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The Effectiveness of Using STEM Strategy on Improving Problem-Solving Skills For K-12 Students: Meta-Analysis

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Abstract

The integration of STEM (Science, Technology, Engineering, and Mathematics) education is increasingly recognized for its potential to enhance problem-solving skills among K-12 students. This meta-analysis synthesizes findings from 18 diverse studies—spanning qualitative, quantitative, and mixed-methods approaches and various national contexts—to evaluate the effectiveness of STEM education in improving these critical skills. The studies, covering periods before, during, and after the COVID-19 pandemic, consistently affirm the positive impact of STEM pedagogy on students' problem-solving abilities. Additionally, this research explores the specific role of project-based learning (PBL) within STEM education, aiming to determine how much this teaching strategy can further augment students' problem-solving competencies. The results highlight the significant benefits of employing STEM strategies in general classroom settings and within PBL contexts in fostering enhanced problem-solving and critical thinking skills among K-12 students. This study contributes to the ongoing discourse on educational strategies, underscoring the value of STEM education in preparing students to tackle complex problems effectively.

Keywords: *STEM strategy, Problem-solving skills, critical thinking, Project-based learning, Teaching method, and Teachers' Education.*

1. Introduction

Integrating STEM (Science, Technology, Engineering, and Mathematics) strategies as a pedagogical approach in K-12 Education has garnered considerable attention in recent years. This study delves into the intricate relationship between using STEM methodologies and enhancing problem-solving skills among students within the K-12 educational framework. STEM education is characterized by its interdisciplinary nature, fostering a holistic understanding of real-world challenges through applying scientific principles, technological innovation, engineering design, and mathematical problem-solving (Chen et al., 2019, Yousef et al., 2021). As we explore the effectiveness of STEM strategies in this context, it is imperative to consider the growing demand for a workforce equipped with robust problem-solving skills to navigate the complexities of the modern world.

The amalgamation of findings from the following three comprehensive studies on STEM education in K-12 settings reveals a consistent positive impact on students' problem-solving skills. A longitudinal study conducted by Smith et al. (2018) with K-12 students demonstrated a significant improvement

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in problem-solving abilities by integrating STEM-based learning modules and real-world problems. Brown et al. (2019) expanded on this impact in middle school, showcasing enhanced creativity and adaptability among students engaged in project-based STEM learning. Lee et al.'s (2020) comparative analysis in high school physics education further reinforced the trend, illustrating a statistically significant improvement in problem-solving skills among students exposed to STEM-based approaches. The studies collectively emphasize the effectiveness of incorporating STEM strategies, including interdisciplinary and real-world applications, to foster critical thinking and analytical skills across diverse educational levels. According to Sarwi et al. (2021), The utilization of STEM in educational exercises serves as a platform for honing students' abilities in fostering creativity, critical thinking, collaboration, and effective communication, collectively known as the 4Cs. This approach equips students with problem-solving skills that apply to real-life challenges, enabling them to articulate solutions proficiently. Integrating STEM with the Project-Based Learning model further enhances students' problem-solving proficiency. STEM is an educational paradigm that imparts the knowledge and competencies essential for navigating the complexities of the 21st century. This educational model is mainly designed to cultivate problem-solving skills, emphasizing its crucial role in preparing individuals for the challenges of the modern era.

This paper focuses on the effectiveness of employing STEM (Science, Technology, Engineering, and Mathematics) strategies to enhance problem-solving skills, which contributes significantly to Education. Stemming from a profound understanding of pedagogical methodologies, the research delves into the impact of integrating STEM approaches within the educational framework. The authors meticulously analyze the correlation between engaging students in STEM activities and developing robust problem-solving competencies. Through a thorough literature review and empirical evidence, the paper highlights the theoretical underpinnings and provides concrete examples of successful implementation in real-world educational settings. Moreover, the paper sheds light on the role of teachers, emphasizing their pivotal role in orchestrating compelling STEM-oriented learning experiences. With its comprehensive exploration and detailed insights, the paper is a valuable resource for educators seeking evidence-based strategies to enhance problem-solving capabilities within the STEM domain.

In this exploration, we will delve into existing literature, examining studies investigating the impact of STEM strategies on problem-solving skills by improving critical thinking skills (CT) in K-12 students. Through a comprehensive review of empirical evidence, we aim to provide insights into the effectiveness of incorporating STEM methodologies as a teaching approach and its implications for developing problem-solving competencies in young learners. This investigation is motivated by the aspiration to contribute valuable knowledge to the educational discourse, supporting educators and curriculum developers in making informed decisions about integrating STEM strategies in K-12 Education. In all, we will journey to answer the following question: To what extent does using the STEM strategy as a teaching approach enhance problem-solving skills in K-12 students?

