Trends and Challenges in the Classroom Implementation of Engineering Design Process (EDP): A Systematic Literature Review

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Abstract

The engineering design process (EDP) is a structured, iterative approach to solving problems and creating solutions. In this context, the present study describes the trends and challenges in implementing EDP in the classroom. A systematic literature review (SLR) was conducted based on the PRISMA protocols, with data extracted and analyzed from 31 studies published from 2020 to 2024. The findings indicate that there is continuing research on the use of EDP in STEM education, with case studies being the most commonly adopted research design. Meanwhile, implementation across grade levels in various academic subjects was observed. The EDP classroom implementation types are (1) STEM challenges, STEM projects, or context-based problem scenarios; (2) robotics and technology; (3) typical classroom activities; and (4) learning models and experience plans. Furthermore, studies have shown improvements in several skills, including creativity, problem-solving, critical thinking, collaboration, and conceptual understanding, which are identified as the top five skills enhanced by the EDP. Lastly, this SLR documented the nine (9) EDP implementation challenges, such as time constraints, resource availability, teacher expertise, and adherence to EDP. It is recommended that the interests of students should be considered in implementation, teachers' training should be conducted, and studies on EDP should continue to refine practices.

Introduction

The engineering design process (EDP) is as an education pedagogy that introduces engineer-related practices. In EDP, students' engineering design skills were developed to guide them in the educational artifact creation process. Moreover, learners apply scientific knowledge and mathematical ideas to analyze and solve problems based on real-life situations. According to TeachEngineering from the University of Colorado, EDP is a series of steps that guide learners to solve problems, and teamwork and design are two overarching themes in the engineering design process. In addition, students enhance their comprehension of open-ended design by developing collaboration, encouraging learners to construct new ideas, applying scientific knowledge, analyzing data from prototype testing, and striving for creativity throughout the learning process. Likewise, Tipmontiane and Williams (2021) also explain that the various engineering design steps are considered iterative and creative learning processes by applying interdisciplinary concepts from science, mathematics, and technology.

The steps in the EDP include defining the problem, conducting research, generating ideas, selecting the best solution, developing and testing prototypes, refining the final design, and communicating results with others (Hafiz & Ayop, 2019). Furthermore, each step of the EDP fosters critical thinking, creativity, and collaboration among students, including essential skills such as problem-solving, communication, and decision-making. In the same way, Dankenbring et al. (2014) explain that as students design, build, and test their prototypes or products, they challenge their conception of scientific phenomena and witness firsthand flaws in their understanding. Fan et al. (2020) provide a framework for implementing an Engineering-Focused STEM Curriculum that concentrates on implementing STEM curricula by secondary technology and engineering teachers. Additionally, the descriptive study of Bunprom et al. (2019) reported that engineering design process skills were observable among grade 10 students. In addition, the learning activities used in the study encourage learners to integrate science, technology, engineering, and mathematics (STEM) in solving problems or situations under specified conditions. Furthermore, Yildiz and Ozdemir (2018) documented that engineering design-based activities positively affect the development of the spatial abilities of middle school students. Meanwhile, Syukri et al. (2018) investigated the impact of integrating the engineering design process (EDP) in physics learning modules to improve problem-solving skills among secondary school students.

Furthermore, Radloff et al. (2019) reported the integration of engineering design in undergraduate biology using a life science design task in quantitative and qualitative design methods. The authors develop a life science design task requiring the participants to research and build a model of the composting process to help Puerto Rico's citizens recover from hurricanes. Meanwhile, Lakose (2015) focused on the development of learning activities that are engineering design-oriented based on the Next Generation Science Standards (NGSS) in the United States. The development was driven by the need for more activities incorporating engineering design in the life sciences. Moreover, while the application of STEM, specifically engineering, is recommended, the author is convinced that the integration of engineering into the STEM curriculum is still in the early stages. On the other hand, English and King (2015) investigated the incorporation of engineering into elementary school curricula using a framework of five comprehensive core engineering design processes adapted from the literature on design thinking in young children. Overall, these studies and literature on the engineering design processes suggest this educational approach is particularly beneficial for STEM students and improves learning outcomes.

Lammi et al. (2018) reported the sample engineering design challenges in pre-college settings. The researchers described that engineering design should be authentic to the learners, should be related to the area of engineering, should have open-ended scenarios, modeling integration, and optimization for improvement of outputs, and the activities must promote the habits of the engineering mind. On the other hand, the bibliometric analysis of Ali and Tse (2023) described the research trends and issues on the engineering design process in STEM education in 2011-2021. The systematic literature study provides the leading research trends on EDP, such as the implementation of EDP to enhance the professional development of teachers, the use of design thinking and computational thinking through the engineering design process, the role of EDP in improving the competencies of students in STEM, the interdependence of scientific inquiry and engineering design process in STEM education, and limiting the gender gaps in STEM with the use of EDP. Similarly, researchers noted some issues and possible research opportunities in EDP, such as STEM knowledge integration, lack of professional development on EDP, challenges in computational thinking and design thinking, and insufficient studies on learning behaviors in EDP.

On the other hand, the systematic literature of Winarno et al. (2020) described the results of empirical research on EDP in science education from 2010-2020. The authors reported that projects were used in the implementation of the engineering design process, and these varied based on the contents being discussed. Additionally, the engineering design process enhances cognitive skills, develops procedural skills, and fosters positive attitudes. They also emphasized that the engineering design process is a new trend in science education, requiring research to provide essential data for policy decisions involving teachers, students, and other stakeholders in science education. As provided in the available studies, few to no investigations have attempted to describe the implementation of the engineering design process in the classroom. Thus, this current research will focus on the pedagogical trends and challenges in the implementation of the engineering design process. Notably, this will provide empirical data on the trends of how EDP is being implemented; specifically, the challenges were also documented for the improvement of the pedagogy.

Research Questions

Generally, this study aims to determine the trends and challenges of classroom implementation of the engineering design process (EDP) from year 2020 to 2024. Specifically, this literature review sought to answer the following questions:

1. What are the characteristics of the journal articles included in the analysis?
2. What are the trends in the use of engineering design process?
3. What are the challenges in the classroom implementation of the engineering design process?

Method

This investigation is a systematic literature review (SLR), a rigorous and methodical approach to analyzing existing research and publications on a specific topic, in this case, the classroom implementation of the engineering design process. Likewise, the literature review process involves identifying, evaluating, and synthesizing relevant studies to provide a comprehensive understanding of the subject matter (Pati & Lorusso, 2018). Specifically, this inquiry includes articulating clear research questions, establishing inclusion and exclusion criteria, conducting extensive searches across multiple databases, and critically appraising the quality of the selected studies. Lastly, by organizing and analyzing the research findings, this study aims to highlight the trends and challenges in classroom implementation of the engineering design process, offering valuable insights and directions for future research and practice.

Search Strategy

The data in this study was collected on December 23, 2024, from reputable databases, including DOAJ, ERIC, ACI, and SciDirect. These sources are renowned for providing high-quality scientific publications in various international journals. The systematic search was conducted using the keywords “engineering design”, “engineering design process”, and “engineering design process in the classroom”. All gathered journal articles are peer-reviewed, ensuring the quality and trustworthiness of the literature review process.

Publication Selection

The study employed the protocols from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), with the systematic search diagram flow for the engineering design process presented in Figure 1.

