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# A Scoping Review on STEM Education: The Best Practices Recorded Through Previous Studies in Early Childhood Education Setting

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## Abstract

STEM (Science, Technology, Engineering, and Mathematics) education is a 21st century learning approach that is extremely important to students and children nowadays. Many developed countries have emphasized this approach to early childhood education (ECE). Although there are some challenges in promoting children's cognitive development in preschool, there are some best practices that early childhood educators can use as a guideline in planning, implementing, and evaluating their development at school. Four databases were used to find the best practices consist of Scopus, ERIC, Web of Science, and Science Direct. These databases are consulted to analyze published articles that produce findings on the best practices and challenges of implementing STEM activities that have been recorded either in kindergarten or preschool environments. The findings revealed there were 23 themes for the best practices and 10 themes for challenges that were successfully analyzed. In order to ensure that STEM education can be implemented with better quality in the future, educators should know the best way to implement the activities by practicing the best practices. In addition, educators also need to take action wisely when there are challenges in implementing STEM activities so that children can acquire meaningful experience when participating in the activities.

## Introduction

Science, technology, engineering, and math (STEM) literacy and proficiency are seen as crucial human capital competencies for the 21st century by policymakers, educators, and researchers (Angoro at el., 2021). Moreover, in schools, STEM is seen as a platform for student development. The effectiveness of a STEM education teaching and learning session is determined by how a teacher applies the value of creativity. Creativity in teaching is essential for ensuring that children are interested in STEM (Amran et al., 2021). Teachers should be more serious in practicing the approach through STEM Education when teaching children in order to ensure that students can enjoy quality learning both inside and outside of the classroom. This happens is due to the primary focus of STEM Education is more open in comparison to the traditional approach, which is more focused on two-way learning. Instead of using contemporary student-focused applications and methodologies, most counting lessons have been taught using conventional (traditional) or relatively sophisticated teacher-centred methods (Belias et, al., 2013). Additionally, educators found the traditional teaching method to be familiar and comfortable, making the transition to creative STEM teaching a difficult process (Stylianidou et al., 2018). Therefore, the selection of the STEM Education approach needs to be implemented by the teacher because the fact that it is a multidisciplinary course and incorporates creativity might improve STEM instruction, make it more interesting and meaningful for the students, and take the place of a typical, teacher-led art classroom. (Mohd Hawari, & Mohd Noor, 2020). Finally, the restructuring of practices and teacher education programs to be carried out in learning environments will be facilitated by STEM education (Çiftçi & Topçu, 2021).

In STEM education is very important to children in today's world because it provides many new opportunities that children can explore on their own. Looking more clearly at the importance of the four STEM elements, it can be illustrated that each element needs to be strengthened by children from day to day. From the perspective of early math according to a study conducted by Doss et al. (2022), they stated that early mathematical achievement predicts subsequent mathematics success. This can be supported by the findings based on the study conducted by Hofkens et al (2022), where they stated that achievement in math can give clear insights into how young children's capacity for attention and concentration relates to their mathematical development and learning in primary school. Moreover, from the perspective of the importance of early science in ECE, it promotes democracy and social justice, it urges us to investigate, and when necessary challenge and suggest alternatives to the practices and traditions of ECE science (Hanson et al., 2021). Yacoubian and Hansson (2020) have argued that science instruction should dispel common misconceptions about science and scientists in order to support educational goals and values connected to democracy and social justice. It is because in ECE, it is important that this entails presenting more varied representations of scientists as well as broader perspectives on the nature of science, the process by which scientific knowledge is created, and the place of science in society.

In addition, if viewed from the technology element, early childhood skills on the use of technology have been emphasized since the beginning of school. Children should have the chance to build computational artefacts that may be shared with others and support a widening variety of computational literacy abilities, from novice to expert (2020). In order to provide children with crucial skills, countries around the world have started integrating computing courses into their national curricula in recent years (Papadakis, 2021). Thus, the introduction of technology is not only important for adults, but it also needs to be learned by children. Last but not least, from the perspective of the importance of engineering elements to children, many studies have revealed why problem-solving and decision-making skills need to be mastered by children. Nowadays, young children are becoming more interested in engineering (Lippard et al., 2017). This can be supported by the findings from the study of O' Reilley et al., (2022), where they stated that studies on critical thinking in young children are particularly important for engineering field. In ECE, results are not a real benchmark in evaluating children's engineering development. But most importantly is how children go through when interacting with engineering activities. Recent research has focused on integrating engineering into ECE classrooms because of how crucial it is to introduce engineering to children at a young age (Van Meeteren, 2018).

This scoping review will narrow the perspective into two constructs, namely the best practises and the challenges, by delving deeper into previous studies regarding the implementation of STEM education for preschool and kindergarten students. All previous studies will be included in the table, which will then be analyzed and syntactically. The findings of this study will provide ECE teachers across the world with a clearer explanation of what type of preparation is technically required when teaching preschool and kindergarten children as well as the best way to implement STEM activities in and out of the classroom. There are two objectives outlined in this study as below:

1. Determine the Best Practices in Early Childhood STEM education.
2. Determine the challenges faced by early childhood teachers in teaching STEM education.

## STEM Education in ECE Setting

Various countries have prioritized STEM development in various fields. The last ten years have seen a lot of interest in STEM (Wright et al., 2016). STEM development is being highlighted not only in the employment industry, but also in the field of early education. A range of educational and life pathways that start in the early grades are directly related to achievement in STEM education at the highest levels (Great Lakes Equity Center, 2016). The role of teachers in fostering a successful learning environment is crucial for ensuring that STEM education is always evolving and turns into a program for kids to acquire high-quality knowledge. As proof, early childhood classrooms as potent environments for identity work and, more particularly, as a location (or not) for fostering the early development of STEM identities (Hachey, 2020). Through the positive interaction that children build in the classroom while carrying out STEM activities, it will give them an advantage to develop holistically. The process of forming an identity as well as the self-understandings that students finally embrace depend on role exploration, the positioning it results in during social interaction, and the accompanying educational acts embodied by children (Talafian et al., 2019). Young children internalize both internal and external academic subjects, which shapes their attitudes and views about their potential for success in STEM later in life (Martin-Hanson, 2018).

Commenting further, there are many challenges faced by both children and teachers in creating active and meaningful learning when carrying out any STEM activity at school. For example, the lack of teacher knowledge about STEM education (Daud, 2019), teachers struggle to incorporate elements of creativity that could inspire children’s creativity in the classes because they lack the necessary information about creativity (Amran, 2021), early childhood teachers are unfamiliar with STEM education and have low self-efficacy in STEM teaching (Toa, 2019), STEM education is challenging, esoteric, and dull (Conradty & Bogner, 2019), and also teachers struggle with a number of issues, including curriculum restrictions and a lack of time, money, and space for creative teaching (Stylianidou et al., 2018). Based on these issues, it is possible that STEM education will not be promoted directly to children in ECE centers. As a result, teachers must understand how to solve these issues. There must be numerous methods and practices that teachers can employ to provide the best learning opportunities for children when participating in STEM activities. A study suggests that to produce quality teachers in STEM, the professional development programs encouraged teachers to investigate the STEM class in depth, to deepen or correct their original understanding of STEM, and to comprehend the STEM curriculum (Huang, 2021).