2. Methodology

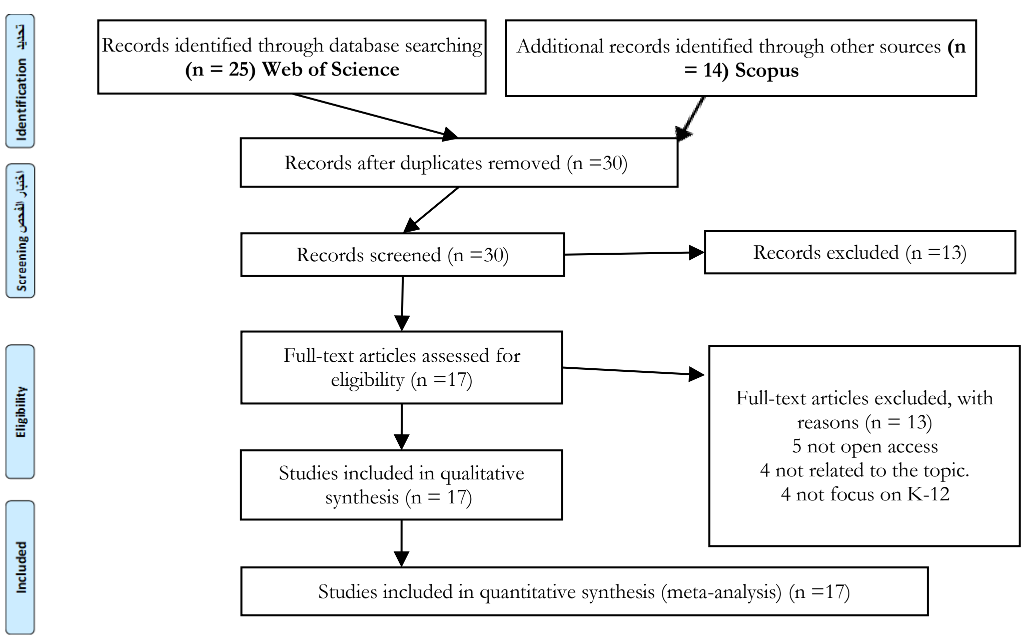
A meta-analysis identifies relevant research that helps us answer our question: To what extent does using the STEM strategy as a teaching approach enhance problem-solving skills in K-12 students? This meta-synthesis uses an interpretive rather than an aggregating method from qualitative and a few quantitative studies methodologies. Additionally, we have incorporated findings from another meta-analysis study, enriching our analysis with results relevant to the chosen topic.

This paper aims to find and integrate all studies that examined the same or are closely related to STEM strategy in improving problem-solving skills in K-12 students.

The meta-analysis commenced on November 11, 2023, encompassing a search for English-language articles across two prominent databases: Scopus and Web of Science. The search terms employed were "STEM," "Teaching," "K-12," and "problem-solving." The initial electronic search yielded 39 articles. After eliminating nine duplicates identified between Scopus and Web of Science, the corpus was refined to 30 unique articles. A stringent criterion for relatedness was applied to ensure relevance to our focus. Subsequently, the 30 articles were evenly distributed among four researchers within the group, with each researcher meticulously examining 7 to 8 studies. Their scrutiny involved a comprehensive review of each study, scrutinizing its entirety for alignment with our research topic.

Furthermore, to ensure the accuracy and consistency of the researchers' decisions regarding the relevance of each study, all team members convened meetings to discuss and assess each article collectively. These collaborative sessions were instrumental in confirming that studies marked for exclusion were unrelated to the research topic, contributing to the overall rigor of our selection process. After completing this thorough review, 17 articles were deemed pertinent and fully downloaded for further analysis. The remaining 13 articles were excluded from the pool of 30. The exclusions were attributed to factors such as non-accessibility (four articles), lack of relevance to the research topic (four articles), and a focus misalignment with K-12 students (four articles). The remaining eighteen studies were downloaded in full-text PDF to Mendeley's website and thoroughly read by Four authors. All 17 studies are included in this review. Discuss 13 studies to answer Q1 and four to answer Q2 in our paper. We extracted information from the studies about our research question by classifying the necessary information in the table. The table includes ten columns for each survey: numbering, year, country, Participants/ Data source, article type, thematic focus, problem of research, and the results of the study. In the section on results, we focused on the answer to our research problem. Extracting data means reading each study more carefully. During this process, I found different fields of stem that can be applied to improve problem-solving skills, such as engineering, computer science, and artificial intelligence.

4.1. PRISMA



3. Discussion

As we commence this analytical expedition, we aim to amalgamate and critically examine pre-existing research, providing a comprehensive overview of the cumulative evidence at our disposal. By immersing ourselves in the essence of STEM education and its influence on the adeptness of problem-solving, this meta-analysis endeavors to contribute nuanced insights to the ongoing discourse on innovative pedagogical practices to answer the following question:

"To what extent does using the STEM strategies improve problem-solving skills in K-12 students?" To answer this question, we distribute ideas about STEM's efficacy in general and project-based learning (PBL), answering our sub-questions:

Q1: What is the effectiveness of applying STEM strategy to improve problem-solving skills in K-12 students?

Q2: What is the impact of using STEM strategy to improve problem-solving skills using project-based learning in K-12 students?

