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# Unveiling the Pedagogical Approaches in STEM Classroom: A Scoping Review

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**Abstract.** In this scoping review, 27 empirical and peer-reviewed research articles published in the English language between 2015 and 2023 were examined to explore and categorize the pedagogical approaches used by educators to increase the effectiveness of STEM activities in classrooms. The methodology of the current study consisted of searching the ERIC database via EBSCOhost and academic search complete databases. After a two-stage filtering process (inclusion and quality criteria), suitable articles were selected for review. The articles are relevant to early childhood primary and secondary education across a variety of national contexts. The findings indicate that teachers in STEM classrooms frequently use a combination of constructivist and active learning strategies, including integrated learning, problem-based inquiry, project-based learning, real-world practices, design-based approaches, experiential, and student-centered learning. However, teachers encounter several challenges in STEM teaching, particularly a lack of resources, including limited time, insufficient funding, restricted access, inadequate training and professional development opportunities. Therefore, it can be speculated that STEM pedagogies require teaching staff to be supported in the professional sphere, provided with the required resources at schools, and given the training they need in order to overcome the barriers that can act as inhibitors of change.

**Keywords:** STEM education; Pedagogical approach; Classroom activities; Project-based learning; Problem-based inquiry

## 1. Background of the study

Integrated STEM education involves the holistic learning of students across four distinct disciplines: science, technology, engineering, and mathematics, comprising the technologically-spatially oriented fusion of the acronym STEM (Davis et al., 2019; Gardner, 2017). While the majority of traditional education systems emphasize specific subjects, integrated STEM education employs an

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interdisciplinary approach to allow learners to grasp the applied skills and established the knowledge necessary in the future for their careers (Ammar et al., 2024). Integrated STEM learning is now being emphasized across all levels of education from early childhood to university studies (McClure et al., 2017). STEM education originated from the term 'SMET,' introduced by the National Science Foundation (NSF) in the 1990s to describe fields requiring mathematics and science knowledge for societal and environmental applications (McComas, 2014). Since then, the demand for STEM-literate workers has increased, and elementary and secondary schools around the world are integrating STEM curriculums and pedagogy into their classrooms for the sake of developing a skilled human workforce for the 21st century (Bryan et al., 2015; Margot & Kettler, 2019).

STEM education has gained acceptance and undergone significant evolution globally, with each region presenting distinct approaches and challenges (Zhan et al., 2022). On an international scale, approaches to and conceptualizations of STEM education are inconsistent (Sheffield et al., 2018), which represents a threat to high-quality STEM education in different educational settings. In the United States, the emphasis has been on integrating STEM disciplines to foster problem-solving skills and real-world application (White, 2014). In the United Kingdom and European Union, efforts have been directed towards reshaping compulsory schooling by emphasizing STEM education through a rigorous national curricula, policy implementations and enhancing interdisciplinary connections (Pressick-Kilborn et al., 2021). In developing countries, STEM education often prioritizes workforce development over knowledge integration (Ismail, 2018). Consequently, efforts are concentrated on improving access and quality through curriculum enhancements and teacher training programs (Fitzpatrick et al., 2018). Despite the divergent efforts, the overarching global objective remains consistent in ensuring equitable access to high-quality STEM education for all. Through these endeavors, stakeholders in developing countries aspire to equip students with the necessary skills and competencies to thrive in an increasingly complex and technologically-driven world. More work is needed to ensure that the often abstract research and policy initiatives (Murphy et al., 2019) are translated into accessible and manageable support for practicing STEM educators across all settings.

Similar to other countries in the world, Australian education also recognizes STEM education as one of the key approaches to developing a skilled workforce in this century. The country outlined the "National STEM School Education Strategy" in 2015 to reach STEM education goals. This is aligned with similar global initiatives, such as the release of the Next Generation Science Standards (NGSS) in 2014 (Bybee, 2014). The Australian National STEM strategy (2015) highlights the issues of STEM education during school years, presents major actions that need to be taken, and focuses on desired outcomes through STEM activities. Furthermore, the strategy identifies primary and middle school as the most crucial years for students to form their interest and sense of confidence in STEM, demanding the integration of engineering aspects into the Australian school curriculum with a focus on enhancing the students' computational thinking, problem-solving, and creativity. In response, Australian education has emphasized a cross-curricular priority in their curriculum (ACARA, 2018).

Despite that, the curriculum implementation requires appropriate classroom practices, which are only possible when teachers use student-centered pedagogical approaches (Barton et al., 2014), many of which require considerable time investment and expertise to employ (Deehan et al., 2024).