Although preschools help young students gain a general sense of school preparedness, develop positive social skills, and have exposure to STEM-rich material, they also provide them their first interactions with the suspension and expulsion procedures (Allen, 2022). Thus, it is crucial for the teacher to act as a mentor and facilitator to assist students in deciding whether inquiry studies or projects are appropriate and in helping them to create achievable goals (Vongkulluksn et al., 2018). To ensure that teachers can truly understand how STEM education works, it is important to make an effort to provide support to teachers in conducting STEM education by providing professional development (Margot & Kettler, 2019). A study found that preschoolers who are explicitly supported through well-planned, exciting, and developmentally appropriate activities can achieve better levels of STEM learning (Aldemir & Kermani, 2017). In addition, it can be supported by another study which has stated that STEM modules included a lot of spatial exploration exercises (He et al., 2021). Therefore, even though there are specific issues in preschools or ECE centers in implementing STEM activities, the creativity and efforts of teachers are very important in making class activities more effective. That is why, for preschool students with low emotion knowledge, teacher-child closeness may be especially important in promoting academic readiness (Marks, et al., 2023) while they are learning.

This scoping review will be the first to expose ECE professionals, particularly preschool teachers, also known as kindergarten or pre-k teachers in some countries. Furthermore, this review will serve as a guideline for educators in the future as they prepare the greatest STEM learning. Children’s development will accomplish comprehensive goals if activities are implemented correctly and effectively. This scoping review has three key goals, which are as follows:

**STEM Education in ECE from the International Context**

Many countries have taken seriously the implementation of STEM activities for their citizens. This is proven through many past studies that have been conducted by researchers around the world. According to a study conducted by Turkish namely Yalçın and Erdan (2021), they found that preschool STEM education based on the design thinking model permanently improves children’s creativity and problem-solving abilities. It was also discovered that in children, creative problem-solving skills improved, communication and collaboration improved, and the process contributed to peer learning. In addition, through the findings of a research that has been carried out in Turkey as well, early childhood educators should give priority to integrating STEM education into the early childhood curriculum to help children learn about STEM areas and concepts during this era of rapid learning and growth (Çiftçi, 2020). The policy objectives of STEM education in Turkey were reported to include teacher preparation and curriculum integration. It is crucial to keep in mind during this process that the teachers will execute any curriculum utilized in early learning centers (Aktürk, 2017). Therefore, the implementation of interesting activities can improve children’s development. As proof, STEM-based educational initiatives have a substantial impact on kids’ problem-solving abilities (Sahin, 2021).

From the perspective of the United States of America (USA), researchers from there also believe that the active involvement of children at an early age in STEM activities will develop their development from various fields. When preschoolers are supported especially through well-planned, exciting, and developmentally appropriate activities, they can achieve higher levels of knowledge in STEM (Aldemir & Kermani, 2016). A strong emphasis on operationalizing STEM education with equality at its core, ensuring that every student has access to and opportunity for high-quality STEM learning (Roberts & Roberts, 2023). In addition, the American government also supports various parties in conducting research related to STEM education at the initial stage. Fundamental research across all branches of science and engineering, benefiting the nation (National Science Foundation, 2018). This can be proven through an official document that has been published by the Office of Science and Technology Policy (2019), where there are 4 strategic plans outlined by the USA government in developing STEM education. This includes (i) developing and strengthening strategic partnerships; (ii) where disciplines converge, engage students; (iii) build computational literacy; and (iv) operate with transparency and accountability.

In Japan, topics of human resources development, science, and technology, the synthesis of general education and the elite track “STEM for STEM people,” and policies and programm that affect many elements of STEM education are covered (Cheng, 2022). Many STEM education studies have been implemented in the early stages of schooling. Cross-curricular education has previously been adopted in Japan, where the need for workers with strong engineering and scientific skills has long existed (Matsuura & Nakamura, 2021). The Japanese educational system was thought to need to change from the old method of education centered on specific academic areas to a new education based on cross-disciplinary education encompassing comprehensive learning in order to promote STEM education (Ohtani, 2021). Besides that, to strengthen ECE institutions in Japan, there are several studies that have been carried out such as a conceptual framework proposed for the proper application of STEM education, which was based on the tenets of the Japanese curriculum (Yata et al., 2020).

Otherwise, in Australia there are many promotions that have been done by various parties, especially the government and universities in encouraging the exposure of STEM education at an early stage. The “National STEM School Education Strategy 2016-2026” was endorsed by the state and territory governments of Australia in December 2015. (Murphy, et al., 2019). To give more possibilities for families and children to participate in engaging STEM activities, the Australian Government is dedicated to the development of early learning STEM materials and training for educators (Department of Education, 2022). Through a statement from the STEM Education Research Centre (2021), there is an application developed specifically for their community especially children to play online. The application is called ELSA (Early Learning STEM Australian). In order to fulfill the government’s aspirations in improving STEM education in the early stages of schooling, there is a recommendation that has been suggested by Campbell and Speldewinde (2022), where one way for educators to help young children develop a knowledge of sustainable development is to implement a whole-of-kindergarten strategy that focuses on the systematic development of quality STEM education.

**Early STEM Education in Malaysia Context**

Although the promotion of STEM Education in Malaysia is still in its early stages (Ghazali & Yusof (2022), yet the Malaysia Education Blueprint (PPPM) 2013-2025 places emphasis on several programs including STEM education. In order to encourage more students to pursue STEM careers in school, the Ministry of Education Malaysia (MOE) is intensifying its efforts to promote STEM education (Muhammad & Ibrahim, 2021). The MOE has set a target percentage rate of 60% for student engagement in the science stream compared to literature since 1967. Since that time, the 60:40 ratio guideline has been followed in the country's educational system (Agricultural Science Foundation Center, 2022). In order to ensure that STEM education is empowered from an early stage, various parties, especially schools, need to provide opportunities and active learning spaces. Through the creation of an Implementation Committee, the formulation of suitable policies, and the participation of business, the private sector, and government-linked companies, the Permata Division of the Prime Minister's Department and implementing agencies must right away incorporate STEM into the PERMATA curriculum and offer STEM professional training to educators (Ong et al., 2016). Hence, to ensure that the value of STEM education would be raised in this country, in a variety of activities, teachers function as facilitators for students (Daud et al., 2022).