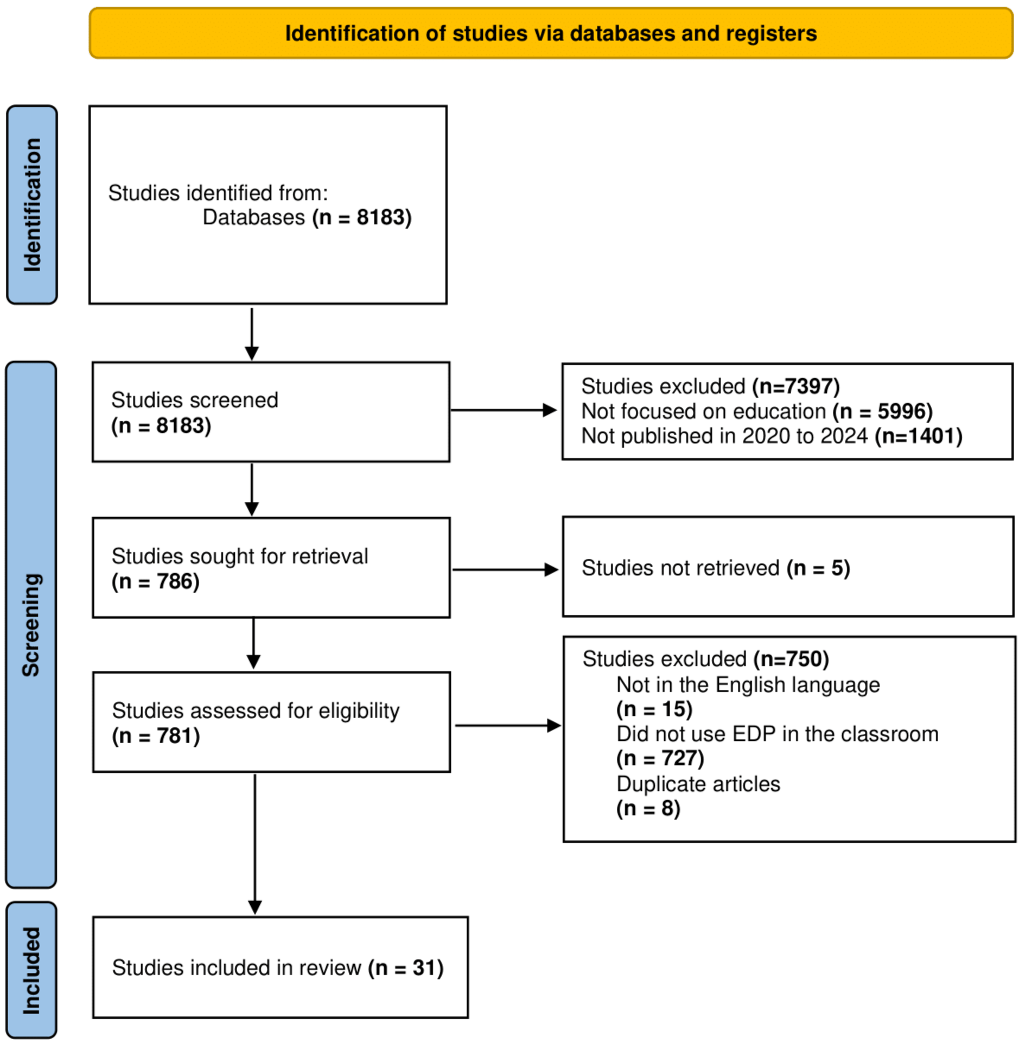

Figure 1. PRISMA Search Diagram for the Engineering Design Process

Initially, 8183 journal articles were identified from all the databases. The selection of years was set to 2020 to 2024, including the button related to education to delimit the articles. Overall, these processes removed 7397 articles. Then, 786 journals were selected for retrieval; after the process, five (5) articles were not retrieved. With this, 781 were checked for eligibility for final review using the inclusion and exclusion criteria in Table 1.

In summary, after checking the articles, only 31 studies were selected for the review. Thus, the studies were essential in providing rich context on the trends and challenges in the classroom implementation of the engineering design process.

Table 1. Search Criteria Utilized in the Selection of Articles on Engineering Design Process (EDP)

Inclusion	**Exclusion**
Explicit use of EDP in the classroom	Not on education and no usage of EDP in the classroom
Published in 2020 to 2024	In other languages
In the English language	Duplicate articles
Peer-reviewed	Articles that are not accessible

Data Extraction

Using the bibliometric analysis matrix developed by the researcher (Figure 2), data were systematically extracted from the studies involved in the literature review. The extracted data included publication year, journal name, publisher, country, authors, titles, grade levels, content/subjects, methodology, sample size, participants, data collection methods, type of EDP implemented, findings, conclusions, recommendations, and challenges associated with implementing the engineering design process.

#	Year	Journal	Country	Authors	Title	Grade Level	Contents/Subject	Methodology	Sample Size	Participants	Data Collection	EDP Type	Findings	Conlusion	Recommendation	Challenges
	2020	Journal of Research in Innovative Teaching & Learning	USA	Hite et al. (2020)	STEM challenge: two years of community-engaged engineering	Grade 6 Grade 7 Grade 8	Physics	Quantitative (survey) and qualitative (open-ended responses)	66	students	Quantitative (survey) and qualitative (open-ended responses)	STEM Challenge	The study found growth in students' 21st-century skills, particularly among underrepresented groups, with year-one data informing year-two improvements in mentor training and exploration of students' EDP experiences during the STEM challenge.	enhanced engineering and 21st-century skills and increased their interest in STEM	measuring short-term impact, longitudinal research of STEM programs is necessary to refine programs to better serve the future needs of K-12 STEM students, especially those elements that offer insight into how students, especially URGs, come to learn and enjoy STEM	time contraints
	2021	International Journal of STEM Education volume	Taiwan	Lin et al. (2021)	Effects of infusing the engineering design process into STEM project-based learning to develop preservice technolo	preservice teachers	Physics - friction, Newton's first law of motion, material processing, engineering graphics	quasi-experimental design	28	preservice teachers	in-depth, semistructured interviews	STEM project used in this study was the mousetrap car	STEM project-based learning to develop preservice technology teachers' engineering design thinking	infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking.	designing learning activities that are relevant to real-life will cultivate practical knowledge and problem-solving capabilities in preservice technology teachers and improve their ability to address real-life subjects.	insufficient time, weaknesses of preservice technology teachers
	2021	Jurnal Pendidikan Sains (JPS)	Indonesia	Utomo et al. (2021)	The Effect of Agrosains Based Engineering Design Process Learning Model With A STEM Approach to SMP Student	Grade 7	Agriscience	quasi-experiment with pre and post-test control group design	63	students	pretest, postest	EDP learning model	Student's HOTS improvement in experiment class was higher (N-gain = 0.494) than control class (N-gain = 0.279).	significant effect in increasing student HOTS, which belongs to the moderate improvement category.	For further researchers with the same topic, it is hoped that they can test the reliability of the test instruments used	Validity of test items used in the assessment
	2021	Jurnal Penelitian dan Pembelajaran IPA	Japan	Sulaeman et al. (2021)	Exploring Student Engagement in STEM Education through the Engineering Design Process	Grade 9	Wind power and solar energy	single case study	16	students	self-assessments, worksheets, presentations, and videos of lessons	STEM Activity	The results showed that the students' level of engagement was very high.	An engineering element in an elective science class was valuable for JHS students and provided a way to enhance science lessons.	For further research, the deeper exploration by gender is needed to understand more the characteristics of engagement based on gender	Our finding suggests that more time needs to be allocated for STEM activities to facilitate students' ability to design their solution.
	2022	Scientiae Educatia: Jurnal Pendidikan Sains	Indonesia	Maryati et al. (2022)	Fluid Learning with Arduino-Based on Engineering Design Process (EDP) to Improve Student's Problem Solving Ability	High School	Physics	quasi-experimental research method with a pretest-posttest controlgroup design	72	students	problem-solving ability test sheets and student worksheets	Arduino-based engineering design process(EDP)	a significant difference in increasing problem-solving skills.	felt happy and motivated,provided benefits, every process undertaken by students providedchallenges in solving the	Arduino-based EDP can be used on other physics material so that students' problem-solving ability levels	takes quite a longtime to do this prototype design to get perfect results.

