Countries where the selected studies were conducted

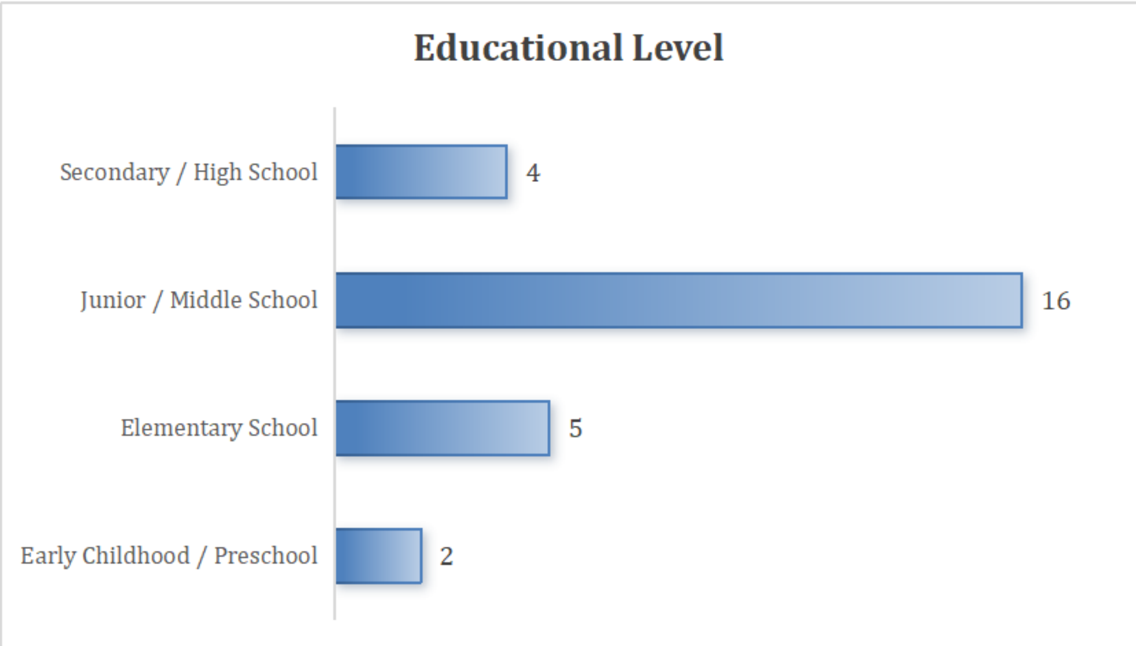

Figure 4: Educational level of school in the studies

The Developed Themes

The implication of instructional strategies integrated with the EDP on students at school levels - RQ 1

Extensive research examining the integration of instructional strategies with the Engineering Design Process (EDP) demonstrates significant implications for student learning outcomes across school levels. Thematic analysis of these studies reveals consistent advancements in five critical dimensions: (a) the development of 21st-century competencies, (b) enhanced student engagement and motivation particularly within STEM domains, (c) the implementation of scaffolded teaching approaches, (d) iterative problem-solving processes that explicitly incorporate learning from failure and (e) the contextualization of learning through authentic real-world scenarios, interdisciplinary connections, and inclusive educational environments as shown in Table 3.

Table 3
Implication of approached strategies with EDP on student

Author	Themes				
	Development of 21st-Century Competencies	Enhancement of Student Engagement, Motivation, and STEM Identity	Scaffolded Teaching Practices and Supportive Instructional Strategies	Iterative Problem-Solving and Learning from Failure as Core to EDP	Contextualization through Real-World, Interdisciplinary, and Inclusive Learning Environments
Marttin et al. (2020)		/	/		/
Aranda et al. (2020)	/	/		/	
Hite et al. (2020)	/	/		/	
Gencer et al. (2020)		/		/	/
Dedetürk et. al (2021)			/		/
Zhou et al. (2021)	/			/	
Guzey et al. (2021)	/		/		/
Ergül & Çalış (2021)	/	/			/
Anggoro et al. (2021)	/	/		/	
Gök & Sürmeli (2022)		/			/
Duong et al. (20222)	/	/	/		
Kocaman (2023)	/			/	/
Xue et al. (2023)		/		/	/
Baze et al. (2023)		/	/		/
Putra et al. (2023)	/			/	/
Precharattana et al. (2023)			/	/	/
Simpson et al. (2023)	/	/			/
McNair and Hayward (2023)		/		/	
Putra et al. (2023)			/		/
Putra et al. (2023)			/		/
Kim & Park (2023)	/		/		
Thomason & Hsu (2024)		/	/		
Ioannou et al. (2024)		/			/
Barajas-Salazar et al. (2025)		/			/
Pramasdyahsari et al. (2025)				/	/
Thammaariyasaakun et al. (2025)	/		/	/	
Hewitt & Forcino (2025)	/	/			