In fact, Malaysia is one of the nations that performed poorly in the Mathematics and Science categories of the Program for International Assessment (PISA) (Connie, Ling Teng & Sapirai, 2021). This happens because there are several issues that occur in schools, whether kindergarten, preschool, primary school or secondary school. Those challenges consist of lack of children's attention during the learning process (Daud, 2019), absence of leadership support from the school for supporting STEM education and the lack of exposure and preparation for teachers (Ismail et al., 2020), teachers do not receive sufficient STEM education training (Mahmud et, al., 2018), a lack of parental support to encourage children to pursue STEM education (Ghani et al, 2020), and last but not least is monitoring the development of STEM abilities in pre-service teachers is still difficult (Hoon, 2021). In order to resolve these issues from continuing to be a major problem to the development of the education system in Malaysia, there are several initiatives that need to be done in the future. One of the initiatives is it is important for researchers and educators to create and assess culturally relevant approaches to early STEM education as well as to be conscious of any prejudices or assumptions that can limit young children's ability to learn about and succeed in STEM (Li et al, 2020).

## Method

Scoping reviews are generally employed for "reconnaissance," or to define the operational definitions and conceptual limits of a subject or field. Therefore, scoping studies are especially helpful when a body of literature hasn't been thoroughly examined or shows a complex or heterogeneous nature that makes a more in-depth systematic examination of the evidence impossible (Peters et al., 2015). Scoping reviews are frequently used to [categorize or group] the current literature in a specific topic in terms of its nature, features, and volume and are very useful for synthesizing research evidence. Note: A scoping review and a mapping review are frequently misunderstood.

There are two distinct categories of reviews. While mapping reviews are more question-based, scoping reviews are more topic-based. Scoping reviews, in accordance with Grant and Booth (2009), are "preliminary evaluation of the research literature's prospective size and scope. Aims to define the type and scope of research evidence, which typically includes active research." This scoping article review utilized a five-stage procedure created by Levac et al. (2010) in their study, "Scoping studies: expanding the technique." Technically, Arksey and O'Malley provided the initial inspiration for this framework in 2005. The authors have identified 5 systematic processes in this process, which are:

1. *Framework stage one: Identifying the research question.*
2. *Framework stage two: Identifying relevant studies.*
3. *Framework stage three: Study selection.*
4. *Framework stage four: Charting the data.*
5. *Framework stage five: Collating, summarizing, and reporting the results.*

In Framework stage one, which is identifying the research question, the researchers have considered two very clear questions why this scoping review needs to be studied. Firstly, what are the best practices of STEM education in ECE? Secondly, what are the challenges faced by early childhood teachers in teaching STEM education? Next, the research process continues with Framework stage two where researchers need to identify relevant studies. In this stage, researchers need to use several databases from high-impact journals to produce a list of past studies related to the implementation of STEM education in ECE. The four separate databases, namely Scopus, World of Science (WoS), ERIC, and Science Direct Gates, were used for the scoping study. "STEM education" and several related terms, such as "preschool" and "learning," were utilized as the primary, secondary, and tertiary keywords, respectively. In order to find relevant papers that have been published that address the implementation of STEM education in preschool or other children's institutions around the world that are known by other names such as pre-k, or kindergarten, the Boolean operator was used in the search. This operator most frequently AND, OR, and NOT, are employed to either broaden or narrow search results, according to Enago Academy (2020). In addition, this operator function is available in the majority of journal index systems and requires capitalization. To describe more clearly the search strings performed by the researcher, it can be seen in Table 1:

Table 1. The Search Strings Used in 4 Different Databases

| **Database Search Strings** | |
|---|---|
| Eric | Collection ("STEM Education" AND "Preschool" AND "Learning")<br>Publication Date: Since 2019 (Last 5 Years) |
| Web of Science (WoS) | All= ("STEM Education" AND "Preschool" AND "Learning")<br>Refined by: (Publication years: 2018 or 2019 or 2020 or 2021 or 2022)<br>Document Type: Article<br>Language: English |
| Direct Science | Advanced Search ("STEM Education" AND "Preschool" AND "Learning")<br>Refined by: (Publication years: 2018 or 2019 or 2020 or 2021 or 2022)<br>Document Type: Article<br>Language: English |
| Scopus | TITLE-ABS-KEY ("STEM Education" AND "Preschool" AND "Learning") AND (LIMIT-TO (PUBYEAR, 2022 ) OR LIMIT-TO ( PUBYEAR , 2021 ) OR LIMIT-TO ( PUBYEAR , 2020 ) OR LIMIT-TO ( PUBYEAR , 2019 ) ) AND ( LIMIT-TO ( DOCTYPE , "article" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) |

Next, the research process continues with Framework stage three which is the researchers need to analyze the study selection. The scoping review's research questions served as the benchmark for finding pertinent studies. The inclusion and exclusion criteria were established in order to retain the search's focus. Five criteria were established, and they are as follows:

Table 2. The Inclusion and Exclusion Criterion Considered to Retain the Search's Focus

| No. | Criteria | Inclusion | Exclusion |
|---|---|---|---|
| 1 | Component | STEM Education in Early Years | STEM Education in Primary, Secondary, And Tertiary Schools |
| 2 | Years Of Publication | 2018-2022 | 2018 And below |
| 3 | Research Type | Empirical | Systematic Article Review, Scoping Article Review, Article Review, Meta-Analysis, Chapters in Book, Meta-Synthesis, Newspaper or Other Peer Review Articles |
| 4 | Sample | Samples Or Respondents Can Be from Preschool, Kindergarten, And Pre-K Students and Teachers | Samples Or Respondents from Other Level of Education Such as Primary, Secondary, And Higher Institution Students |
| 5 | Findings | Report On the Topics or Issues Related to The Implementation of STEM Education In Early Schooling | Report On the Topics or Issues Related to The Implementation of STEM Education in Other Level Of Schoolings |

Articles that do not meet the first criteria are omitted. This means that articles that do not make STEM education the primary focus of the article, despite the presence of the word, are removed because they do not report on STEM education-related topics. Second, articles published prior to 2018 were eliminated since they were out of date and may have different conclusions than current studies. Third, papers that are not empirical in nature where they do not report on technique and findings, are not considered to be the main sources in this scoping review. It means that review papers, magazines, newspapers, and other non-empirical articles are excluded from the scope of this review. Since the purpose of this research is to identify the approaches that have been used to study the implementation of STEM education in ECE, identifying empirical studies is essential for this scoping review. Fourth, the study sample and respondents should be those who are still studying in ECE (ECE) centers such as preschool, kindergarten or pre-k. In addition, early ECE teachers whether in-service teachers, pre-service teachers, or practical teachers are counted as samples or respondents of this study. Finally, research findings must be gathered in child education facilities; any other findings are not considered to meet the criteria for research findings.