5.1. STEM

Answering Q1: What is the effectiveness of applying STEM strategy to improve problem-solving skills in K-12 students? By discussing 13 articles from our results, each article provides an indication and answers our question to prove that using STEM improves problem-solving skills by strengthening critical thinking skills (CT), using AI, and improving teachers' performance with engineering professional development.

Firstly, one study highlights the potential of A. I am a pedagogical tool for deepening STEM education, especially in mathematics and computational thinking. The positive correlation between explicit support, prior knowledge integration, and A. My problem-solving proficiency underscores the significance of thoughtful curriculum design, which enhances k-12 students' problem-solving skills. In this theoretical work, the researchers have examined the design of a game-based learning environment by integrating A. For high school STEM education, findings prove that it positively impacts development of problem-solving skills for K-12 students. (Leitner et al, 2023, Hendawi et al. 2024).

Moreover, despite their apparent limitations, the studies that made up this review have shed light on some of the intricate roles played during STEM classes in K-12 students' lives. As previously stated, the role of teachers and students with STEM in K-12 students, every study supports the idea that using a STEM technique can help students in grades K–12 become better problem solvers. Researchers examined how professional development in engineering education affected secondary STEM teachers' views of engineering. They found that teachers improved their confidence in engineering pedagogy after attending engineering workshops. Researchers' investigation shows that engineering can be a powerful tool in developing teachers' and students' critical thinking and problem-solving skills (Christian et al., 2021- Boaler et al., 2022; Alsoliman, 2022; Li et al., 2022, Qadhi et al., 2023). students gain real-world problem-solving experience from STEM activities, which improves their capacity to address issues in various fields, promotes holistic thinking, and helps students make connections between ideas and tackle problem-solving from multiple angles. This demonstrates that disadvantaged individuals who managed to attend college despite several social obstacles are not given the same chance to succeed in STEM disciplines and diagnostic examinations, and this is proof that using STEM in teaching helps students to become proficient problem solvers to finish jobs (Burkholder et al., 2022, Bodner et al., 2017).

In addition, the study by Kilty et al. (2021) indirectly underscores the importance of adaptability and planning in K-12 Education, aligning with STEM principles and emphasizing planning for hands-on, inquiry-based learning. In the context of the pandemic, disruptions necessitate a revaluation of STEM teaching methods, highlighting the need for flexibility and pre-emptive planning to promote problem-solving skills in diverse learning scenarios. Data includes field notes and observations of the planning process, participant thoughts on the planning process, and observations of course implementation. This study produced lesson plans, scenario descriptions, and participant thoughts recorded in final interviews.

Moreover, Peel et al. (2022) investigation into unplugged computational thinking (C.T) aligns to improve K-12 students' problem-solving skills through effective STEM strategies, mainly through integrating CT-AE into science classes. This approach enhances scientific understanding of computational literacy and fosters a synergistic learning environment, addressing STEM inclusivity concerns. In addition, traditional perspectives on computers in K-12 education center on problem-solving abilities and logical thinking. However, a new study indicates that kids may use computers to tackle real-world problems in various ways. According to the findings, computers can be used to educate kids on how to tackle complex issues. According to the National Institute of Standards and Technology, computational thinking abilities are essential to all STEM professional training. STEM professionals are learning new techniques to improve their thinking and problem-solving skills by using computers Fidai et al. (2020) confirm the effectiveness of Arduino and Scratch interventions in improving C.T. skills and problem-solving abilities in K 12 students within the STEM framework, emphasizing the positive impact across various dimensions. However, the study of Kite and Park (2022) aligns with ongoing discussions on integrating STEM strategies in Education, emphasizing the role of teachers in shaping students' problem-solving abilities through STEM and highlighting the need for widespread, high-quality STEM professional development for teachers (Abu-Shawish, et al., 2022).

Conclusively, these studies contribute valuable insights into the principles and strategies of STEM education for improving problem-solving skills in K-12 students. Asunda et al. (2023) highlight those students, though not entirely consciously, who use computational thinking to decode problems and challenges and find solutions. The students are subconsciously solving problems by stages that belong to artificial intelligence (AI) or machine learning (ML), or generally, this model of solving problems is called computational thinking. The students at high school were observed practicing four skills: decomposition (which is analyzing the Problem, decoding it, and segmenting it into its contents), pattern recognition (which is the classification of problems), algorithmic thinking (which uses algebra in finding probabilities), and abstraction (which is engineering thinking to imagine the shapes or the ideal perception of things). These four skills belong to STEM integration, not one domain. Even natural science is, in some way, used. Pattern recognition is the skill of classification, primarily a natural science practice. Other skills are distributed among engineering, mathematics, and technology.