Figure 2. Bibliometric Analysis Matrix of EDP Journal Articles

Data Analysis

The extracted data were organized and tabulated using the frequency in Google Sheets, followed by the creation of tables and graphs to present the data in a clear and insightful manner. In addition, Zotero (Version 7.0.11, 64-bit) was utilized to store and organize article information as formatted references. Further, the data was exported in RIS file format—a standardized tag format developed by Research Information Systems, Inc.—to facilitate data exchange between citation programs (Texas A&M University Libraries, 2024). Lastly, the exported data was then used in VOSviewer (Version 1.6.20) to generate visualizations utilized in the current literature review.

Findings and Discussion

Characteristics of the Journal Articles included in the Analysis

This systematic literature review examined 31 studies on the classroom implementation of the engineering design process. The keywords from these articles were analyzed using VOSviewer to identify prevalent keywords and their associations. Figure 3 displays the keyword network visualization using the weights on total link strength. The analysis revealed that the engineering design process (EDP) emerged as the dominant keyword in the articles, as indicated by the largest red circle. This was followed by keywords such as problem-solving skills (biggest green circle) and STEM education (2nd big red circle). Furthermore, the EDP is closely associated with these concepts, as illustrated by the connecting curved lines. Notably, the retrieved articles used in the review clearly present data on the impacts of classroom implementation in STEM education, including the improvement of problem-solving skills, collaborative behaviors, and design skills.

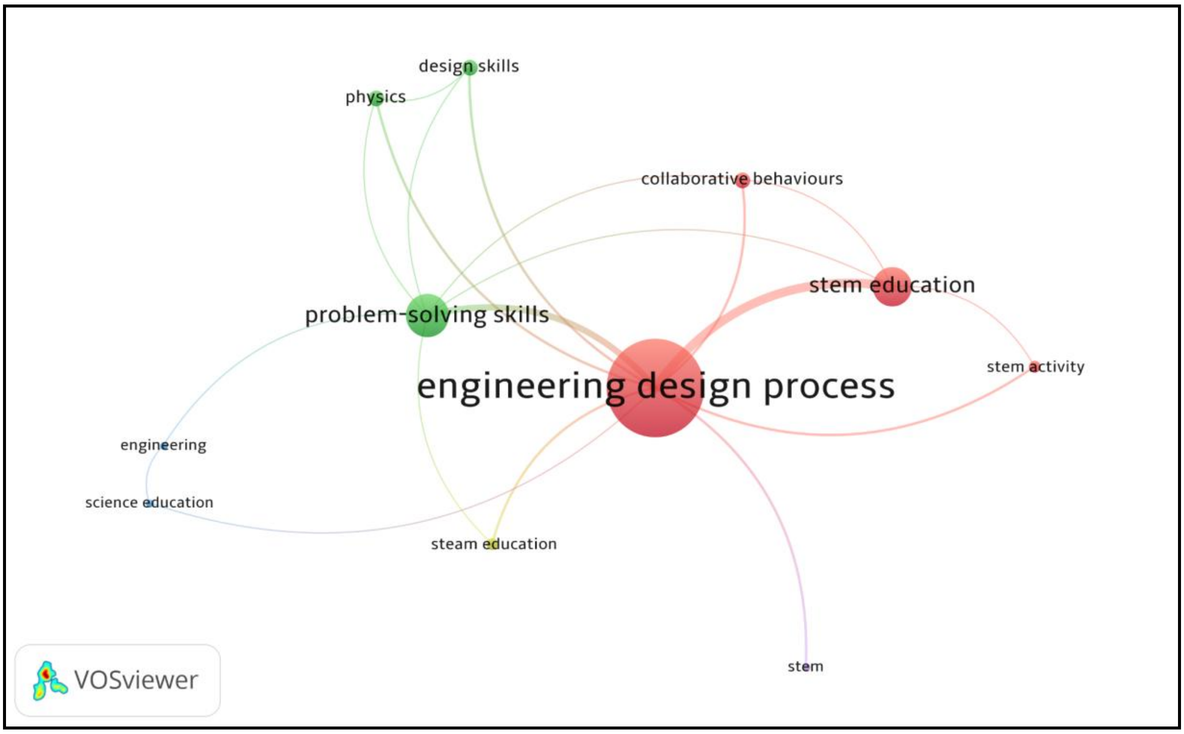

Figure 3. Keywords Network Visualization in VOSviewer

On the other hand, using the titles and abstracts of the studies, overlay visualizations were generated in Figure 4, highlighting year-to-year trends in the classroom implementation of the engineering design process. The data revealed that "student" and "research" are the most prominent terms, suggesting a consistent focus on research on improving students' skills during the implementation of the engineering design process. Lastly, this trend is particularly evident in studies conducted from 2020 to 2024.

Figure 5 illustrates the co-authorship analysis generated in VOSviewer. This bibliometric network visualization presents scholars, research organizations, and countries based on jointly authored studies (Anjum et al., 2020; Marzouk et al., 2023). The bibliometric map of co-authorship revealed two distinct clusters. Notably, Putra, Sulaeman, and Kumano, belonging to Cluster 1, have eight links with a total link strength of ten and two documents with an average publication year of 2022. Additionally, these authors have the greatest total power from the articles reviewed. Meanwhile, Takahashi, Ide, Minete, and Hakamada in Cluster 2 have six links with a total link strength of six and one document with an average publication year of 2021.