This research will then proceed to Framework stage four, where researchers will chart the data. For the thematic and comparative analysis, the data were specifically summarized using the Microsoft Excel software. It includes the author's information, publication year, research methodology, constructs or variables, findings, and themes. The analysis will be explained in the findings section. Finally, this research will continually proceed with the Framework stage five which is the researcher's needs to collate, summarize, and report the results. Technically, common themes and conclusions drawn from the publications were established at this point. At this point, it was also decided to discuss any further noteworthy information, such as the study's starting point, publication year, and any relevant supporting paperwork.

**Procedure of Data Collection**

Data was collected from the beginning of December 2022 to the middle of March 2023. Two researchers conducted the data search, which included searching four distinct databases. The researcher discovered 31 papers that had been chosen to answer study questions 1 and 2. The inclusion and exclusion principle was utilized in all the publications that were searched, and the needed data collection totaled N=31 articles. Figure 1 depicts how the researchers gathered data. The database search extracted 169 articles based on the above-mentioned search techniques (Table 1). Due to duplication, 22 of these articles were omitted from the initial list. So, the total number of articles that can be considered is only 147. A total of 52 papers were then excluded based on the title and abstract due to methodology, publication type, language, timeline, and subject. After a thorough analysis of the remaining 95 papers, 61 were eliminated due to apparent irrelevancy to the scoping study's objective. Only 31 publications were selected after a thorough selection process based on the Preferred Reporting Items for Systematic Review, which is known as PRISMA, adapted by Moher et al. (2015) (see Figure 1).

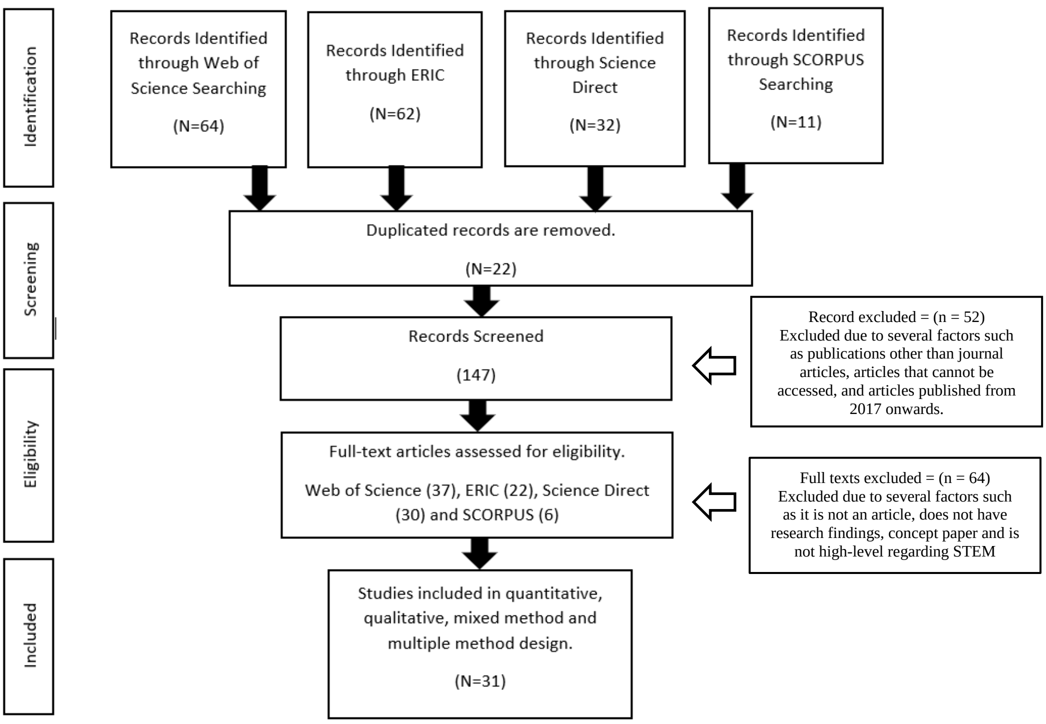


Figure 1. PRISMA Flow Diagram of the Study Selection Process

Based on the aforementioned search methods, 169 articles were pulled from the database (see Table 1). 22 of these articles were originally included in the list but were removed due to duplication. Therefore, only 147 items in total can be considered. A total of 52 studies were then rejected based on the title and abstract owing to technique, publishing type, language, timeframe, and subject. The remaining 95 papers were carefully examined, and 61 were dropped since they seemed to have no relevance to the goal of the scoping study. After an extensive selection procedure based on the Preferred Reporting Items for Systematic Review (PRISMA), which Moher et al. (2015) modified, only 31 papers were chosen.

Furthermore, the publications chosen were confined to quantitative, qualitative, and mixed empirical investigations from journal articles published between 2018 and 2022. According to Southern New Hampshire University (2023), a decent rule of thumb for research in the arts, humanities, literature, history, and so on is to use sources published within the last ten years. Conference proceedings were eliminated from consideration for the paper due to a lack of systematization and transparency due to customary judgements. Hodgkinson and Ford (2014). As a result, it was necessary for this study to pick high-quality articles published within the last six years for a scoping review.

**Procedure of Data Analysis**

They have selected content analysis techniques. Previous research methodology is classified into research design and study site. Furthermore, past study data are used as an important component to see the best practices in the implementation of STEM activities for children and the obstacles that instructors experience while applying them. The data was calculated using descriptive statistics to determine the frequency of certain themes. Analytical results are given and discussed in the following subtopics.

## Results

### Research Method

In this study, four research approaches were used by previous researchers to provide high-quality empirical research data. The percentage of research designs utilized in prior studies is depicted in Figure 2.

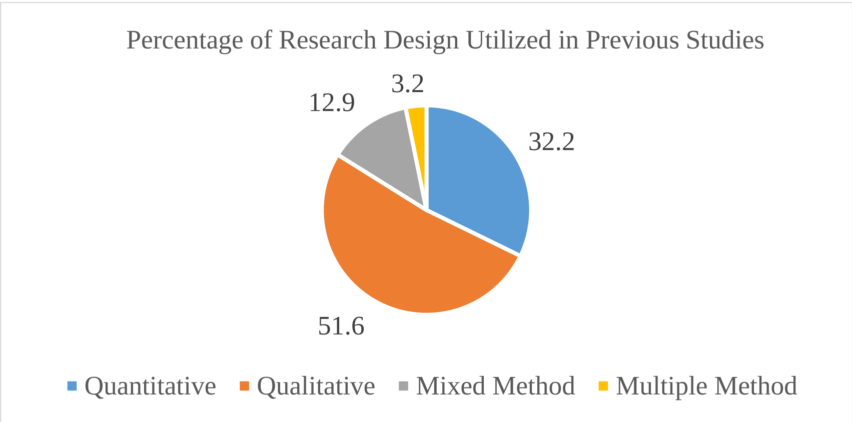


Figure 2. Categorization of Research Designs used in Previous Studies

Figure 2 indicates that each researcher's research design does not display a balanced percentage and number. The researchers' preferred design was qualitative (N=16, 51.6%), followed by quantitative (N=10, 32.2%), mixed method (N=4, 12.9%), and finally multiple method (N=1, 3.2%). Based on their observations of the chosen papers, the majority of prior researchers chose to utilize interview and observation tools in qualitative studies. In terms of quantitative design, however, most researchers have chosen questionnaire instruments and tests at various degrees of development.