Furthermore, Love et al. (2022), in their mixed method article, surveyed 170 schools to demonstrate the attitudes toward physical computing that enhances computational thinking (C.T.), which should be developed by educators teaching STEM interdisciplinary. Students who finished the screen-based unit had more positive attitudes concerning computing topics. Physical computing offered students in the treatment group more opportunities for hands-on learning. This research has implications for improving physical computing instruction in STEM classrooms. Male students rated their attitudes higher than females. Wing (2006) reported that C.T. is a "fundamental problem-solving skill that can benefit students in solving abstract problems and understanding human behavior." The C.T. is a collective skill and a packet of competencies gathering mathematical and scientific principles and rules. C.T. practice in STEM branches and courses will empower students and give them a breadth and depth of knowledge to deal with complicated conditions, wicked dilemmas, and puzzles. Even in human arts and in managing social relations, STEM integration and C.T. can inspire K-12 students because, with all these compound techniques, their brains won't remain flat nor approach the problems linearly. Also, CT thinking will deepen K-12 students' STEM courses more than the solid, rigid way of studying them. To catch up with the Next Generation Science Standards (NGS), educators must teach their students methods of multidimensional thinking that widen their understanding and enrich them with plenty of choices derived from artificial intelligence dynamics and multi-faced STEM curricula. Physical computing is also a promising trend in schooling nowadays. It's a kind of augmented reality where digital inventions help in physical jobs. In the United States, physical computing started invading the education arena by introducing highly sophisticated devices that mimic the subject being taught. For example, by explaining the four chambers of the heart, instead of depending on drawings, it is physically computed, so the students can see what's happening and not deal with the matter by perception. This way, in all STEM courses, enhances students' problem-solving skills, who would have a broad base of probabilities and choices.

Another study by Petrosino et al. (2018) pointed to an educational gap in which math teachers cannot predict what is easy and hard for their students to solve. One diagnosis of this expert blind spot (EBS), as named in the literature, is that teachers predict the levels of their students based on the curriculum as the central organizing structure. At the same time, they should consider the students' experiences and developmental marches. In this study, the authors demonstrate a strong correlation between algebra and engineering and that Problem-solving skills depend on the two in one, not on each separately. The authors denoted a gap constraining problem-solving skills because of a lack of mathematical engineering coverage in educating K-12 students. The engineering-oriented courses of K-12 education systems supply the students with engineering knowledge. Yet engineering graduate students need a mathematical (mainly algebraic) education before joining the college to have a full spectrum of mathematical learning, without which no good problem-solving will be possible (Carr et al., 2013, Qadhi, 2023). Thus, Petrosino et al. (2018) examined the necessity of a connection between two branches of STEM: math and engineering.

5.2. Project-based learning (PbL)

Answering Q2: What is the impact of using STEM strategy to improve problem-solving skills using project-based learning in K-12 students? By clarifying four articles from our results, each article indicates that using project-based learning in STEM improves problem-solving skills by strengthening students' critical thinking abilities, designing their drones, co-robotics engineering design program, and evaluating data.

The paper of Bhuyan et al. (2022) explores a program that aims to enhance critical thinking skills and foster interest in STEM careers among minority students through the innovative use of aerial drones. Incorporating an engaging element, such as drones, indicates a proactive approach to making learning more captivating and applicable to real-world scenarios. Students learned about drone operations using the Python programming language and cybersecurity challenges and solutions. The Academy improved students' STEM problem-solving and critical thinking abilities. The pupils were inspired to work in information technology and cybersecurity. A notable aspect of the program's success, as highlighted in the paper, is the emphasis on mentoring. The involvement of HBCU (Historically Black Colleges and Universities) mentor faculty, graduate and undergraduate students (K-12 students), and Alumni Association representatives played a crucial role in shaping the positive outcomes of the initiative. The frequent interactions between participants and mentors created an informal yet constructive platform for students to express their interests and seek guidance about potential career paths. This mentoring dynamic went beyond the conventional classroom setting, allowing students to benefit from the personal experiences of those working in the computer science field. The mentors guided the project's technical aspects and shared insights into their professional journeys, providing valuable context and inspiration for the students. This mentorship-driven approach is commendable for several reasons. Firstly, it acknowledges the significance of a supportive network in students' academic and professional development. The paper implies that mentorship goes beyond the transfer of technical knowledge; it encompasses a holistic approach, incorporating advice on career choices and insights into the realities of working in STEM fields.

Additionally, the paper of Ziaeefard et al. (2017) introduces an innovative, dynamic, and cross-disciplinary program aimed at engaging students in engineering design from an early age. The program utilizes two co-robots, GUPPIE and Neu-pulator, designed to be both cost-effective and easy to manufacture. The study describes a cross-disciplinary curriculum that uses co-robots GUPPIE and Neu-pulsator to engage early-aged kids in engineering design. The program focuses on problem-solving and utilizing STEM knowledge to benefit humans and the environment by teaching design, building, program, and testing. Through a week-long co-robotics engineering design program, students are immersed in hands-on activities, learning to design, build, program, and test a product. The focus on problem-solving, the engineering design process, and the application of practical methods and STEM knowledge underscores the program's commitment to fostering comprehensive skills in students. One notable aspect of the program is its emphasis on helping both humans and the environment by applying science and technology. This aligns with the broader societal goals of leveraging technological advancements for the betterment of individuals and the world. The hands-on nature of the curriculum, coupled with the incorporation of scaffold learning, suggests a holistic approach to Education that not only imparts technical skills but also encourages critical thinking and creativity. The successful implementation of the co-robotics program with 76 high school and 51 middle school students from rural areas of Upper Peninsula Michigan in 2015-2016 underscores its feasibility and effectiveness. The fact that students not only learned but also actively practiced the engineering design process and built co-robots demonstrates the tangible outcomes of the program.