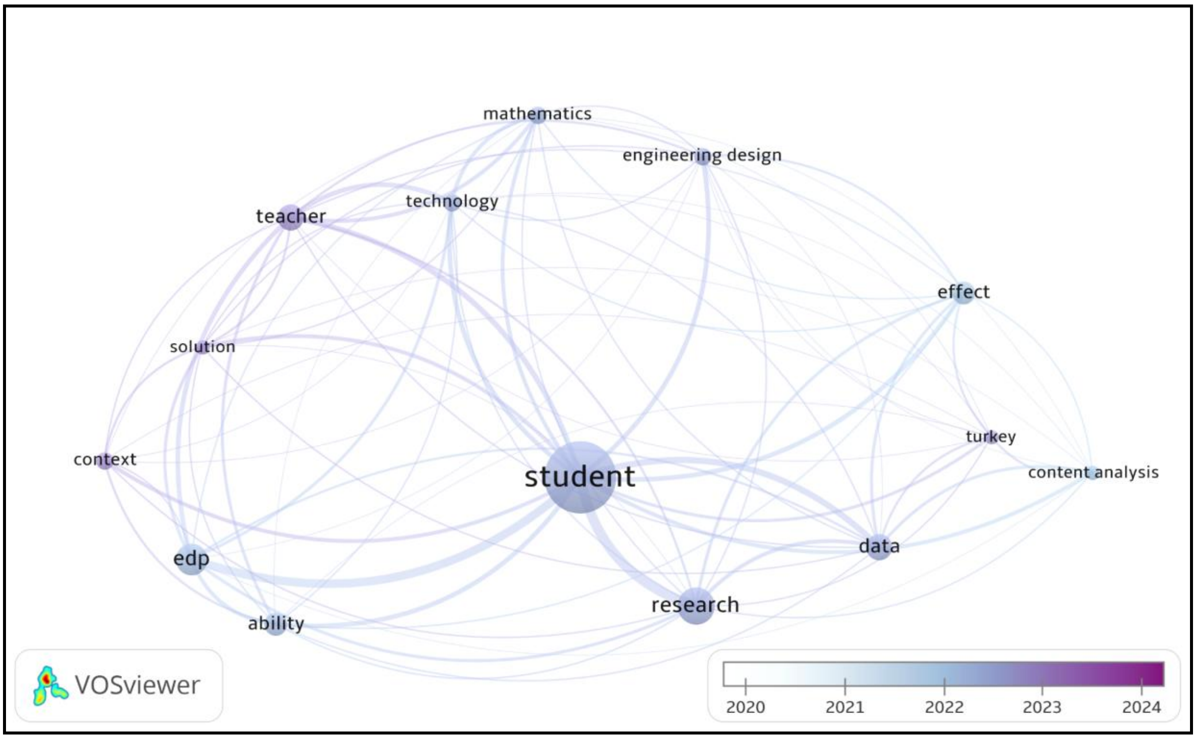

Figure 4. Overlay Visualization of Titles and Abstracts in VOSviewer

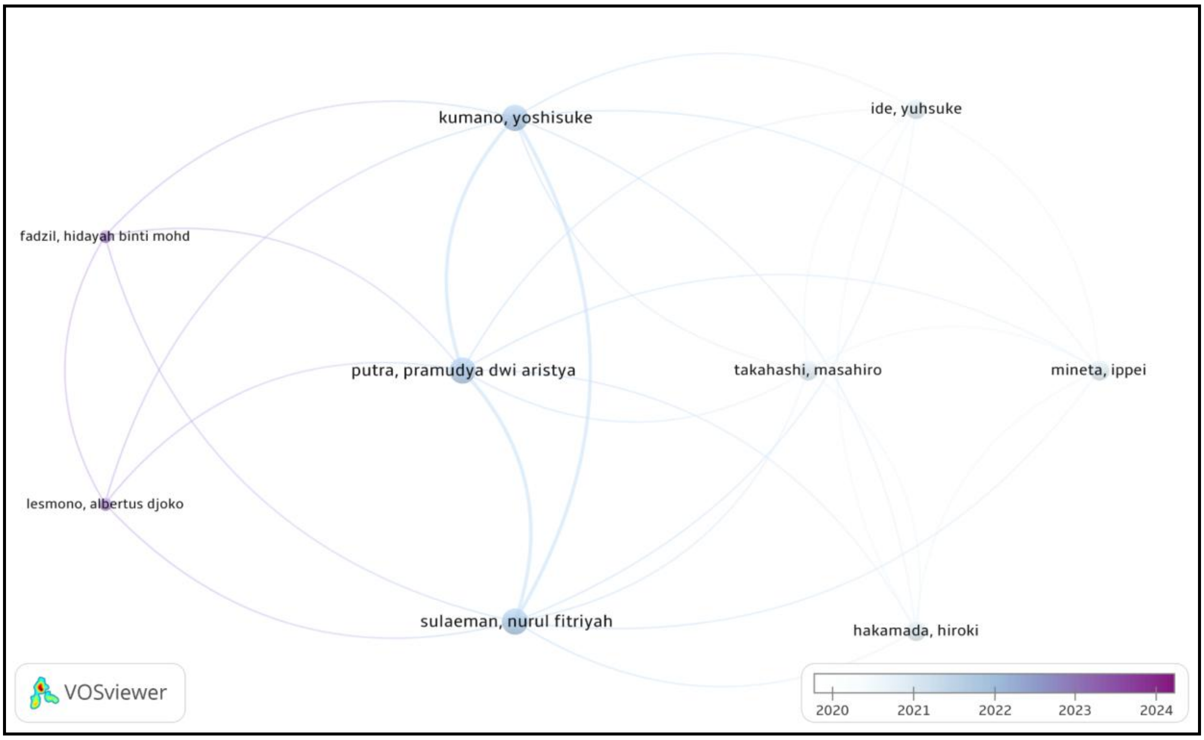

Figure 5. Overlay Visualization of Co-authorship Analysis in VOSviewer

Figure 6 illustrates the citation counts of the articles included in the systematic review.

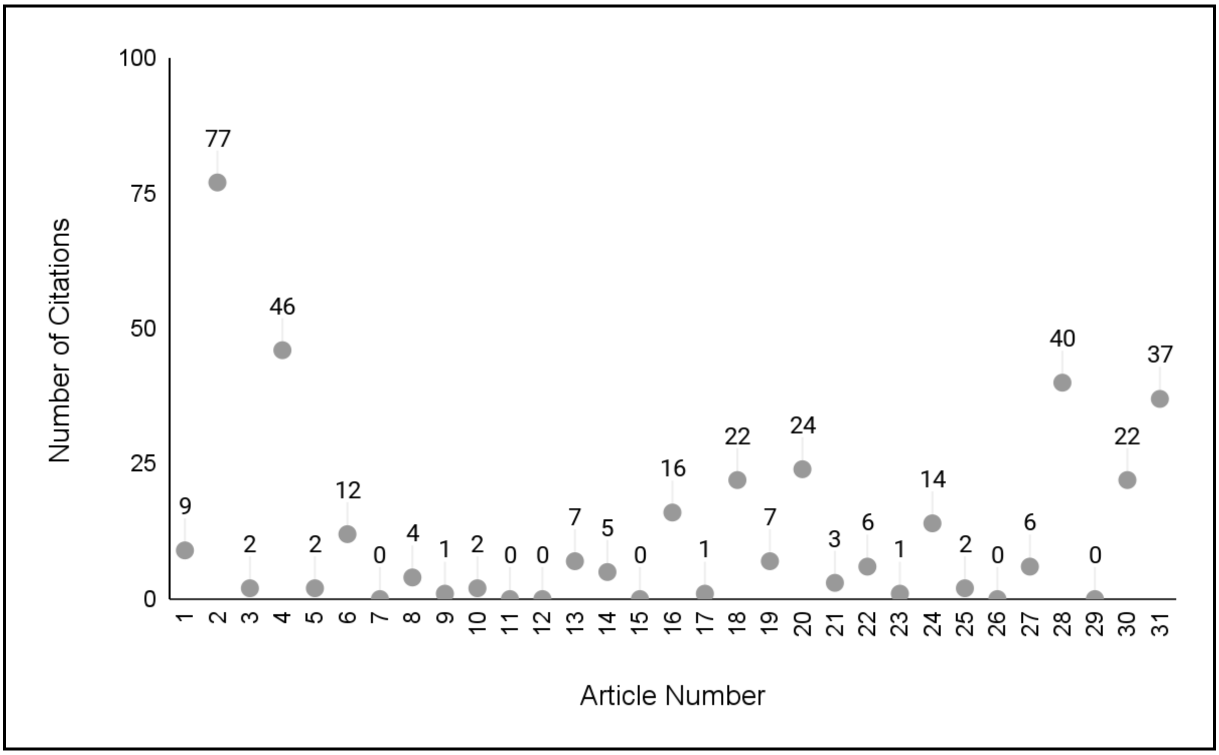

Figure 6. Citations of Journal Articles

Notably, the second article has the highest citation count of 77. Additionally, six articles have garnered more than 20 citations. In contrast, some articles have yet to receive any citations, likely because they were published in the same year the review was conducted. Despite having few or no citations, the proponent reports that all of the articles were published in peer-reviewed journals, highlighting the trustworthiness of the findings. Therefore, the studies serve as credible sources to address the research questions of the current systematic literature review.