**Research Location**

The researchers did not limit the study only in Malaysia but based on data analyzed from the four databases described earlier, there are many successful STEM education studies implemented to early children in other countries. According to Figure 3, 16 countries are involved in these 31 studies.

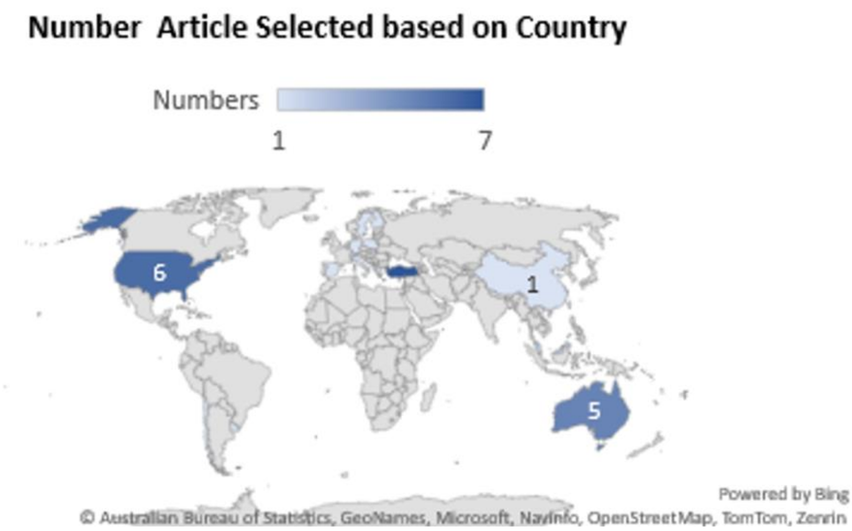


Figure 3. Categorization of Studies Conducted Based on Country

According to the Figure 3, there are 16 nations represented in the 31 studies chosen by the researcher. Despite the fact that the total frequency of research implemented by countries is N=32, there is a study that was conducted in two separate countries, which is the study pf Greca Dufranc et al., (2020), which was conducted in Sweden and Spain, respectively. According to this conclusion, the biggest number of the 31 articles chosen is a study conducted in Turkey, where (N=7, 21.8%) was accepted to answer the research question. Followed by USA, Australia and Malaysia. Other than those countries, it recorded the lowest proportion, indicating that all of the articles were chosen based on studies conducted in a single country, which is (N=1, 3.1%), such as China, Taiwan, Poland, and others.

**Main Results**

According to Table 3, there are 31 different papers that have been analyzed in this scoping study. Based on the findings, it reveals that there are 12 best practices for teachers and students that can be applied when participating in STEM activities at school have been identified. Furthermore, there are nine major problems that teachers and children encounter in order to promote STEM education at the early education level.

Table 3. The Themes Determined for the Best Practices of STEM Education for Early Children and the Challenges Faced in Implementing Them

| No | Publication | Theme For Best Practices | Theme For Challenges |
|---|---|---|---|
| 1. | Türk, A., & Akcanca, N. (2021) | 1. Exploration of material<br>2. Play-Based learning | 1. Limited knowledge faced by children |
| 2 | Akcanca, N (2020) | 1. Problem-based learning strategy | 1. Lack of knowledge faced by teachers |
| 3. | Ültay, N., & Ültay, C. (2021) | 1. STEM-based approach | 1. Lack of knowledge faced by teachers |
| 4. | Greca Dufranc, et al., (2020). | 1. Play-Based learning<br>2. STEM-based approaches | 1. Difficulty in finding materials |
| 5. | Çakir, Z., & Altun-Yalçin, S. (2021) | 1. Problem-based learning strategy<br>2. Exploration of Material<br>3. Team-Based Learning<br>4. Child-Lead Activities | 1. Difficulty in finding materials<br>2. Lack of knowledge faced by teachers |
| 6. | Şahin, H. (2021). | 1. STEM-based approaches<br>2. Problem-based learning strategy | 1. Providing a quality STEM programs/activities |
| 7. | Awang et al., (2020) | 1. Inquiry-based learning<br>2. learning-by-doing activities | 1. Providing a quality STEM programs/ activities |
| 8 | Dilek et al., (2020) | 1. Inquiry-based learning<br>2. STEM-based approaches | 1. Lack of knowledge faced by teachers |
| 9 | Cabello et al., (2021) | 1. Technological aid<br>2. Facilitating Problem based Learning | 1. Lack of knowledge faced by teachers<br>2. Classroom Environment and Spaces |
| 10 | Rönkkö et al, (2021) | 1. Inquiry-based activities<br>2. Project-based learning | 1. Providing a quality STEM programs/ activities |
| 11 | Kewalramani et al., (2020) | 1. STEM-based approaches<br>2. Experimentation technique<br>3. Inquiry-based activities | Lack of STEM education promotion from various responsible parties |
| 12 | Amran et al., (2021) | 1. Facilitating problem-based Learning<br>2. Module-Based Learning | 1. Lack of knowledge faced by teachers<br>2. Difficulty in finding materials |
| 13 | Anggoro et al., (2021). | 1. Problem-based learning strategy<br>2. Play-based learning | 1. Providing a quality STEM programs/ activities |
| 14. | Cinar, (2019) | 1. Task-oriented strategy<br>2. Problem-based learning strategy | 1. Lack of knowledge faced by teachers |