In addition, the study by Sen et al. (2021) discusses the engagement of gifted and talented K-12 students in robotics-related activities within STEM (Science, Technology, Engineering, and Mathematics). The study discovered that EDP-STEM discussion sessions effectively highlight students' critical thinking skills. The atmosphere and discussion direction were proven beneficial in revealing gifted and talented kids' reasoning and problem-solving talents. By asking "why" and "how" inquiries, the goal was to stimulate intellectual engagement. It highlights the significant role of computational thinking skills in these activities, mainly focusing on the ability of these students to define problem situations effectively. The study suggests that this initial step is crucial, as a clear problem definition lays the groundwork for successful problem-solving. Notably, the results indicate that all students, regardless of individual giftedness, demonstrated effective utilization of computational thinking skills throughout the Engineering Design Process (EDP) in STEM activities. The EDP framework facilitated their progression through stages such as defining problems, developing models, creating products, and evaluating solutions. During the evaluation phase, students exhibited high problem-solving skills, identifying challenges and proposing innovative solutions. This showcases their critical thinking abilities and adaptability, aligning with broader STEM education studies emphasizing the positive impact of engaging students in complex problem-solving situations.

Related work, through experiential, inquiry-based learning, STEM strategies help students become better problem solvers. Students are encouraged to exercise critical thinking, evaluate data, and use their knowledge to address issues in the real world by participating in STEM-related activities. STEM—science, technology, engineering, and mathematics—is interdisciplinary. Additionally, group projects in STEM strengthen students' communication and cooperation abilities, improving their capacity to develop creative ideas (Boaler et al., 2022; Li et al., 2022). Overall, STEM tactics offer a vibrant and valuable learning environment that supports students' development of solid problem-solving abilities; students' cooperation and problem-solving skills increased and were related to one another, according to analyses of the post-intervention results. Of the forty-three student pairs, only nineteen of them worked collaboratively throughout the preassessment; the integrity and consistency of STEAM projects are ensured, and meaningful discipline integration is promoted by instructors' ongoing communication and collaboration throughout cooperative instruction.

After discussing 18 studies, 13 focus on answering Q1, and the rest focus on answering Q2, which leads to answering the central question: To what extent does using STEM strategies improve problem-solving skills in K-12 students? All studies confirm that STEM improves problem-solving skills by using project-based learning that improves 4C skills: creativity, critical thinking, collaboration, and effective communication.

5.3. Results

Resulting discussion for Q1: What is the effectiveness of applying STEM strategy to improve problem-solving skills in K-12 students? Articles indicate that with careful curriculum design and engaging learning environments, educators can foster a dynamic educational experience that cultivates problem-solving skills and prepares students for the evolving demands of STEM fields to enhance k-12 students' problem-solving skills. Another way to use STEM effectively and to improve problem-solving skills is by creating a game-based learning environment for teaching A. I to high school students to integrate AI and games in STEM strategy (Leitner et al., 2023). As illuminated by Kilty et al. (2021), advancing K-12 students' problem-solving capabilities within STEM education is a multifaceted endeavor. Their insights advocate for adaptable learning spaces and practical recommendations like online/hybrid formats and interactive discussions. The integration of the C.T-AE approach in biology classrooms, as demonstrated by Peel et al. (2022), showcases a promising method for seamlessly embedding computational thinking principles into science education. Fidai et al. (2020) indicate that integrating STEM with an exploration of Arduino- and Scratch-enabled interventions underscores their potential to impact problem-solving skills positively.

Meanwhile, Kite et al. (2022) examination of teacher perceptions provides essential patterns for effective STEM integration. They underscored the ongoing importance of professional development in shaping a conducive learning environment for enhanced problem-solving skills in K-12 students because they subconsciously adapt computational thinking (C.T) to deal with problems. In addition, decomposition, pattern recognition, algorithmic thinking, and abstraction are connected seamlessly, forming the C.T. of students. STEM educators can benefit from integrating it and making students more problem solvers (Asunda et al., 2023; Christian et al., 2021, Romanowski & Qadhi,2022). Another promising intermediate is physical computing, which can function as a tool to integrate CT into STEM education for the good of problem-solving skill development (Love et al., 2022)—concentrating on K -12 classrooms and searching for notions, beliefs, and ideas that would hold throughout several STEM fields (Burkholder et al., 2022). To fulfill the coursework requirement, one must demonstrate in-person and virtual teaching and learning proficiency. STEM and robotics comparison (Alsoliman, 2022).