There are many complex and often overlapping pedagogical approaches to STEM education. Pedagogies such as inquiry-based learning, hands-on exploration, and problem-solving activities promote more student involvement and knowledge retention (Sukontawaree et al., 2022). Providing projects that are intended to solve complex problems while also making use of multidisciplinary learning allows the students to develop important 21st-century abilities such as communication and creativity (Waluyo & Wahyuni, 2021). Collaborative learning, on the other hand, imitates teamwork, which is a core of STEM professions. This fosters communication skills and scientific discourse engagement (Latip et al., 2020). Researchers have already identified several elements of classroom practice that should be taken into account when teaching STEM subjects, for example, personalized learning, active learning, evidence-based learning, critical skills development, continuous improvement, collaborative learning, special needs, educational laboratories, and conceptual modeling (Kreijns et al., 2013, Merle, 2016). These diverse pedagogical approaches in STEM are essential as they support different learning styles as part of inclusivity (Clements et al., 2023), maintain engagement to enhance retention and problem-solving (Bllkstein, 2013), and foster critical thinking and collaboration, which is a key part of STEM success and adapting to evolving careers (Hmelo-Silver et al., 2007).

However, the diversity of STEM approaches may also be related to a lack of clarity and direction for time-poor teachers (ACARA, 2019; APPA, 2014) who are often practicing in resource-scarce contexts (Rowe & Perry, 2019). Research has shown that the classroom interventions reported in the STEM literature are heavily dependent upon resources and external experts that may not be accessible in every classroom or setting (Deehan et al., 2022). It is imperative that recent research, policies and conceptual contributions to STEM education be consolidated with a solid understanding of tangible, replicable pedagogies that can be implemented amidst the challenges of typical classrooms.

From the above explanations, it is understandable that pedagogical approaches in STEM classrooms are a significant area of research. However, there is a lack of systematic reviews compiling the most effective pedagogical approaches for STEM classrooms. Recent reviews on STEM education have covered diverse areas, from teacher perspectives to regional trends, as well as technological integration. Margot and Kettler (2019) reviewed the teachers' perceptions of STEM, while Rahman et al. (2021) analyzed the practices of mathematics teachers in STEM. Regional studies, such as those by Aslam et al. (2022) in Pakistan and Ilma et al. (2023) in Indonesia, have highlighted STEM approaches to developing 21st-century skills. On the other hand, Pellas et al. (2016) and Cetin and Demircan (2020) explored technological tools in STEM while Li et al. (2020) and Aguilera and Ortiz-Revilla (2021) highlighted the key trends and concepts in STEM education. There is a lack of research regarding the pedagogical approaches used in STEM classrooms. To contribute to this ongoing need to bridge theory and practice, this scoping review answers two research questions:

I. What demographic trends (publication year, region of publication, educational level, and research method) characterize the research articles on current pedagogical practices in STEM classrooms?
II. What types of pedagogical approaches are emphasized in the current K-12 STEM education research literature?

## 2. Theoretical Perspective: Constructivism as a Learning Theory

In the changing context of STEM education, pedagogical approaches have become rather important in forming the students' outcomes and engagement. The current research involves a critical review of the current pedagogical approaches practiced by teachers within STEM classrooms. These approaches are predominantly determined by the theoretical foundation of constructivist learning theories (Ankiewicz, 2024). Constructivist theories, especially those developed by Piaget and Vygotsky, are the basis of understanding the nature and effectiveness of the various STEM pedagogical approaches. Piaget's major idea, in the framework of cognitive constructivism, is comprised of learners constructing knowledge actively. Additionally, they combine it with the particular form of embedding and adjusting new information into the already-existing scheme, which may be assessed by their readiness to transfer and apply it (Piaget, 1952). This approach is in accordance with experiential learning and student-centered approaches. In experiential learning, students actively make sense of their environments while they learn from their experiences. Additionally, social constructivism by Vygotsky emphasizes that one's knowledge is co-constructed based on their social and cultural context (Vygotsky, 1978). Thus, real-world practices should be integrated, and more cooperative learning sites should be designed as students share the burden of thinking about the practices or projects that represent real-life problems.

The application of constructivist theories to pedagogical approaches is multifaceted. Integrated learning connects different disciplines, promoting a holistic understanding of complex concepts by contextualizing learning within real-world applications and connections (Beane, 1998). Problem-based inquiry, grounded in cognitive constructivism, involves students in critical thinking and problem-solving activities that encourage active knowledge construction through exploration and investigation (Hmelo-Silver, 2007). Project-based learning (PBL) supports both cognitive and social constructivism, allowing students to engage in extended projects that promote individual cognitive development through hands-on activities and collaborative learning through social interactions (Thomas et al., 2000). Additionally, incorporating real-world practices bridges the gap between theoretical knowledge and practical application, aligning with Vygotsky's emphasis on learning within authentic contexts (Brown et al., 1989). Kolb's theory involves experiential learning, active experimentation and reflection which enhances the understanding and retention of complex concepts through hands-on activities (Kolb, 1984). Finally, student-centered learning focuses on the needs, interests, and abilities of students, allowing them to take an active role in their

education and creating meaningful and personalized learning experiences rooted in both cognitive and social constructivist theories (Sharkey & Weimer, 2003).
It can be inferred that by integrating both cognitive and social constructivist views, educators can use pedagogies such as problem-based inquiry, project-based learning, real-world practices, experiential learning, design-based and student-centered approaches to create an enriched and meaningful learning environment. Moreover, the above strategies are not only consistent with the basic tenets of constructivist theories but they are also relevant to the needs of the current generation of students who have to deal with a more complex world.