Figure 7 illustrates the distribution of publications related to the implementation of the engineering design process (EDP). The data reveals that the majority of retrieved research articles were published in 2021, while only two articles were recorded in 2020. Notably, the period from 2021 to the present reflects a sustained focus on studies incorporating EDP into classroom settings to improve the skills of the students and enhance academic outcomes. This current data is corroborated by the literature review of Ali and Tse (2023), who have a similar trend of research on the engineering design processes in science, technology, engineering, and mathematics education.

Figure 8 presents the distribution of publications by country. The data indicates that Turkey had the highest number of publications, with 11 articles included in the current literature review, followed by Indonesia, Thailand, and the USA. Meanwhile, Taiwan, Japan, China, Portugal, Germany, Greece, and South Korea each contributed one study on the classroom implementation of the engineering design process.

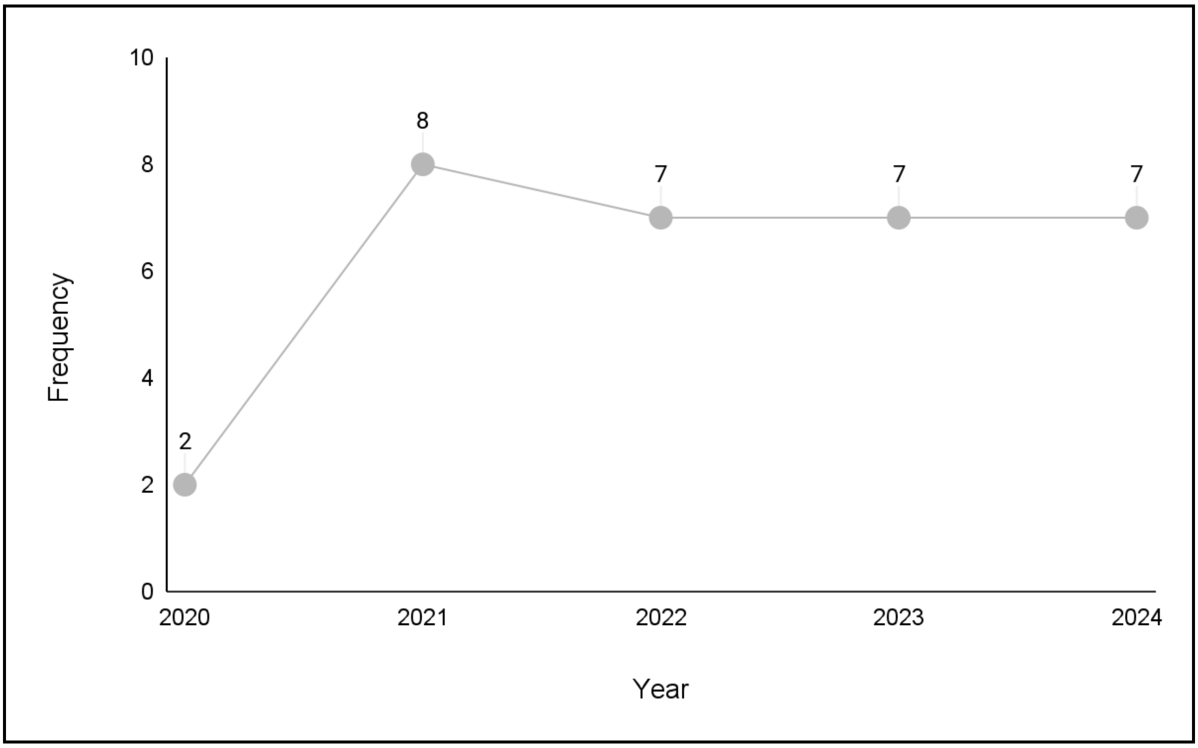

Figure 7. Distributions of Publications Every Year

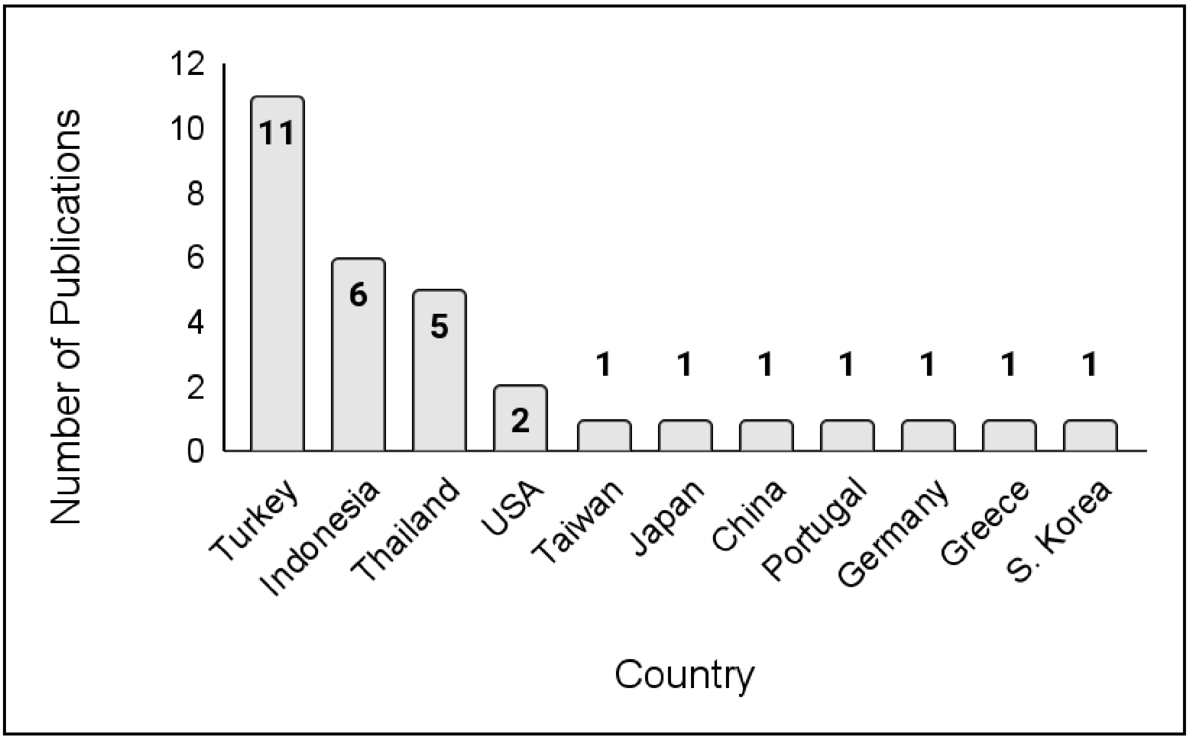

Figure 8. Distribution of Publications by Country

The grade-level implementation of the engineering design process is presented in Figure 9. The data shows that the majority of studies reviewed in the current investigation focused on implementing EDP with students in middle and high school levels, representing the Grade levels from 6 to 12. Meanwhile, seven studies explored the application of EDP with elementary students ranging from Kindergarten to Grade 5. Additionally, three studies investigated the implementation of EDP with pre-service teachers. These results highlight the broad application and implementation of the engineering design process across all grade levels; this literature review documented the potential implementation of EDP with undergraduate students as well.