Multiple studies highlight the advancement of critical competencies necessary for modern education and workforce preparation. Research by Marttin et al. (2020) and Aranda et al. (2020) in their studies demonstrates that EDP-embedded instructional approaches develop problem-solving, creativity, collaboration, and communication skills (Hite et al., 2020;

Guzey et al., 2021; Ergül and Çalış, 2021; Duong et al., 2022). These competencies as stated by Kocaman (2023) emerge through student engagement with authentic engineering challenges that simulate real-world dilemmas, thus fostering adaptability and critical thinking (Xue et al., 2023).

The motivational aspect of EDP-integrated teaching is highlighted across multiple studies. Authors such as Baze et al. (2023) and Putra et al. (2023) demonstrate that these instructional strategies significantly increase students' intrinsic engagement and motivation which positively impact their STEM identity formation (Precharattana et al., 2023; Simpson et al., 2023). This effect is attributed to contextualized learning tasks that make STEM disciplines accessible, relevant, and personally meaningful. Barajas-Salazar et al. (2025) and Pramasdyahsari et al. (2025) further strengthen this view by underscoring the link between motivational scaffolds and inclusive learning environments that empower diverse student populations.

Effective implementation of scaffolded teaching emerges as a vital pedagogical approach. Marttin et al. (2020) and Aranda et al. (2020) consistently document how supportive instructional strategies scaffold students' cognitive processes and skill acquisition within iterative EDP cycles (Hite et al., 2020; Ergül & Çalış, 2021; Anggoro et al., 2021). McNair and Hayward (2023) along with Thomason and Hsu (2024) provides evidence that structured support reduces cognitive load, enabling progressive mastery over complex engineering tasks. These studies highlight the importance of instructional sequencing and timely feedback in sustaining student progress.

A distinctive feature of EDP-focused strategies is the emphasis on iterative problem-solving paired with learning from failure. This dimension is echoed by researchers including (Marttin et al., 2020); Aranda et al., 2020; Thammaariyasaakun et al., 2025) who argue that embracing failure as a learning opportunity fosters resilience and deeper conceptual understanding. These findings are discussed by (Ioannou et al., 2024; Hewitt & Forcino, 2025) who position iterative experimentation as fundamental in cultivating a growth mindset and engineering habits of mind.

The final theme relates to situating learning experiences within meaningful, authentic contexts. Gencer et al. (2020) and Guzey et al. (2021) focus on the pivotal role of designing interdisciplinary projects that reflect real-world challenges and promote exclusivity. These approaches anchor student engagement and facilitate the application of STEM concepts beyond the classroom, extending to societal relevance (Putra et al., 2023; Barajas-Salazar et al., 2025). This broad and inclusive framing ensures diverse learners see themselves as competent participants in STEM fields.

Key Challenges in the Implementation of the EDP in STEM Education at Schools - RQ 2

The effective classroom implementation of the Engineering Design Process (EDP) in STEM education confronts multifaceted challenges requiring targeted pedagogical approaches. Collective research evidence identifies five principal barriers (Table 4); (a) curriculum constraints, (b) insufficient teacher preparedness, (c) student engagement issues and motivation, (d) resource limitations and learning environment, and (e) task complexity and assessment difficulties. This fundamentally impede the translation of EDP theoretical frameworks into practice. This synthesis systematically delineates instructional implications derived from the literature, classified according to these core challenge domains.