## 3. Methodology of the study

A scoping review is a comprehensive review of a broad topic, which is different from a systematic review that concentrates on exploration instead of looking at specific questions (Moher et al., 2015). The key strength of this approach is that it can cover a large and very complex literature database that can be applied to the field of emerging or fast-growing topics (Pollock et al., 2021). Generally, the scoping review framework is based on six stages: defining the research questions, identifying relevant studies, selecting, charting, and summarizing the data, and providing a consultation (Arksey & O'Malley, 2005). In education, scoping reviews are gaining popularity as a resilient tool to investigate different issues critically, influencing the rapidly expanding field of educational research as a result (Davis et al., 2009).

To be included in this scoping review, papers were required to report on empirical research exploring the pedagogical approaches practiced in the STEM classroom for the early childhood, primary, and secondary levels. This scoping literature review utilized the PRISMA guidelines and flow chart. The PRISMA guidelines include a 27-item checklist and a 4-phase flow diagram outlining the items essential for transparency in conducting literature reviews.

### 3.1 Eligibility criteria

This review emphasizes two types of criteria for selecting articles, specifically the inclusion-exclusion criteria and quality evaluation criteria. To be included in this review (under the inclusion-exclusion criteria), the studies needed to be peer-reviewed and published in a scholarly journal (trade journals, magazines, and newspapers were excluded) between 2015 and 2023 (mentioned in Table 1). For the starting year, 2015 was chosen as it represented a major inflection point for STEM education in Australia, with the release of the National STEM School Education Strategy 2016-2026 (Education Council, 2015), and globally (Bybee, 2014). Since the release of the Next Generation Science Standards (NGSS) (National Research Council [NRC], 2013), there has been a marked increase in STEM and STEM-adjacent research production (Morris et al., 2024). Hence, we have chosen to analyze publications from 2015 to 2023. Eligible studies also needed to be published in English and be empirical (editorials and monographs were excluded). The study also needed to address at least one of the review's research questions.

After the initial inclusion, we also applied the quality evaluation criteria suggested by Mullet et al. (2017) and, following their criteria, each of the seven parts (objectives and purposes, review of the literature, theoretical frameworks, participants, methods, results, conclusions and significance) was scored on a 4-point scale where 1= Does not meet standard, 2= Nearly meets standard, 3= Meets standard, and 4= Exceeds standard. After summing the 7 parts, the total possible score for each article ranged from 7 to 28, and articles scoring 14 or less were excluded for not meeting the quality standard.

**Table 1: Inclusion and Exclusion Criteria**

| Inclusion criteria | Exclusion criteria |
|---|---|
| ▪ Published between 2015-2023<br>▪ Published in English<br>▪ Empirical research (qualitative, quantitative, mixed methods, or meta-analyses)<br>▪ The study included school-level participants<br>▪ Published in peer-reviewed journals<br>▪ Aligned with the current research study. | ▪ Editorials<br>▪ Monographs<br>▪ Conference proceedings<br>▪ Not peer-reviewed<br>▪ Article related to tertiary education |

### 3.2 Data sources and search

The databases searched were electronic and concerned the areas of education and social science. The exact databases searched were Academic Search Complete and ERIC via Ebscohost. The article search was conducted in October - November 2023. The following search terms were used to search each database: "Pedagogical approaches OR teaching methods OR instructional strategies" AND "STEM activities OR STEM education OR STEM approach" AND Teachers. After an initial search, the results were as below (Table- 2).

**Table 2: Searching string, database, and search limiters**

| Searching String | Database | Search limiters | Hits |
|---|---|---|---|
| "Pedagogical approaches" OR "teaching methods" OR "instructional strategies"<br><br>**AND** "STEM activities OR STEM education OR STEM approach" | ERIC via EBSCOhost | Scholarly (peer-reviewed) Journals<br><br>Published: 2015–2023 | 456 |
| | Academic Search Complete | Scholarly (peer-reviewed) Journals<br><br>Published: 2015–2023 | |

Note. Searches were performed against article abstracts**

After the completion of the search, the inclusion and exclusion criteria were followed rigorously, and 32 articles were finally selected for the further procedure of quality evaluation. After assessing the quality, 5 articles were excluded, and 27 were retained. The 5 articles were excluded due to having incomplete objectives, the lack of significance of the study, the absence of a theoretical framework, an incomplete methodology, or a poorly-articulated data collection and data analysis. Following the screening, a diagram (Figure-1: The process of article selection) was developed to explain the process:

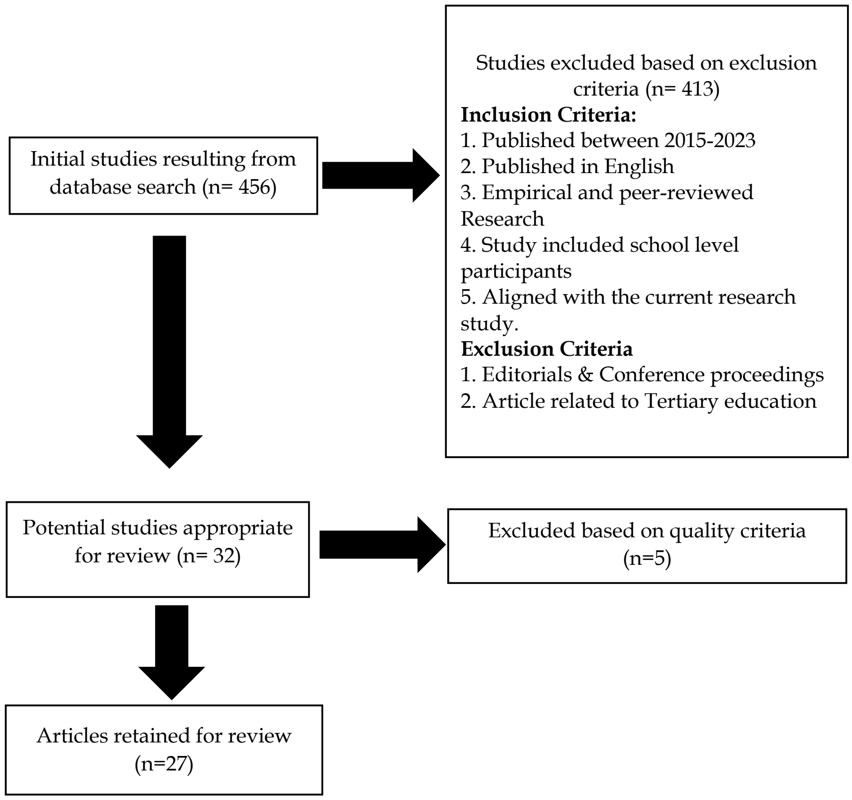


**Figure 1: The process of article selection**

### 3.3 Data analysis of the study

In this research, we explored the demographic trends of the 27 selected articles. The articles were sorted based on year of publication (2015-2023), publication region, the participants' academic level, and the research methods used. We divided the selected articles into three-year intervals (2015-2017, 2018-2020, and 2021-2023) to facilitate the systematic analysis. Additionally, the papers were categorized according to continental region (Asia, Africa, Europe, North America, and Australia). The studies focused on students in early childhood, as well as in the primary and secondary levels of education. The authors used different types of methodologies for their respective research. Consequently, we sorted the selected articles accordingly.

Thematic analysis (Braun & Clarke, 2019) was used as a method for identifying, analyzing, and reporting themes (or patterns) within the data. Each theme is meant to capture important information. Following the constructivist and active learning pedagogical aspects, this scoping review found seven themes for final analysis. The themes are the integration of STEM subjects, student-centered design, project-based learning for STEM education, preference for the problem-based inquiry method, emphasis on real-world practice, importance of design-based approaches in STEM classrooms, and the emphasis on experiential learning.

## 4. Result and Findings

### 4.1 Findings: Research Question 1

The scoping review is characterized by the wide variety of articles that have been published over different periods of time, in different regions of the world, at a range of academic levels, and using a number of research methods (see Table 3). Throughout the years, the number of articles has been growing – 6 in the period of 2015-2017, 7 in 2018-2020, and almost two times higher, 14, between 2021 and the end of 2023. The studies were conducted across a large number of regions worldwide. Specifically, the sample consists of articles from Asia (UAE, Qatar, Taiwan, South Korea, Thailand, Malaysia), Europe (Ireland, Romania, Turkey, and UK); Africa (Egypt and South Africa), as well as Australia and North America, predominantly the USA. The presented articles cover different levels of education; 6 focus on early childhood education, 10 are on primary education, and 11 concern secondary education. As for the research methodologies, the review includes 11 articles based on qualitative methods, 10 focused on quantitative methods, and 6 that involve mixed methods. This review includes a wide range of research and presents various perspectives and methodological approaches to the educational issue in a diverse global context with different educational levels of focus.

**Table 3: Demographic data**

| Type | Categories | Number of publisher articles |
|---|---|---|
| **Articles published in different timelines** | | |
| **Year** | 2015-2017 | 06 |
| | 2018-2020 | 07 |
| | 2021-2023 | 14 |
| **Articles published from different regions** | | |
| **Region** | Asia (UAE, Qatar, Taiwan, Thailand, South Korea, Malaysia) | 08 |
| | Europe (Ireland, Romania, Turkey, UK) | 05 |
| | Africa (Egypt, South Africa) | 02 |
| | Australia | 07 |
| | North America (USA) | 05 |
| **Articles published on different academic levels** | | |
| **Academic levels** | Early Childhood Education | 06 |
| | Primary Level | 10 |
| | Secondary Level | 11 |
| **Article based on Research Methods** | | |
| **Research Methods** | Qualitative | 11 |
| | Quantitative | 10 |
| | Mixed Method | 06 |

### 4.2 Findings: Research Question 2

This section explores the pedagogical approaches used in STEM classrooms at various academic levels. The researchers focused on pedagogies, the reasons for their implications, and the efficiency of STEM classrooms. Table 4 shows a summary of the themes identified in the scoping review of STEM pedagogies and their prevalence across the reviewed articles. After analyzing the patterns of pedagogies used in STEM classrooms, this research found that the integration of STEM subjects was the most commonly focused theme, appearing in 10 papers. Project-based learning for STEM education and emphasis on real-world practices were also prominent, discussed in 9 and 7 papers, respectively. Other significant themes included student-centered design and the importance of design-based approaches, each covered in 6 papers, while experiential learning and the preference for problem-based inquiry methods were addressed in 5 and 4 papers, respectively.