| No | Publication | Theme For Best Practices | Theme For Challenges |
|---|---|---|---|
| 15 | Chen & Tippet (2022). | 1. project-based learning<br>2. STEM-based Approaches<br>3. Facilitating Problem–Based Learning | 1. Lack of STEM program/training for teachers |
| 16. | Speldewinde, (2022) | 1. Inquiry-based activities<br>2. Play-Based Learning<br>3. nature-based learning<br>4. Problem-based learning strategy | 1. Difficulty in finding materials |
| 17. | Haber et al., (2021). | 1. Questioning and answering technique<br>2. inquiry-based activities | Create active teaching and learning in classroom |
| 18 | Hofkens, et al., (2022) | 1. Task-oriented strategy | 1. Limited knowledge faced by children |
| 19 | Castaneda et, al., 2022 | 1. Inquiry-based activities<br>2. Educational tv shows<br>3. Reading resources<br>4. Questioning and answering session | 1. The involvement of parents in supporting children at home |
| 20 | He at al., 2021 | 1. Project-based learning<br>2. Learning-by-doing activities | 1. Continuous research in early STEM education |
| 21 | Pulak & Szczotka (2019) | 1. Problem-based learning strategy<br>2. Inquiry-based activities | 1. Lack of STEM program/training for teachers |
| 22 | Fleer, M. (2021). | 1. Storytelling technique<br>2. Role play technique<br>3. Inquiry-based activities<br>4. Music Teaching Strategies<br>5. explanatory response strategy | 1. Providing a quality STEM programs/activities |
| 23 | Convertini, (2020) | 1. Exploration of Material<br>2. Trial and error method | 1. Create active teaching and learning in classroom |
| 24 | Nikolopoulou, (2022) | 1. Experimentation Technique<br>2. Technological-Aid<br>3. Exploration of Material | 1. Create active teaching and learning in classroom |
| 25 | Hollenstein, (2022) | 1. Problem-based learning strategy<br>2. Technological aid<br>3. learning-by-doing activities | 1. Lack of STEM program/training for teachers |
| 26 | Speldewinde & Campbell (2022) | 1. Nature-based learning<br>2. Problem-based learning strategy<br>3. Inquiry-based activities | 1. Providing a quality STEM programs/ activities |
| 27 | Gerosa, et al., | 1. Exploration of Material | 1. Difficulty in finding materials |

| No | Publication | Theme For Best Practices | Theme For Challenges |
|---|---|---|---|
| | (2022) | 2. Technological aid<br>3. Facilitating Problem–Based Learning | |
| 28 | Polinksy et al., (2022) | 1. Exploration of Material<br>2. Technological aid | 1. Lack of knowledge faced by teachers |
| 29 | Müller-Brauers at el., (2020) | 1. Exploration of Material<br>2. Technological aid | 1. Continuous research in early STEM education |
| 30 | Bower et al., (2020) | 1. Exploration of material | 1. Providing a quality STEM programs/activities |
| 31 | Fleer et al, 2022 | 1. Play-Based Learning | 1. Continuous research in early STEM education |

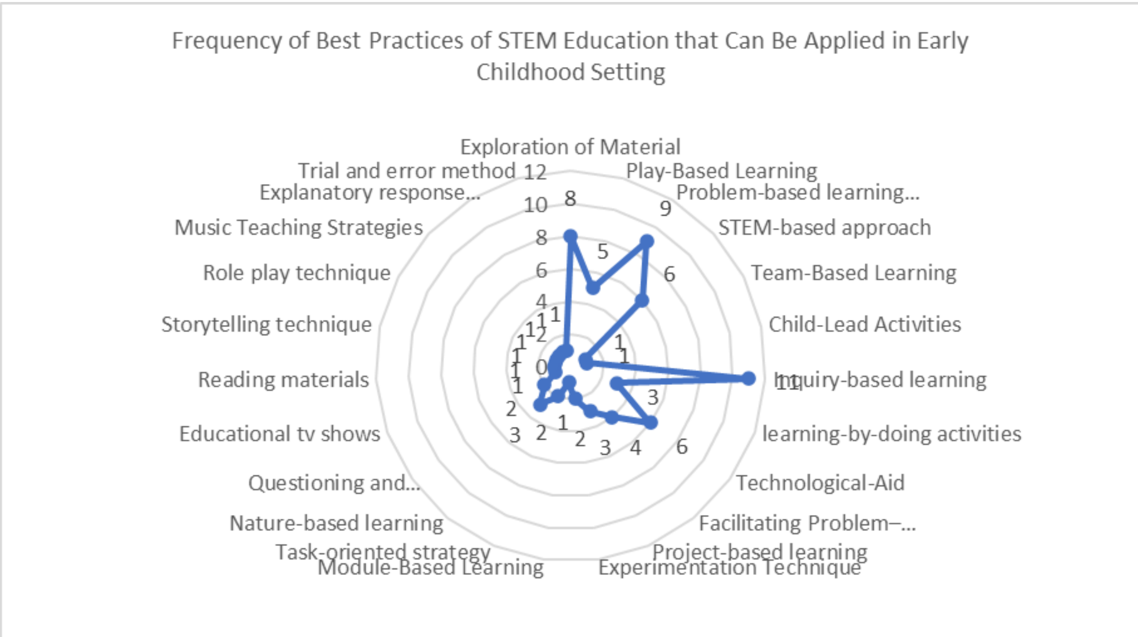


Figure 4. Best Practices of STEM Education Successfully Recorded

According to the figure above, researchers discovered that most researchers who did empirical studies discovered several best practices in implementing STEM activities for early children in kindergarten or preschool. The most frequently mentioned theme is that most teachers choose inquiry-based learning (N=11, 16.1%) to improve the quality of their STEM instruction. Based on observations and analysis of several articles stating that inquiry-based learning is one of the best practices in implementing STEM education, it has been revealed previous researchers believe that this practice can create direct experience for children when implementing STEM activities for children. Inquiry-based activities also not only give children the opportunity to see a process from beginning to end such as the process of growing beans, but they will also continue to wonder why and why the process occurs. With the existence of this situation, it can improve their development to communicate with the people around them. Hence, they explained that this practice can pique children's interest when they try to connect with the activity.

Besides, the best practices that have been successfully recorded are problem-based learning strategy (N=9, 13.1%), followed by exploration of material (N=8, 11.8%), and followed by technological-aid and STEM-based approach (N=6, 8.8%) respectively. Previous research has found that most children require direct experience to improve their ability to interact with STEM activities. It is important for them to be given the opportunity and space to explore these activities freely. Preparing interesting and high-quality materials can pique children's interest in solving any problem they try to concentrate on in the activities provided. Furthermore, technology assistance is important in increasing children's interest in any activity provided in class. If observed correctly, the theme of the STEM-based approach is recorded because combining all of the STEM elements themselves can encourage children to participate in activities at school. In other best practices, no STEM elements are combined in any school activity, and some teachers only combine Math and Science elements when carrying out any activity.

On the other hand, the other best practices found through previous studies are play-based learning (N=5, 7.4%), and followed by facilitating problem–based learning (N=4=5.9%). Play-based learning, also known as the learning through play approach, is a practice that ECE teachers and children aged 4-6 years are familiar with. This practice not only provides children with a natural experience for development, but it also inspires them to come to school to play while doing activities or to play while learning. In addition, the analysis of the study has also revealed that teachers as facilitators in helping children to carry out activities are also very important to be practiced in schools. As evidence, teachers who observe children doing activities will shape their personalities through the scaffolding process. This means, teachers are not the ones who complete the activities assigned to the children, but they become the ones who encourage the children to complete the activities in a better way.