Table 4
Challenges in the Classroom Implementation of the EDP

Author	Themes				
	Curriculum Integration and Time Constraints	Teacher Preparedness and Professional Development	Student Engagement, Motivation, and Diverse Needs	Resource Availability and Learning Environment Challenges	Complexity of Design Processes and Assessment Difficulties
Martin et al. (2020)	/		/		
Aranda et al. (2020)		/			/
Hite et al. (2020)	/			/	/
Gencer et al. (2020)	/	/	/		
Dedetürk et. al (2021)	/	/			
Zhou et al. (2021)	/	/			/
Guzey et al. (2021)			/		/
Ergül & Çalış (2021)	/	/		/	
Anggoro et al. (2021)	/	/		/	
Gök & Sürmeli (2022)		/		/	
Duong et al. (2022)	/			/	/
Kocaman (2023)	/	/			/
Xue et al. (2023)	/	/		/	
Baze et al. (2023)		/		/	
Putra et al. (2023)	/	/		/	
Precharattana et al. (2023)	/		/		
Simpson et al. (2023)	/	/			
McNair and Hayward (2023)	/	/		/	
Putra et al. (2023)			/		/
Putra et al. (2023)			/		/
Kim & Park (2023)	/		/		
Thomason & Hsu (2024)	/	/			/
Ioannou et al. (2024)			/	/	/
Barajas-Salazar et al. (2025)			/	/	/
Pramasdyahsari et al. (2025)	/		/		
Thammaariyasaakun et al. (2025)		/		/	
Hewitt & Forcino (2025)	/		/	/	

Curriculum and time constraints stand out as the primary structural barrier. As noted by Martin et al. (2020), the incorporation of EDP often contends with a packed curriculum.

This results in a pedagogical dilemma for teachers who must decide between fulfilling traditional learning standards and embracing design-based approaches that require prolonged periods for thorough exploration (Hite et al., 2020; Kocaman 2023). Additionally, these constraints are intensified by exam-oriented assessment systems which encourage rote learning and restrict opportunities for innovative teaching practices (Zhou et al., 2021; Xue et al., 2023).

Teacher preparedness and access to ongoing professional development represent critical determinants in the landscape of educational effectiveness. However, these factors are often overlooked by policymakers and educational institutions alike. Numerous studies underscore the significance of this issue, as evidenced by the findings of Dedetürk et al. (2021) and Zhou et al. (2021) which illustrate that a pronounced lack of targeted training in educational design practices EDP leaves teachers feeling uncertain and inadequately equipped when it comes to planning and implementing design-based educational activities (Gencer et al., 2020; Ergül & Çalış, 2021; Thammaariyasaakun et al., 2025). This uncertainty as indicated by Baze et al. (2023) can lead to a diminished effectiveness of various educational interventions as teachers may struggle to apply best practices in their classrooms without the necessary training and support.

Resource limitations and constraints within the learning environment present a significant and practical challenge that can profoundly impact the educational experience especially in schools that have inadequate infrastructure and insufficient facilities. Studies by Aranda et al. (2020) provide compelling evidence that a lack of essential equipment, insufficient laboratory space (Ergül & Çalış, 2021) and the unavailability of necessary design materials contribute to a notable decline in the overall quality of educational activities. Putra et al. (2023) found that deficiency not only hampers the effectiveness and engagement of the activities in which students participate but also has a detrimental effect on the morale of both students and teachers alike as stated in studies by Barajas-Salazar et al. (2025). When educators are faced with limited resources and inadequate environments conducive to learning, their ability to deliver high-quality instruction becomes compromised (Precharattana et al., 2023). As a result, students may experience frustration and disengagement and this weakening their motivation and enthusiasm for their studies.