In addition, the results of answering Q2: What is the impact of using STEM strategy to improve problem-solving skills using project-based learning in K-12 students? Previous studies show the success of applying project-based learning in STEM programs outlined in previous papers underscores the crucial role of mentoring in educational initiatives aimed at promoting critical thinking and interest in STEM among K-12 students (Bhuyan et al., 2020; Ziaeefard et al., 2017). Also, the study by Sen et al. (2021) suggests that activities enhance students' problem-solving skills and contribute to their collaborative abilities. So, this aligns with the overarching goals of STEM education, emphasizing individual competency, cooperative learning, and teamwork By the theoretical framework of project-based learning (PBL), STEAM proved applicable to making Chinese K-12 students more flexible in solving problems after the pandemic period (Li et al., 2022, Chaaban, et al., 2022).

Moreover, Petrosino et al. (2018) examined the relationship between algebra and engineering for K-12 students and university ones. They proved that the two branches function as dependent on each other in problem-solving, which is supportive of STEM integration. While including STEAM in the formal curriculum can promote the field's growth and increase awareness among primary school students and teachers, there is a chance that STEAM may not be adequately taught. Despite teachers' time and classroom space demands, assignments are finished on time. Nonetheless, STEAM instruction can support kids in enhancing their ability to solve problems in the classroom (Li et al., 2022).

Overall, results contribute effectively to the field of STEM, showing how the stem approach can be applied efficiently and integrated with different teaching approaches. Applying STEM strategies to enhance problem-solving skills in K-12 students shows promising results. Careful curriculum design, engaging learning environments, and game-based approaches contribute to dynamic educational experiences. Integrating computational thinking principles and exploring interventions like Arduino and Scratch positively impact problem-solving. Teacher perceptions emphasize the importance of professional development, while project-based learning effectively promotes critical thinking and collaborative abilities. The interdependence of algebra and engineering further supports the holistic development of problem-solving competency. Despite challenges, including time constraints, the findings underscore the continued value of STEM strategies in fostering robust problem-solving skills among K-12 students.

Table: Overview of Studies' Context

# INDB	Authors	year	Ref.	Country	Participants/ Data source	Article type	Research Method	Thematic focus	Issue/ gaps	Recommendations
2.	Christian, KB; Kelly, AM; Bugallo, MF	2021	10.	USA	The survey sample included 60 STEM teachers in the treatment group and 28 teachers in the control group.	Article	Mix method.	Engineering education, K-12 Education, Mixed methods research, Precollege STEM preparation, Professional development, and STEM integration	research are needed on how secondary science, technology, engineering, and mathematics (STEM) teachers conceptualize the integration of engineering knowledge and practices in traditional STEM classrooms.	Teachers expressed their views of engineering as a potentially powerful tool in developing students' critical thinking and problem-solving skills, particularly when integrating science and engineering practices with the instruction of disciplinary content.
3.	Boaler, J; Brown, K; LaMar, T; Leshin, M; Selbach-Allen, M	2022	4.	USA	This paper shares the results of a teaching intervention that combined the two approaches, infusing mindset ideas into a calculus summer course taught to 99 incoming students at a U.S. university in 2019 with the research question.	Article	Mix method.	calculus; mindset; mathematics; problem-based teaching; active learning; collaboration	Students' prior experiences and misconceptions can negatively impact their experiences in university STEM courses.	This paper describes a short course on the "big ideas" of calculus that offered students an approach to problem-based learning.
4.	Alsoliman, BSH	2022	1.	Saudi Arabia	The study collected transcript data from students and teachers who experienced virtual and physical robotics as a tool for teaching and learning STEM subjects.	Article	Qualitative		Previous studies have cited many obstacles to using robotics in the classroom, including virtual classrooms, STEM, virtual robots, and teaching methods. These obstacles include the costs of supplying students with robots, fixing and modifying the robots, and school facilities and infrastructure that negatively influence a teacher's ability to teach a particular STEM subject.	The study explores the experience of eighth-grade students and their teachers engaging with a virtual platform in five different K–12 schools that have formally incorporated physical robotics into STEM classroom teaching. The study's main recommendations are for teachers to be innovative, observe, and listen carefully to their students, relying on their pedagogical knowledge to use available technology to serve teacher-student objectives.
5.	Bodner, GM; Ferguson, R; Çalimsiz, S	2017	5.	USA	This research was initially done by faculty in Colleges of Education who taught courses for preservice teachers and focused their research on K -12 students.	Article	Qualitative	chemistry education · educational research · organic chemistry courses · problem-solving	Eventually, this research was done on college- or university-level students, as well, and there was a shift toward what has been called discipline-based educational research (DBER) that looks at the problems associated with the teaching and learning of a given discipline, such as chemistry.	. This paper will discuss the research results on problem-solving in chemistry that has been done in our research group, with particular emphasis on the challenges of teaching and learning organic chemistry. The goal of this paper is to show what can happen when one listens carefully to students and begins to appreciate the difference between what we think we have taught and what the students learned
6.	Burkholder, E; Salehi, S; Sackeyfio, S; Mohamed-Hinds, N; Wieman, C	2022	7.	USA	The design and implementation are based on deliberate practice as applied to learning real-world problem-solving.	Article	Quantitative	Physics 1, problem-solving, STEM careers.	A significant challenge with this course is the large spread in the students' incoming physics preparation. This level of preparation is strongly predictive of a student's performance because of the overlap between Physics 1 and high school physics courses.	There are some limitations as to the data we provide concerning the efficacy of this course. First, due to both practical and ethical constraints, there was no control group at Stanford. At Auburn, we had no comparison as to learning problem-solving skills across sections nor a control group with active learning but focusing on more traditional physics problems and problem-solving. We hope this work will encourage further studies and improvements on this approach for achieving success in physics for all students, regardless of their background. This suggests that this is a widespread pattern, substantiating the substantial overlap between the excellent covered in a good high school physics class and the college Physics 1 class.
9.	Bhuyan, Jay, Wu, Fan;Thomas, Cassandra;Koon, Kai; Hur, Jung Won; Wang, Chih-hsuan	2020	3.	USA	30 ethnically and racially diverse high school students and five teachers from the partnering school districts for immersion in a STEM-intensive	Article	Qualitative	Minority students. K-12 computer science. STEM interest. Cybersecurity, Drone	The project aims to introduce scholars to programming through an engaging App Inventor experience before transitioning to traditional languages like Python. App Inventor, a cloud-based open-source software, utilizes a visual blocks-based language. Scholars explore data types, variables, expressions, conditional statements, loops, procedures, events, event handlers, databases, and web services. Future research involves qualitative studies on students and teachers, using focus groups and interviews to understand their experiences and factors influencing career decisions. The focus is on identifying ways to support teachers in implementing similar projects to enhance the participation of minority students in STEM.	How can drone technology help my community map the geographic landscape suitable for farmers to grow crops? & [Ecology] How can drone technology help my community find discarded waste products in uninhabited areas? & [Transportation and Weather] How can drone technology help my community find safe routes for school buses after a flood? & [Health] How can drone technology deliver medical supplies to district agencies in my community?