**Table 4: STEM pedagogies identified in the reviewed articles**

| SL Number | Name of the Theme | Number of selected articles focused on a particular theme |
|---|---|---|
| 01 | Integration of STEM subjects | 10 |
| 02 | Student-centered design | 06 |
| 03 | Project-based learning for STEM education | 09 |
| 04 | Preference for problem-based inquiry (PBI) Methods | 04 |
| 05 | Emphasis on real-world practices | 07 |
| 06 | Design-based approaches in the STEM classroom | 06 |
| 07 | Emphasis on experiential learning | 05 |

The details of the themes are explained below.

*4.2.1 Integration of STEM Subjects*

The integration of subjects or disciplines in STEM practices is an important factor in creating a holistic learning environment that gives students the necessary comprehensive understanding of the complexities of the modern world (Jamil et al., 2018). Bringing STEM disciplines into the classroom practice allows students to participate in meaningful, interdisciplinary learning activities (Chen & Tippett, 2022; Hourigan et al., 2021). Through this integration, students can explore real-world problems and come up with solutions collectively, providing them with the opportunity to acquire critical STEM competencies such as observation, questioning, predicting, investigating, and summarizing data, and developing solutions (EL-Deghaidy et al., 2017). Research proposes different integration models, including multidisciplinary, interdisciplinary, and transdisciplinary approaches, as being the most effective for STEM education initiatives and the best for student learning outcomes (Ozturk & Korkut, 2022). One key aspect of effective integrated STEM design involves setting up problems that engage students in inquiry aligned with disciplinary practices. This approach challenges students to represent their understandings and findings, often through exploration. Interdisciplinary and transdisciplinary approaches in curriculum design have demonstrated positive outcomes for students beyond the regular expectations of pedagogical practices, bringing in the aspect of holistic learning and offering opportunities for real-world problem-solving (Siew et al., 2015; Kelley et al., 2021). Additionally, teachers act as key figures in the integrated STEM learning process by adopting a constructivist learning approach and offering sufficient opportunities for exploration and inquiry-based learning (Aydeniza & Bilicanb, 2018; Chen & Tippett, 2022). Integrating STEM subjects through collaborative problem-solving and project-based learning is a way to increase student engagement, relevance, and 21st-century skills. Teachers should be provided professional development opportunities to practice integrated STEM teaching methods in the classroom, which would improve their Pedagogical Content Knowledge (PCK) and help students acquire interdisciplinary learning through the curriculum (EL-Deghaidy et al., 2017).

*4.2.2 Student-centered design*

The student-centered approach to STEM education is becoming more popular as it aims to create a cooperative environment that not only arouses the students' interest and motivation but also improves their engagement in STEM subjects (EL-Deghaidy et al., 2017; Lang et al., 2018; Shaw et al., 2021). STEM teachers are tasked with employing student-centered pedagogies and bridging STEM subjects by combining mathematics, science, and technology in problem-solving and project-based learning which, in turn, leads to student engagement and relevance (EL-Deghaidy et al., 2017). According to the study by Shaw et al. (2021), Immense Learning Experiences (ILE) in STEM education help to switch to a student-centered approach to teaching, which emphasizes imagination, creativity, and exploration through the process of doing. Consequently, children are able to understand the subject matter deeply and learn to be resourceful. Studies show that a number of factors can influence the students' decision to major in STEM including collaborative, child-centered learning, learning with technology, and hands-on activities, all of which contribute to their beliefs about the benefits of STEM subjects (Han, 2017). Fundamentally, the pedagogical features in STEM education are set to foster the students' deep understanding of science, making them collaborative, and having them engage in user-oriented design, which eventually might inspire them to make a difference through their work (Mildenhall et al., 2021). Hence, educators underline the significance of ongoing growth and professional development options that help them improve their subject-matter expertise (PCK) and implement student-centered STEM practices in classrooms in order to inspire the student's interest in STEM activities (EL-Deghaidy et al., 2017).