Student engagement and motivation pose dynamic challenges influenced by a variety of factors that can significantly affect educational outcomes. These factors encompass individual interests, different levels of academic background and varying cognitive abilities among students (Kim & Park, 2023) . Research by Guzey et al. (2021) reveals a concerning trend where students with limited exposure to project-based learning struggle to grasp the iterative logic intrinsic to the EDP. This understanding is vital as the EDP demands both patience and a commitment to reflective thinking which are critical for tackling complex problem-solving tasks (Gök & Sürmeli, 2022). The implementation of differentiated instructional strategies can maximize the effectiveness of the EDP for a diverse student population (Xue et al., 2023; Hewitt & Forcino, 2025). Such strategies are essential to address the varied needs and learning styles of all students that ultimately creating an environment that promotes engagement and motivation (Precharattana et al., 2023).

The complexity of design processes and the related assessment difficulties present a major obstacle to the effectiveness of EDP. Ioannou et al. (2024) highlight that the inherently open-ended and iterative characteristics of EDP pose challenges for alignment with conventional assessment systems. Duong et al. (2022) stated that traditional systems are typically designed for identifying single correct answers which does not reflect the adaptive and exploratory essence of design thinking (Guzey et al., 2021; Putra et al., 2023). In educational contexts, teachers often face hurdles in objectively assessing the creative and collaborative processes vital to EDP (Barajas Salazar et al., 2025) . Consequently, there is a tendency to focus more on the final product of a design project rather than the learning journey students experience throughout the process (Thomason & Hsu, 2024). Rethinking assessment strategies is therefore crucial for capturing the subtleties of the learning experience in EDPs and promoting a richer educational environment that values the iterative and nonlinear aspects of the design process.

Recommendation for Future Research

The study's findings offer valuable insights into the potential benefits and challenges of incorporating the Engineering Design Process (EDP) into STEM education. Future research should tackle the identified barriers while building on the essential pedagogical dimensions highlighted. A lack of teacher preparedness was identified as a significant obstacle. Therefore, future studies should investigate structured and sustainable professional development models that provide teachers with the necessary pedagogical knowledge, scaffolding strategies and confidence to effectively implement iterative and design-based learning. Additionally, curriculum limitations and assessment challenges warrant further examination of flexible curricular frameworks and innovative assessment methods that can capture not only students' final products but also their problem-solving processes and learning experiences from failure.

The study revealed EDP's potential to boost student engagement and develop 21st-century skills but longitudinal and cross-contextual research is necessary to assess the sustainability and transferability of these competencies. Due to ongoing issues with motivation and task complexity, future initiatives should focus on creating and testing pedagogical methods that incorporate authentic, interdisciplinary and real-world scenarios to enhance inclusivity and accessibility especially for underrepresented students in STEM. Furthermore, resource constraints emphasize the need to investigate technology-enhanced learning environments and digital tools as facilitators for effective EDP implementation and to reduce material limitations. Thus, these strategies will provide strong evidence to improve pedagogical practices, inform policy and reinforce the meaningful incorporation of EDP in STEM education.

Conclusion

This systematic literature review makes a unique contribution to the scholarship on integrating the Engineering Design Process (EDP) in STEM education by emphasizing its pedagogical value and the challenges involved in implementation. A key finding highlights the focus of research at the middle school level which points to this developmental stage as a crucial environment for nurturing 21st-century skills like creativity, collaboration, resilience and critical thinking. Middle school settings are particularly suited for the incorporation of scaffolded design-based approaches that enhance engagement and motivation while aiding students in iterative problem-solving and learning from failure. This concentration of studies offers valuable empirical evidence for policymakers and educators aiming to strengthen STEM pathways during a critical phase of learner development.

This review identifies assessment as a key area of underexplored complexity. Although the literature consistently acknowledges the importance of authentic, process-oriented assessment in capturing the iterative and collaborative nature of EDP, current frameworks are still inadequately developed to guide practice. Challenges related to assessment such as the difficulties in evaluating creativity, problem-solving processes and interdisciplinary outcomes have been frequently recognized but rarely addressed with robust models or empirical validation. In affirming the potential of EDP as a transformative pedagogical approach, the review emphasizes the necessity for ongoing teacher professional development, adaptable curricula, enhanced access to resources and innovative assessment methods. Addressing these issues will be crucial for realizing the full potential of EDP in fostering inclusive and effective STEM education.

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