Besides, another best practice found through this scoping review is learning-by-doing activities, project-based learning, and nature-based learning (N=3, 4.4%) respectively. Learning something new or performing a given task directly can improve children's cognitive skills. If you compare children who do homework at home with children who do homework in class, it is different. Children who gain hands-on experience can improve their creative and critical thinking. Therefore, it is not appropriate for children to be given assignments at home because they may not be motivated by a real learning environment. Furthermore, project-based learning is an important approach in schools. It is well known that most children who participate in a project can inspire them to pursue their interests in the future. Children who participate in building model activities, for example, will be instructed to become engineers in the future. Next, when children engage in STEM activities, natural learning is an important component in providing meaningful experiences. The activity of making terrarium, for example, will improve children's cognitive development in making decisions to pattern their terrarium.

Another the best practices that have been successfully recorded are experimentation technique, task-oriented strategy, and questioning and answering technique (N=2, 2.9& respectively. Last but not least, only (N=1, 1.5%) has been recorded for the practices of team-based learning, child-lead activities, module-based learning, educational tv shows, reading materials, storytelling technique, role play technique, music teaching strategies, explanatory response strategy and trial and error method respectively. The opportunity for children to learn on their own and exposure to group learning also provides many benefits to them. If they learn by themselves, they can develop their ideas to create something. On the other hand, if they learn as a group, the value of healthy competition can be formed in producing quality projects that are more productive. Besides, the trial-and-error method seems easy to apply in the classroom, it has many benefits for children. For example, when children are asked to make decisions when creating a simple robot, they will try several times to create the best robot. Therefore, teachers cannot arbitrarily punish children when they fail to develop or produce something. Opportunity after opportunity should be given so that they can learn from the mistakes they made on previous activities or trials.

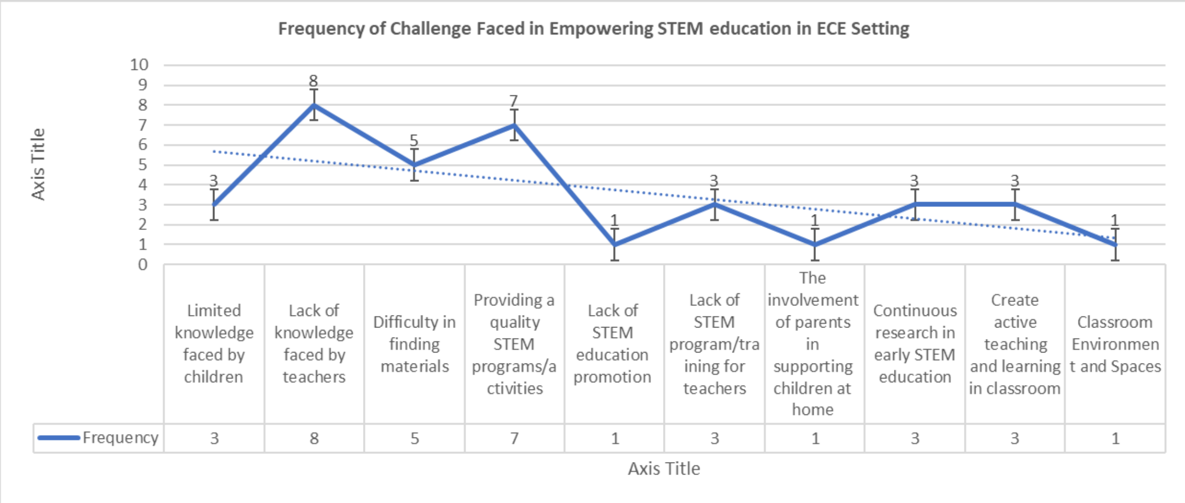


Figure 4. Frequency of Challenges Faced in Empowering STEM education in ECE Setting

According to the diagram above, 10 themes for challenges have been identified across all 31 articles that have been analyzed. The greatest challenge identified by teachers (N=8, 22.9%) was a lack of knowledge. The majority of previous researchers have agreed that this is the most difficult challenge in promoting STEM education in early childhood institutions. This means they believe that teachers who lack sufficient knowledge in implementing STEM activities will cause STEM activities to be improperly implemented. Furthermore, the second challenge that ECE teachers face in improving the quality of their teaching through STEM education is the difficulty in providing high-quality STEM programs/activities (N=7, 20%). According to the current study, teachers are less creative in implementing quality programmes or activities in schools. Some designers have extensive experience educating these children, but they are less experienced in providing activities that shape children holistically.

The third challenge identified by the current researchers is the difficulty in locating materials for teachers to prepare (N=5, 14.2%). Most of them believe that one of the reasons STEM activities cannot be carried out in a conducive environment is that teachers find it difficult to provide quality STEM equipment. As a result, they do not place a greater emphasis on implementing STEM activities with children. Following that, four themes emerged from the findings (N=3, 8.6%), namely limited knowledge among children, a lack of STEM programs/training for teachers, a lack of continuous research in early STEM education, and efforts to promote active teaching and learning in the classroom. Children's difficulties understanding the process of participating in STEM activities at school, as well as their limited knowledge, contribute to these activities not being carried out properly. Teachers, for example, who provide engaging STEM activities will face challenges if students are unable to respond to the activities. On the other hand, previous research has shown that teacher training is critical for improving teachers' knowledge of STEM education for early childhood. Changes in teaching and learning sessions will occur on a daily basis. As a result, appropriate and continuous training must be implemented on a regular basis to all science or mathematics teachers.

Finally, the four new themes with the lowest number and percentage recorded are the provision of a good and non-threatening classroom environment and spaces, a lack of STEM education promotion from various responsible parties (stakeholders, media, government), and parental involvement in supporting children at home when implementing STEM education (N=1, 2.9%), respectively. Due to a lack of support from stakeholders, schools, government, or responsible entities in providing STEM training and programmes to teachers, so they might be facing various kinds of challenges in diversifying STEM activities in schools. Finally, a good space and environment must be provided at school so that children can enjoy themselves fully, freely explore their play world, and translate their emotions in a positive way when carrying out the teacher's activities.

## Discussion

Although the scoping review of this article only provides two different findings, which are the best practices in the implementation of STEM activities in ECE centers and the challenges of various parties in promoting these activities, it provides an overview for future studies on what additional actions various parties need to take in planning a higher quality activity. Although, children may have quick and in-depth learning possibilities with STEM education (He, at el., 2021), however, teachers retain prior perspectives and experiences that will influence their STEM instruction as significant individuals in a student's skill development (Margot & Kettler, 2019). Based on previous research, it has been revealed that one of the contributors to the best practice in empowering STEM activities in schools is through the implementation of activities through inquiry-based learning (IBL). Although this method seems difficult to be implemented by teachers at school, it is quite easy to implement as long as the teacher knows the right way how it can be implemented. Based on the findings of Eti and Sigirtmac (2021), ECE can use a variety of inquiry levels to do inquiry-based activities in the classroom or outside of the classroom. There are various advantages in implementing this teaching method and one of them is the authenticity of an activity is enhanced when students have the opportunity to apply what they have learned to real-world issues because they can see how the lessons, they have learned can benefit them outside of the classroom (Ryan & St-Laurent, 2016). In addition to allowing students to learn by experience, IBL also enhances a variety of skills (Öztürk, Kaya & Demir, 2022).