*4.2.3 Project-Based Learning for STEM Education*

Project-based learning (PBL) is an instructional approach where students actively engage in exploring real-world problems and challenges over an extended period. The process culminates in the creation of a tangible product or presentation that demonstrates their understanding and the solutions undertaken (Han, 2017). PBL seems to be one of the fundamental pedagogies for STEM education. The reason for choosing PBL is because of the easy integration of the tenets and aims of STEM activities. Effective STEM design involves creating problems based on disciplinary practices, developing tasks that reflect these problems, and enabling students to demonstrate their knowledge through hands-on exploration and inquiry (Tytler et al., 2021). Therefore, student-centered approaches such as PBL resonate with science and mathematics teaching in the STEM context as it focuses on hands-on-activities and experiences. PBL initiated by authentic and real problems leads to the contextualization of science and mathematics in the broader picture of STEM practices and problems (Karpudewan et al., 2022; Lin et al., 2023). In a similar vein, PBL methodologies and the incorporation of STEM disciplines like science, mathematics, and engineering help the promotion of engagement as well as the critical competencies necessary in the STEM disciplines (Chen & Tippett, 2022). The STEM-PBL approach is appropriate for STEM education because it meets the goals of active learning, creativity, critical problem solving, and the promotion of interdisciplinary collaboration between the sciences, technology, engineering, and mathematics (Siew et al., 2015).

STEM teachers prefer pedagogical approaches based on interdisciplinary learning that focus on real life and the development of 21st-century skills (EL-Deghaidy et al., 2017). Project-based learning is becoming one of the most popular choices among educators as it provides students with opportunities for collaborative problem-solving and real-world applications (Sellami et al., 2022). The role of the teacher becomes more important within the framework of each project, as it involves asking and encouraging, as well as experimenting and solving the problem collaboratively. In this respect, it is possible to observe that the teachers' questioning, experimenting, and collaborating provide the students with continuous curiosity and learning (Chen & Tippett, 2022). Even though there is no doubt about the possibility and usefulness of implementing project-based learning, educators often face problems during the process. For example, sometimes teachers are not prepared enough to perform the projects or some of the material and financial resources are lacking. It is also important to mention that, despite the varying comfort levels of instructors in the area of PBL, there is a general understanding that collaboration is important for enhancing the practice of teaching in the area of STEM (MacDonald et al., 2021).

*4.2.4 Preference for Problem-Based Inquiry (PBI) Methods*

Problem-based inquiry (PBI) is a student-centered pedagogy in which students learn by investigating and solving complex, open-ended problems (Jamil et al., 2018). This approach emphasizes critical thinking and deep understanding through inquiry, research, and collaborative problem-solving (Ergun & Kulekci, 2019). The preference for PBI in STEM education results from the fact that it is effective at fostering deep engagement, critical thinking, and real-world relevance among students (Chen & Tippett, 2022). PBI incorporates multiple disciplines, such as science, technology, engineering, and mathematics, which is in line with the interdisciplinary nature of STEM education (Sellami et al., 2022). Teachers make use of PBI methods to plan integrated projects based on the students' interests so then they can explore authentic problems and design solutions together (Chen & Tippett, 2022). The research findings reflect the positive alignment of PBI with reform-based practices in STEM education, which revolve around problem-based and design-based instruction, inquiry learning, and hands-on training. Some additional benefits of PBI include the development of creativity, systems thinking, and real-world problem-solving skills among the students, which is especially prominent in the case of engineering design activities (Aydeniza & Bilicanb, 2018).

Ergun and Kulekci (2019) carried out a study aimed at investigating the influence of problem-based instruction on the perceptions of engineering and technology. They concluded that PBI promotes a diverse depiction of engineers, reduces stereotypical gender representations, and broadens the recognition of technology beyond traditional electrical tools. The authors presented several practical implications, such as the integration of PBI with different disciplines, problem-based learning with engineers and hands-on applications, the use of PBI in researching the longitudinal effects of studying engineering and career deviations of students, and having programmatic support in the form of learning and support handbooks to follow (Ergun & Kulekci, 2019). By practicing PBI, teachers can create a dynamic learning environment that allows students to experience something and provides them with a means of learning STEM competency, equipping them with the necessary competencies for the 21st century.

*4.2.5 Emphasis on real-world practices*

In the sphere of STEM education, the incorporation of real-world-related instructional approaches is crucial in the promotion of meaningful learning experiences and helping students attain valuable skills for dealing with the challenges of the modern world (Hudson et al., 2015). Research in the field of STEM has repeatedly shown the necessity of real-world applications in stimulating learner interest and motivation (Chen & Tippett, 2022; Chiriacescu et al., 2023). These instructional approaches foster curiosity and intrinsic motivation in STEM subjects by providing students with direct contact with concrete, practical problems from real life (Mildenhall et al., 2021). In addition, researchers have found that incorporating real-world applications into STEM instruction promotes problem-solving skills and content-driven dialogue among students (Rinke et al., 2016). Students are encouraged to think critically, to analyze information, and to apply their knowledge in meaningful contexts when they are presented with real-world problems and projects. These hands-on, inquiry-based STEM activities also deepen the students' understanding of STEM concepts and equip them with the essential skills needed to navigate complex real-world challenges (Siew et al., 2015).