10.	Ziaeefard,Saeedeh; Miller, Michele H.; Rastgaar, Mo; Mahmoudian, Nina	2017	24.	USA	One hundred twenty-seven participants, including 50 high school and 13 middle school girls.	Article	Quantitative	Robotics education Co-robots Marine robots' Assistive robots Engineering design Hands-on activity K-12 stem education	before attending the program. Thus, they needed more time to learn the topics in more detail. This program aimed to familiarize students with those concepts and increase awareness and understanding of learning these topics. Students with prior robotics camp experience had a better grasp of the task at hand and faced the challenges with higher interest and confidence.	This paper presents a new dynamic and cross-disciplinary program that engages students from an early age in engineering design through hands-on activities with two co-robots called GUPPIE and Neu-pulator. The co-robots, standardly available standard components, are easy and inexpensive to manufacture. During the week-long co-robotics engineering design program, students learn how to design, build, program, and test a product. They exercise problem-solving by following the engineering design process and applying practical methods and STEM knowledge. The objective is to help humans and the environment using science and technology—a critical scaffolding element in this hands-on-based curriculum. The co-robotics program was successfully offered to 76 high school and 51 middle school students from Upper Peninsula Michigan rural areas in 2015-2016. Students learned and practiced the engineering design process and built co-robots. Recommendations:The teacher training workshop will be piloted with two local teachers in Spring 2017. The first teacher workshop is planned for August 2017. Training teachers in using the co-robots and troubleshooting during the workshop builds their confidence to adopt this new teaching approach in their classrooms. Projects of this type are critically important, as many states and teachers feel unprepared and are hesitant to adopt NGSS standards
12.	Sen, Ceylan; Ay, Zeynep Sonay; Kiray, Seyit Ahmet	2021	21.	Turkey	seven gifted and talented students diagnosed by the Guidance and Research Center (GRC) and pursuing their support education programs at the Science and Art Centre	Article	Qualitative	Computational thinking skills Engineering design process Integrated STEM Gifted and talented students	the EDP-STEM activities were designed to allow students to be free and flexible in their work while expressing their thoughts. Many researchers state that interdisciplinary educational opportunities effectively reveal gifted and talented students' creative skills (Drain, 2008; Hockett, 2009; VanTassel-Baska & Brown, 2008). Choi (2014) underlines the significance of a flexible environment supporting their creativity among the opportunities STEM education provides to gifted and talented students. Similarly, Gotlieb et al. (2016) indicate that STEM education emphasizes curiosity, creativity, and exploration among gifted and talented students. Based on this result, it is concluded that the EDP-STEM activity supports gifted and talented students' creative skills and effectively uncovers their innovative thoughts.	What computational thinking skills are employed by gifted and talented students during robotics-related activities within the scope of STEM activities based on the EDP?
13.	Leitner, Maxyn; Greenwald, Eric; Wang, Ning; Montgomery, Ryan; Merchant, Chirag	2023	15.	USA	This research plans to run studies with K-12 students to evaluate the effectiveness of the design.	Article	Qualitative	Artificial intelligence · K-12 education · Game-based learning	The proposed design has a notable limitation stemming from its foundation in an exploratory study characterized by a restricted sample size. Moreover, this study was executed within the confines of a private school emphasizing STEM education. It is anticipated that students in institutions with fewer resources or less emphasis on STEM/Computational Thinking may exhibit distinct or additional requirements not considered in our design. This assertion extends to students across various grade levels within the K-12 spectrum and those from demographics inadequately represented in our sample. Additionally, the efficacy of the design remains unverified in studies involving students, raising uncertainties about its ability to comprehensively address diverse needs and yield intended outcomes across all categories of A.I. students.	Uncover how high school STEM students approach A.I. concepts.