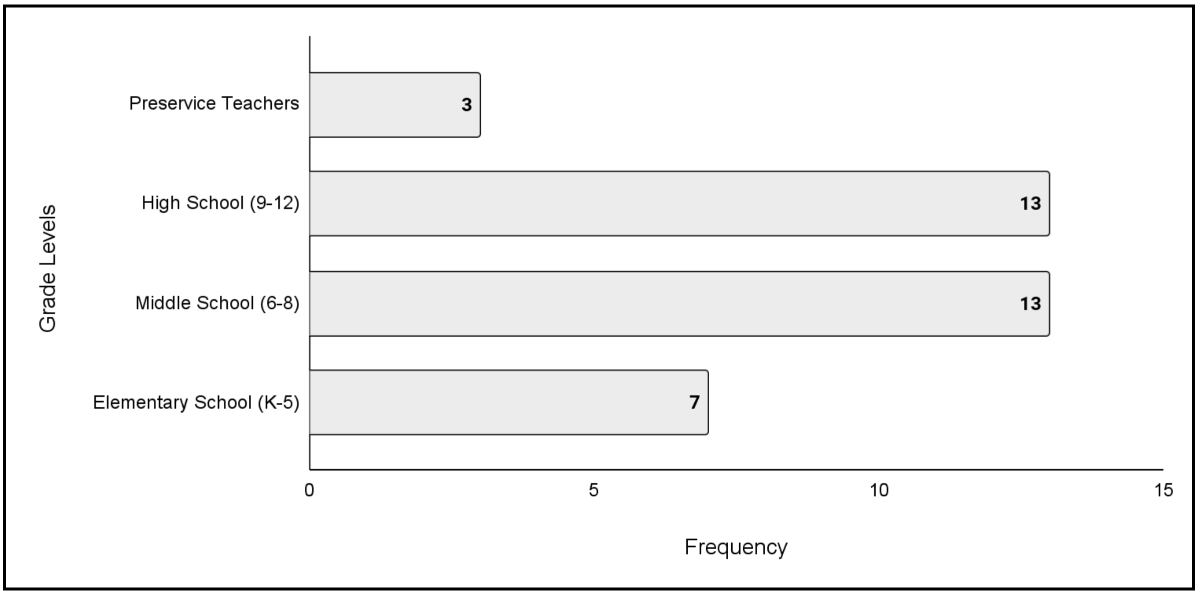

Figure 9. Grade-level Implementation of the Engineering Design Process

The research designs employed in the implementation of the engineering design process (EDP) are presented in Figure 10. Notably, case studies were the most frequently utilized, appearing in 11 studies. This was followed by one-group pre-test and post-test designs, implemented in 8 studies. Quasi-experimental designs were observed in 7 studies. Additionally, mixed-methods and qualitative exploratory designs were each employed by two studies. Finally, one study utilized a multi-year design approach to describe how to implement the EDP in the classroom.

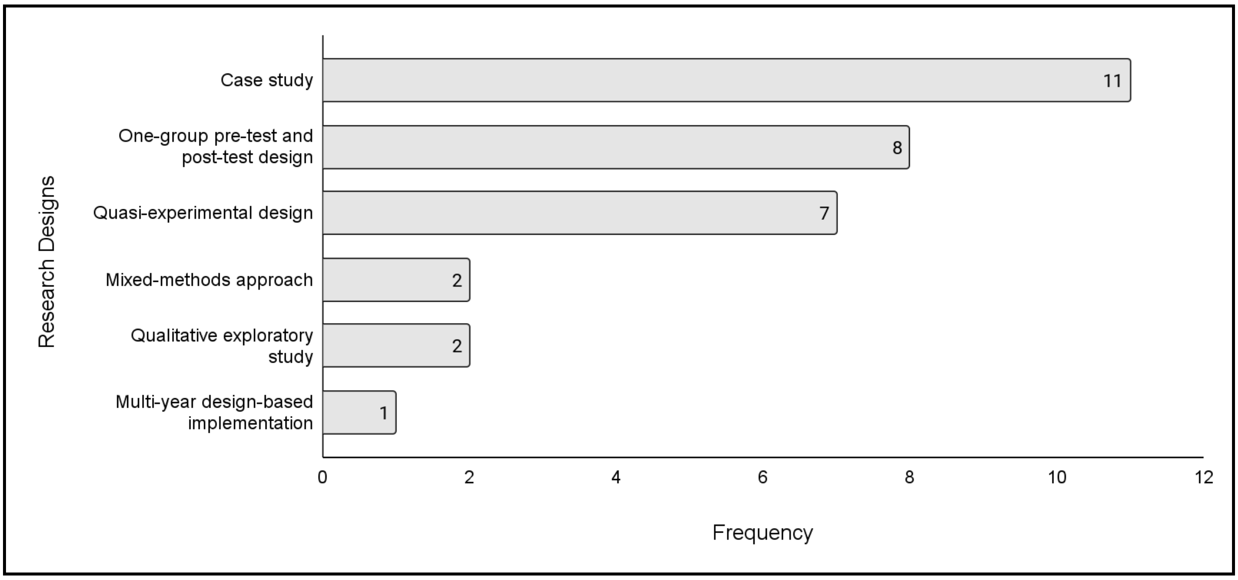

Figure 10. Research Designs used in the Implementation of EDP

Trends in the Classroom Implementation of the Engineering Design Process

The trends in classroom implementation of the engineering design process (EDP) were identified through the systematic examination of the journal articles utilized in the current literature review. As shown in Table 2, four distinct implementation types were documented:

(1) STEM Challenges, STEM Projects, or Context-Based Problem Scenarios;

(2) Robotics and Technology;

(3) Typical Classroom Activities; and

(4) Learning Models and Experience Plans.

Moreover, for each implementation type, frequencies were recorded, and exemplars, including the sources, were also provided. Based on the findings, 15 studies employed either STEM challenges, STEM projects, or context-based problem scenarios, while five studies utilized learning models or experience plans in implementing the engineering design process. Notably, the utilization of robotics and technology is becoming a prominent trend in the implementation of the EDP. Meanwhile, other studies have employed traditional classroom strategies, such as worksheets and other activities enriched with argumentation.