In addition, real-world connections in the STEM context allow for interdisciplinary learning and contribute to the development of 21st-century skills (EL-Deghaidy et al., 2017). Nowadays, educators are more inclined to opt for pedagogical methods where problem-based collaborative learning and project-based activities are employed and used to integrate different STEM subjects in the context of their real-world applications (Chiriacescu et al., 2023). Real-world connections in STEM allow students to develop the critical skills crucial for their future success in the workplace, like creativity, communication, and collaboration (EL-Deghaidy et al., 2017). They have to learn to think out of the box to solve a real problem, collaborate with other students, and speak clearly and concisely while presenting a project. These skills are vital for STEM and other spheres of work, and are appreciated by employers (Siew et al., 2015).

*4.2.6 Importance of Design-Based Approaches in STEM Classroom*
The design-based pedagogical approach is an instructional method where students engage in designing, creating, and iterating projects or solutions. This approach emphasizes creativity, innovation, and the application of knowledge through hands-on activities, often integrating multiple disciplines to develop functional and aesthetic solutions (Aydeniza & Bilicanb, 2018). In STEM classes, engineering design is usually seen as a preferred approach for a number of pedagogical and non-pedagogical reasons. First, the pedagogical features of this approach include the students' deeper understanding of science, as well as the production of physical artifacts as a result of the students' collaboration and the user-orientation design they are exposed to (Aydeniza & Bilicanb, 2018; Kim & Na, 2022; Mildenhall et al., 2021). All of these can be helpful to any STEM education initiative since they increase the student's ability to apply the learned theory to practice, improve their collaboration skills, and stimulate creativity and innovation.

A mixed-method research study that focused on three models of implementing Design-based STEM education, STEM content inclusion, STEM content integration, and the STEM Content and Practices Integration model indicated that the third model is the most preferable (Kelley et al., 2021). This STEM content practices the integration model and stresses the need to participate in engineering design experiences as one of the key milestones of implementation in all of the STEM disciplines. For example, some of the engineering design experiences include, but are not limited to, defining a problem, developing models, planning investigations, and designing solutions to a problem (Guzey et al., 2016; Kelley et al., 2021). At the same time, what they are engaged in corresponding to the practices of scientific inquiry in the engineering design tasks means that the students should use their scientific knowledge and apply it where necessary.

It should be noted that STEM teachers also report a strong emphasis on the integration of science, technology, engineering, and mathematics content through engineering design (Srikoom et al., 2018). This design helps students to address real-life problems, better understand certain topics, and develop critical and problem-solving skills. The findings of the study by Aydeniza and Bilicanb (2018) also confirm the idea that the use of design-based instruction has the potential to stimulate the students' creativity, systems thinking, and ability to solve problems in the real world. With an emphasis on problem-based and design-based instruction, STEM instructors can promote the learners' ability to explore, discover, and create, which is critical for their success in the fields of science, technology, engineering, and mathematics.

*4.2.7 Emphasis on Experiential Learning*
Experiential learning-oriented teaching practices are recognized as integral to STEM and have attracted considerable attention due to their effectiveness in facilitating contextual learning, cooperation, and intrinsic motivation as well as a profound understanding of STEM content. These teaching practices are designed to shape the learners' skills, competencies, and values, helping them to respond to the challenges associated with STEM concepts. In other words, the attention to experiential learning in the context of STEM education is explained by its ability

to support direct interactions with real-life problems, allowing learners to experience them and develop effective solutions (Chiriacescu et al., 2023). As a result, not only theoretical knowledge but also practical skills are recognized within this approach, where learners understand the relevance of such concepts to their real lives. Additionally, one more reason for the popularity of experiential learning, in this case, is the feeling of interest and motivation that learners experience while engaging in the process of solving real-life problems (Chiriacescu et al., 2023).

The insights from the educational research suggest that educators acknowledge the pivotal role of using experiential learning activities, such as experiments and immersive learning experiences, to enhance student engagement and comprehension within the frameworks of STEM classrooms (Shaw et al., 2021). With the implementation of a student-centered pedagogical approach focused on imagination, creativity, and exploration, the transformative power of experiential learning facilitates the use of an interactive learning environment. The latter fosters the creation of learning settings where students may explore, discover, and learn by constructing knowledge together (Shaw et al., 2021). Moreover, the implementation of specific experiential learning strategies, such as inquiry-based learning and various reflective practices, as the components of a larger "pedagogical repertoire," can be interpreted as an integrated approach to promoting extensive student learning by using multiple instructional methods (Yelland & Waghon, 2023). The strategies mentioned above are closely related to constructivism as the theoretical framework since the emphasis is placed on active learning and the construction of knowledge. In turn, the development of skills such as critical thinking are furthered for the purpose of addressing the complexities of STEM domains. Finally, the research outcomes in the field of STEM education indicate that the inherent stakeholders perceive experiential learning as the only approach appropriate for creating an environment where critical soft skills such as collaboration and problem-solving, as well as creativity, can be developed in learners (Hourigan et al., 2021). The general agreement on the groundbreaking nature of experiential learning proves that this approach aligns with the goals of STEM education, which emphasizes the cultivation of inquiry, creativity, and problem-solving skills to support the acquisition of a deeper understanding of the environment in the modern world (Hourigan et al., 2021).