The use of problem-based learning (PBL) approach activities has also been recommended by instructors as the second-best practice to be applied in kindergartens and preschools for children. This approach can enhance the conventional paradigm while incorporating 21st century learning (Zakaria, Maat & Khalid, 2019). There are numerous benefits to using this method to kid development. Students' science process abilities can be influenced by authentic evaluation provided by teachers (Duda, Susilo, & Newcombe, 2019), and PBL is a novel learning strategy in addition to acquiring practical experience on a large scale. (Vega & Navarette, 2019). Therefore, the implementation of problem-based activities needs to be done by teachers to ensure that children can use their minds as best as possible when trying to solve a problem or task given to them. Last but not least, teachers can give children the opportunity to do group activities as it gives them the opportunity to learn from each other. According to Maraj et al. (2019), most of the students in their study felt that learning from others increased their understanding of the material being studied. Thus, providing opportunities for children to communicate with activities actively in helping them to always be open-minded when trying to solve a learning problem.

Next, the third best practice that children can apply is the use of a play-based learning approach. This is one of the strategies that many early science or mathematic teachers always choose when they implement any STEM activities at preschool or kindergarten. As a result, when children study while playing, they can develop cognitive, social, emotional, artistic, and physical skills through active participation in learning that is perceived as enjoyable, meaningful, socially dynamic, actively engaging, and iterative (Parker, Thomsen, & Berry, 2022). In addition, in the development of social, emotional, physical, cognitive, and creative skills in children, playful pedagogies have been demonstrated to be more effective than "traditional" or more "highly guided" pedagogical strategies (Parker & Thomsen, 2019). Teachers and children need to take a serious part in any play activity at school because it can improve relationships with each other. This is because play is defined as fundamental to children's learning across all domains in a play-based learning program, including social development, self-regulation, and academic learning (Ontario Ministry of Education, 2016). Althought there are many other best practices that can be practiced by teachers when implementing STEM activities such as the exploration of materials, play role techniques, the use of reading materials, the choice of music teaching atrategies and other practices, but these three practices seem as the best practices among the best practices that have been successfully revealed in this scoping review.

Next, discussing about the difficulties in implementing STEM activities for children. There are numerous difficulties that must be solved by children, teachers, and other parties involved directly or indirectly in enhancing STEM education at various levels. The first attention that needs to be given is the lack of knowledge by the teacher himself in carrying out activities with children at school (N Diana, Turmudi, & Yohannes, 2021; Nugroho, Permanasari & Firman, 2019: Rosikhoh et al., 2019; Awad & Barak, 2018). The weakness of teachers in mastering the content of STEM activities will cause the quality of the activities to be unable to be produced. As a result, many parties, particularly the government, must provide quality training or courses to teachers in order for them to be more open when doing STEM activities with children. Additionally, Shernoff et al., (2017) claimed that in order to improve teachers' comprehension of STEM, in-service teachers should have the chance to observe teachers from other districts, have more time for teacher cooperation, and see examples of excellent teaching. To help teachers better comprehend STEM concepts and pedagogical techniques that promote STEM teaching, teachers should be given STEM learning opportunities and encouraged to implement STEM curricula (Huang et al., 2022). The continuing professional development of teachers enables them to adapt teaching methodologies, learning tools, and educational trends (Velychko et al, 2022). By providing quality activities to children, they will not only enjoy learning but they will develop holistically.

## Conclusion

The researchers have successfully analyzed 31 articles in this scoping review. The methodologies for all the articles were extracted and analyzed to identify the data that has been successfully recorded based on different research designs. Based on previous studies, the researchers are able to identify that most empirical studies carried out through qualitative design often use questionnaire and also pre-posttests instruments to obtain data. However, the findings also show that the use of interview and observation instruments has been the choice of previous researchers to collect rich data. The findings of the study have also been divided into 2 main categories which are the best practices of STEM education carried out on children through past studies and the challenges faced in promoting STEM education to children. Besides. The researchers also managed to analyze two side study findings, namely the study design used by all the selected articles and the locations of the study.

Based on the 23 best practices that were successfully analyzed, the researchers found that there are several popular best practices used in these past studies which are (i) the use of inquiry-based learning; (ii) the use of problem-based learning strategy; and (iii) the exploration of material; and others. Although the researchers only focused on the 3 best practices in the discussion section, the other practices are also the best practices that teachers can apply when implementing a STEM activity. Moving on the challenged faced by the teachers and children while connecting to STEM activities, previous research found that Lack of knowledge from teachers causes difficulty in producing a quality and comprehensive activity for children. In addition, the lack of training and professional STEM programs for teachers is also a factor why teachers cannot provide appropriate activities.

Even though there are various challenges that will be faced by teachers in empowering STEM education at the initial stage, the creativity of the teacher himself is able to improve better results through efforts that can be taken from various best practices. Therefore, the efforts of teachers themselves need to be done day by day so that a better STEM activity can be implemented in the future. This noble effort will help children to learn in the best conditions as outlined by the 21st century education concept. And finally, they can grow holistically.

## Recommendations

This study can be used as a guide by the Ministry of Education for a country in improving the quality of science education through the implementation of the best practices of activities that can be conducted in any early childhood institution. For example, the best practices that have been proven through the findings of this study can be used to integrate into the early childhood education curriculum. It is well known that a country has its own curriculum in creating early science or STEM activities for children, but through the evidence explained in this study, stakeholders can strengthen the existing curriculum to improve the quality of the activity itself. This can be proven through the findings of previous studies where STEM activities can be developed starting from early childhood education (Clements & Sarama, 2016) and it can also be integrated in the curriculum (Moomaw & Davis, 2010).

Furthermore, the researchers incorporated past studies from diverse countries in this analysis, and the quantity of studies is not balanced. To ensure that study findings can be compared more clearly, the study samples must be more thoroughly filtered so that the number of samples necessary is balanced and the comparison can be analyzed and synthesized more broadly without bias for a country. Furthermore, taking a country's progress into consideration can reveal great practises that are not immediately evident. For example, implementing the synthesis on the findings from developed-country publications alone will yield more significant and critical discoveries than implementing the comparison between developed-country articles and non-developed-country papers. This is because the sample that received high-income country source abstracts shared all known features with the sample that received low-income country source abstracts (Harris et al., 2015).

## Notes

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