Table 2. Trends in the Implementation of the Engineering Design Process in the Classroom

Implementation Types	Frequency	Exemplars and Sources
STEM Challenge/ STEM Projects/ Context-Based Problem Scenarios	15	*STEM Challenge: build gliders, hovercrafts, or boats* (Hite et al., 2020) *STEM Project mousetrap car* (Lin et al., 2021) *STEM Activities focused on renewable energy* (Abdurrahman et al., 2023) *EDP Activity on thermal isolation* (Nalbantoğlu et al., 2023) *EDP Activity on COVID-19 mask protection* (Precharattana et al., 2023) *Environmental-STEM Activity* (Koculu & Girgin, 2022) *Real-life-based problem scenario* (Baydere & Bodur, 2022; Putra et al., 2023; Sulaeman et al., 2021)
Robotics and Technology	7	*Use of Arduino-based EDP activities or use of robots* (Bampasidis et al., 2021; Cakir & Karlidag, 2024; Maryati et al., 2022; Sen et al., 2021; Sun et al., 2022) *Use of Tinkercad and 3D printing* (Barbosa et al., 2024) *Use of LEGO Mindstorms NXT* (Dedetürk et al., 2021)
Typical Classroom Activities	4	*EDP-based e-worksheets* (Kurniawan & Wahyuni, 2024) *Scientific toy design activities* (Gök & Sürmeli, 2022) *Gears engineering design tasks* (Reuter & Leuchter, 2022) *Activities enriched with argumentation* (Tuğ & Namdar, 2024)
Learning Models and Experience Plans	5	*EDP learning model based on Agriscience* (Utomo et al., 2021) *Engineering design process experience plans* (Tuekkhow et al., 2024) *Realistic Mathematics Engineering model* (Nurmasari et al., 2023)

The classroom implementation of the engineering design process includes content standards across various subject areas, including physics, life sciences, chemistry, mathematics, environmental science, technology, engineering, and interdisciplinary subjects (Table 3). These results suggest that EDP is a flexible approach to teaching and learning and can be incorporated into various concepts or contents across different subjects.

Evidently, the engineering design process integrated contents in physics, such as Newton's First Law of Motion (Lin et al., 2021), fluid material (Maryati et al., 2022), gears (Reuter & Leuchter, 2022), thermal isolation (Nalbantoğlu et al., 2023), electrical energy (Baydere & Bodur, 2022), friction force and water resistance (Gökşen et al., 2024), sound (Dedetürk et al., 2021), electricity and lights (Tuğ & Namdar, 2024), matter and heat (Uzel & Bilici, 2022), electromagnetism (Ergül & Çalış, 2021), motion (Hite et al., 2020; Hutsamin & Bongkotphet, 2020), and heat transfer (Putra et al., 2023). Meanwhile, Sun et al. (2022) and Precharattana et al. (2023) integrated life science concepts such as human systems, sensory, and COVID-19 protection. On the other hand, Muslihah et al. (2024) and Kurniawan and Wahyuni (2024) used chemistry concepts in EDP, such as elements, compounds, mixtures, and composition function material.

In addition, environmental science contents were also used in the implementation of EDP, such as recycled waste (Tuekkhow et al., 2024), environmental issues (Koculu & Girgin, 2022), wind power and solar energy (Sulaeman et al., 2021), and renewable energy (Abdurrahman et al., 2023). Furthermore, Barbosa et al. (2024) and Nurmasari et al. (2023) utilized mathematics content such as measurements, compound geometric shapes, and cylinders in EDP. Moreover, technological contents were also introduced, such as robotics (Bampasidis et al., 2021; Cakir & Karlidag, 2024; Sen et al., 2021; Sun et al., 2022), nanotechnology (Khamhaengpol et al., 2021), and 3D Modeling (Barbosa et al., 2024; Sen et al., 2021). Additionally, Lin et al. (2021) included engineering concepts in EDP implementation, such as material processing and engineering graphics. Lastly, Tuekkhow et al. (2024) used interdisciplinary concepts in EDP and implemented them in kindergarten students.

Table 3. Main Subjects and Contents in the Implementation of the Engineering Design Process

Main Subjects	**Contents in the Engineering Design Process**
Physics	Friction, Newton's First Law of Motion, Fluid Material, Thermal Insulation, Sound, Gears, Motion, Heat Transfer, Matter and Heat, Electromagnetism, Converting Electrical Energy, Electricity, and Light
Life Science	Human Systems and Sensory, COVID-19 Protection
Chemistry	Elements, Compounds, and Mixtures; Composition, Function, and Material
Mathematics	Compound Geometric Shapes and Cylinders
Environmental Science	Recycled Waste Inventions, Environmental Issues, Wind Power and Solar Energy, Renewable Energy
Technology	Robotics, Nanotechnology, and 3D Modeling
Engineering	Material Processing and Engineering Graphics
Interdisciplinary	Winter Equipment, New Year's Day Decoration, Teacher's Day Gift, Antique Toys Collection

Likewise, the classroom implementation of the engineering design process has significantly enhanced various skills of the students. As shown in Figure 11, the skills that have improved include creativity, problem-solving ability, critical thinking, collaboration, conceptual understanding, 21st-century skills, experimental skills, negotiation abilities, engineering design thinking, higher-order thinking, engagement, self-efficacy, psychomotor skills, positive attitude, mathematical literacy, and argumentation skills. Additionally, most studies have reported that creativity, problem-solving ability, critical thinking, collaboration, and conceptual understanding are the top five skills that showed the most improvement.

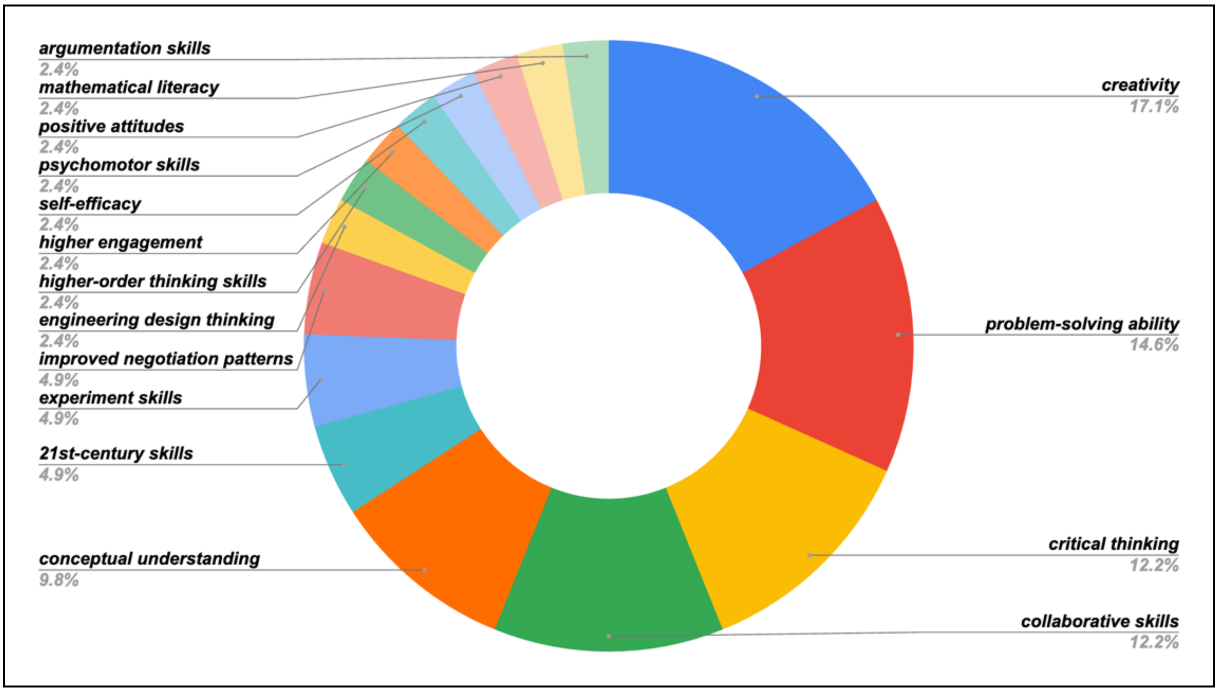

Figure 11. Improved Skills in the Implementation of the Engineering Design Process

Challenges in the Classroom Implementation of the Engineering Design Process

This review also highlights the challenges encountered in the classroom implementation of the engineering design process according to the systematic literature review. Based on the findings, Table 4 presents the nine categories of challenges faced by the researchers or teachers in implementing the EDP: *time constraints, resource availability, teacher training and expertise, adherence to EDP*, *interdisciplinary challenges, student understanding, group dynamics, developmental and parental needs,* and *research gaps*. Further, specific challenges were also provided for each category. Notably, these results highlight the need to address these challenges, which will be crucial for the successful integration of the engineering design process in various educational settings.