## 5. Discussion & Implications

This scoping review addresses the distinct roles of the quantitative and qualitative sections of the findings. The quantitative data is primarily focused on the demographic trends of the selected articles. Meanwhile, the qualitative findings, rooted in constructivist learning theory, explore the pedagogical approaches teachers use in the classroom such as integrated learning, problem-based inquiry, project-based learning, real-world practices, experiential approaches, design-based approaches, and student-centered learning. Although the two data sets do not directly intersect, they complement each other by offering a broader understanding: the quantitative data outlines the characteristics of the selected articles, while the qualitative data offers deeper insights into effective pedagogical strategies in the STEM classroom.

The findings of the first research question show that most of the research articles regarding STEM pedagogy were published from 2021 to 2023 in the geographical regions of Asia, Australia, and North America. Additionally, most of the studies were conducted on participants at the primary and secondary levels, and researchers preferred to use a qualitative design. The findings of the second research question were aimed at investigating the pedagogical approach of optimization to improve student learning and engagement during STEM activities. As teaching science often aligns and advocates constructivist learning theory because of the nature of its activities (Barak, 2017), analyzing the data of STEM pedagogies in light of constructivist learning theory is relevant and rational. From the data, it has been found that integrated learning, problem-based inquiry, project-based learning, real-world practices, experiential learning, and student-centered learning are commonly practiced in STEM classrooms. The attributes of these approaches are interconnected, as each approach supports one another. In general, teachers use these approaches because they are related to real-life experiences and ensure the development of 21st-century skills. On the basis of the results obtained, the following recommendations are for educators and policymakers, and further research is suggested.

It is understandable from the findings that pedagogical approaches in STEM classrooms can be executed efficiently if the teachers' preparedness and professional development (PD) occur in a timely manner (EL-Deghaidy et al., 2017; Eltanahya et al., 2020; Karpudewan et al., 2022). However, it should be a matter of concern that many teachers need special training and support to be prepared for STEM activities, as many of them struggle with their pedagogical content knowledge and skills in relation to how to implement STEM pedagogies (EL-Deghaidy et al., 2017). Authorities should focus on issues such as limited funding, restricted time available, and a lack of STEM teaching opportunities, all of which are crucial for implementing a comprehensive approach in the classroom (Karpudewan et al., 2022). Overall, investment in opportunities for educators will help to create a new generation of students who are inspired by high-quality STEM instruction.

Regardless, even if professional development opportunities are the best route for making teachers ready to teach, too frequently do these remain hard to come by. While studies suggest that teacher preparedness can sometimes be of high quality, they still face challenges when it comes to accessing these opportunities (EL-Deghaidy et al., 2018; Srikoom et al., 2018). In many cases, teachers experience a limited scope in high-quality training when it comes to further employing effective strategies for STEM teaching. Today, policymakers need to improve the financing mechanisms available to ensure that the necessary resources, support, and PD opportunities reach all schools. Simultaneously, policymakers need to work on establishing robust mathematics and science networks where teachers can collaborate. These policies and practices can be implemented by developing the institutional opportunities available and offering the ability to access and share resources and materials with other educators to promote collaborative learning communities. Improved professional development by policymakers can enhance teacher preparedness and positively affect the students' performance. Finally, implementing a curriculum design review, applying constructivist teaching, and further training are matters of practical urgency to ensure effective STEM teaching (Eltanahya et al., 2020).

## 6. Limitations and Directions for Further Research

There are several limitations to this project that must be considered. First, the author could have extended the data searching timeline to explore more research, as well as to include research in languages other than English. Additionally, a comparative regional and educational level analysis based on pedagogy could be done to get a diverse view of the practices used among teachers in different regions and at a range of levels of teaching. On the other hand, there are several promising directions for future research that should be considered in light of the increasing pedagogical clarity of STEM education. Future empirical research should focus on the educators' practical challenges and experiences in the STEM classroom. As the field matures, more attention should be given to professional development and pre-service teacher education to ensure that our developing understanding of STEM pedagogy is reflected in systemic support across education.

## 7. Conclusion

STEM is a well-known educational approach that has gained wide recognition all over the world for developing essential skills such as communication, collaboration, critical thinking, problem-solving, and creativity. This scoping review discussed the range of interactive STEM pedagogies and their significance in classroom practices. By reviewing these pedagogies, it is possible to make specific recommendations, such as the enhancement of institutional support, professional development, and funding to better practice these approaches in the classroom. The analysis indicated that while educators consider several pedagogical approaches to be valuable for students learning, including integrated learning, problem-based inquiry, project-based learning, real-world practices, experiential learning, and student-centered learning, they face challenges such as limited resources, time to perform the activities, the scope of relevant and appropriate training, and professional development. These challenges need to be addressed through comprehensive strategies, including training that is formatted and designed to be appropriate and effective for educators, mentoring programs, and networks of support and communication. Thus, through the targeted investment, the quality of STEM instruction and practices can be increased significantly, consequently inspiring and engaging students through these approaches.

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