The first category in the challenges is time constraints. Moreover, Lin et al. (2021), Maryati et al. (2022), and Sun et al. (2022) also asserted that insufficient time is one of the challenges in the implementation of the engineering design process. This problem is documented by Sulaeman et al. (2021), who suggested that more time is needed for STEM activities that will facilitate the design development of the students.

Table 4. Challenges in the Classroom Implementation of the Engineering Design Process

Category	**Challenges in the implementation of the EDP**
Time Constraints	Insufficient time for activities to design solutions effectively.
	The course duration is too short.
	The time needed for prototype design to achieve desired results.
	Time constraints due to costs, heavy coursework, and exams.
Resource Availability	Need for internet access and electronic devices for e-worksheets.
	Limited resources for printing and prototype creation.
Teacher Training and Expertise	Lack of teacher understanding and preparation for EDP implementation.
	Limited training on integrating E-STEM and fostering creativity.
	Need for professional development programs for teachers.
	Teachers' attitudes and self-efficacy must be high for effective activity implementation.
Adherence to EDP	Students often skip critical steps like researching problems and proposing multiple solutions.
	Participants did not strictly follow the EDP model, merging or skipping steps.
Interdisciplinary Challenges	Difficulty integrating EDP with content at the school level.
	Limited interdisciplinary knowledge, especially during unique situations like the COVID-19 pandemic.
Student Understanding	Some designs lacked realistic solutions or failed to address problems effectively.
	Limited understanding of criteria and constraints, hindering their ability to learn from design failures.
Group Dynamics	Challenges in group management and collaboration.
	There is a need for teachers to address covert conflicts to prevent disengagement.
Developmental and Parental Needs	Tailoring activities to developmental needs.
	Engaging and collaborating with parents effectively.
Research Gaps	More studies are needed on the integration of engineering design processes for elementary schools and other contexts and their long-term implications.

Another challenge is the availability of resources; this problem hinders the implementation of EDP. As reported by Kurniawan and Wahyuni (2024), internet access and electronic devices are needed in the implementation of the activities. Meanwhile, teacher training and expertise are some of the challenges documented; this issue reflects the lack of teacher understanding and preparation for EDP implementation. Gök and Sürmeli (2022) and Cakir and Karlidag (2024) argued that to implement EDP effectively, it is necessary to have qualified teachers who possess high levels of self-efficacy and positive attitudes. Moreover, Tuekkhow et al. (2024) emphasized the importance of teachers thoroughly studying and understanding the plan for implementing engineering design activities. Thus, teacher training and professional development are necessary to implement EDP successfully. This result is consistent with the literature review of Ali and Tse (2023), who posited the need for more comprehensive professional development of teachers in EDP.

On the other hand, Nalbantoğlu et al. (2023) reported that students often skip crucial steps in the engineering design process, such as researching problems and proposing multiple solutions. The authors recommended that teachers must ensure proper adherence to the engineering design process during its implementation. This will help students gain the knowledge and skills necessary to solve the problem. In addition, Precharattana et al. (2023) highlighted the interdisciplinary challenges associated with the EDP. These challenges are particularly evident when integrating EDP with school-level content, especially in addressing interdisciplinary knowledge and real-world situations, such as the COVID-19 pandemic. Furthermore, as EDP is a relatively new learning approach, several issues hamper its effective implementation.

Another challenge pertains to students' understanding of design principles. Skinner and Harlow (2023) emphasized that a lack of clarity regarding criteria and constraints limits students' ability to identify initial design failures, recognize subsequent mistakes, and use these opportunities to continue and learn from the iterative process of engineering design process. In addition, some designs lacked practical solutions or failed to effectively address the identified problems, which may have hindered students from achieving a comprehensive understanding of the learning themes in the activities (Uzel & Bilici, 2022). Another challenge in implementation is group dynamics. The reviewed studies highlighted the critical role of effective group management in the engineering design process (EDP) and the need for teachers to address covert conflicts proactively to maintain student engagement and collaboration (Kim & Park, 2023). Studies have also highlighted the significance of designing activities that align with students' developmental needs while actively engaging and collaborating with parents. This approach ensures the engineering design process is implemented effectively and reflects real-life scenarios. Lastly, further research is essential to effectively implement the engineering design process, providing additional context and enhancing its application in classroom settings.

Conclusion

Based on the findings and discussions on the classroom implementation of the engineering design process, it is concluded that there is a noticeable trend in research to describe the effectiveness of EDP in STEM education. Moreover, many countries have also conducted independent inquiry on the approach using different research designs, such as case studies as the most dominant, followed by one-group pre-test and post-test designs, quasi-experimental designs, mixed-methods, qualitative exploratory, and multi-year design approaches. Moreover, this review also reported the wide range of implementation across grade levels. Additionally, this literature review highlights the frequent implementation of EDP on middle and high school grade levels. Notably, the classroom implementation of the engineering design process includes content standards across various subject areas, including physics, life sciences, chemistry, mathematics, environmental science, technology, engineering, and interdisciplinary subjects. Furthermore, four distinct implementation trends were documented: (1) STEM challenges, STEM projects, or context-based problem scenarios; (2) robotics and technology; (3) typical classroom activities; and (4) learning models and experience plans. Additionally, numerous studies have highlighted that the implementation of the EDP significantly enhances the skills of students such as creativity, problem-solving ability, critical thinking, collaboration, conceptual understanding, 21st-century skills, experimental skills, negotiation abilities, engineering design thinking, higher-order thinking, engagement, self-efficacy, psychomotor skills, positive attitude, mathematical literacy, and argumentation skills. Lastly, reviewed studies have documented the challenges in the implementation of the EDP, including time constraints, resource availability, teacher expertise, adherence to EDP, interdisciplinary challenges, student understanding, group dynamics, developmental and parental needs, as well as existing research gaps in EDP.

Recommendations

Based on the findings and conclusions cited, the following recommendations are provided for consideration.

1. The engineering design process (EDP) should be integrated across various disciplines and grade levels to foster a holistic approach to teaching and learning. In addition, it is essential to tailor the implementation to the developmental needs, interests, and learning styles of students, ensuring that the approach remains relevant and engaging.
2. Teachers must have a comprehensive understanding of the EDP. To achieve this, educational institutions should provide intensive professional development programs focused on EDP that are aimed at enhancing teachers' knowledge, skills, and confidence. These programs should deliver not only theoretical insights but also practical applications, allowing teachers to better integrate EDP into their teaching practices.
3. It is hoped that future research will further contribute to the effective implementation of the engineering design process (EDP) in the classroom by exploring innovative strategies like the utilization of robotics or technology, addressing the identified challenges, and adopting the best practices.

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