16	Kilty, Trina Johnson, Andrea C. Burrows, Dane Christoffersen, Kevin Thomas Kilty, Kate Muir Welsh, Shawna McBride, Philip Bergmaier, Christian Bitzas, and Cierra Rainey.	2021	12.	USA	team of three undergraduate students, including one preservice secondary science teacher, planning and implementing a minilesson to a group of K–12 students	Article	Qualitative	COVID-19 instructional response; instructional planning; preservice teachers; STEM integration; in-service teachers; undergraduate research; flexible teaching	The purpose of this study was to describe both the process (planning) and product (implementation) of the minilesson for STEM outreach to eighth-grade students at a public middle school in the U.S.	The authors' research question asked, "How does an interdisciplinary undergraduate grant team, including a late-term preservice K–12 teacher, prepare science outreach lessons for a broad spectrum of potential delivery modes?"
18	Peel, Amanda, Troy D. Sadler, and Patricia Friedrichsen..	2022	18.	USA	K–12 science education	Article	Qualitative	Computational thinking, Science Education, Unplugged, Instructional approach, SYSTEMS, TECHNOLOGY, K-12	introduces a novel instructional approach for integrating disciplinary science education with C.T. using unplugged (computer-free) activities	The unprofessional approach described in this paper is grounded in theory to support student learning of C.T. and science systems. The method decouples C.T. and programming and provides new avenues for exploring C.T. integration and significance. Significant or moderate effect sizes. This indicates the CT-AE approach supported the development of C.T. skills because students could use more algorithm concepts in their algorithmic explanations after the unit.
20	Fidai, Aamir, Mary Margaret Capraro, and Robert M. Capraro.	2020	11.	United States	K–12 and post-secondary classrooms.	Article	Quantitative	Arduino, Scratch, Open source, Internet of things, Computational thinking	the effects of Arduino- and Scratch-enabled interventions to provide aggregated evidence of the impact of open-source Arduino and Scratch on students in STEM classrooms.	Do Arduino- and Scratch-enabled interventions improve students' overall C.T. skills?
22	Kite, Vance, and Soonhye Park.	2022	13.	USA	secondary science teachers	Article	Qualitative	Computational thinking, computational thinking integration, science education, science practices, teacher professional development	examined secondary science teachers' conceptualizations of C.T., perceived barriers to C.T./science integration, and the types of professional support they believe are needed to overcome these perceived barriers.	What is the nature of secondary science teachers' conceptualizations of computational thinking and its role in science learning? What factors do secondary science teachers identify as barriers to integrating computational thinking into the science curriculum, and what professional support do they need to overcome them?
1-	Asunda, Paul; Faezipour, Miad; Tolemy, Joshua; Do Engel, Milo	2023	2.	United States	for K-12 Science Education	Article	Quantitative	artificial intelligence; computational thinking; curriculum; K-12 teaching; machine learning; problem-solving; STEM integration	This article discusses integrating computational thinking practices of decomposition, pattern recognition, algorithmic thinking, and abstraction as essential to problem-solving practices that may enhance the development of AI and ML capabilities in high school students.	The intent of this article is to contribute to ongoing discussions among educators, employers, parents, and all those concerned with how best to prepare a digitally revolutionized citizenry. Implications are offered for assessing C.T. integrated within STEM, curriculum, pedagogy, and professional development for STEM teachers.
2-	Love, Tyler S; Asempapa, Rueben S.	2022	17.	United States	every K-12 student in the United States	Article	mixed methods	Computational thinking; Design and technology; Integrated STEM education; Physical computing; Tangible interaction; Technology and engineering education.	The teachers in that study also cited factors such as limited time, technical difficulties with the hardware, and insufficient training or instructional resources as the main issues preventing them from implementing physical computing activities. Interestingly, the teachers did not report frequent collaboration with other educators to teach physical computing.	. This study provides implications for improving physical computing instruction and integration within STEM education contexts. The results indicated that students who completed the screen-based unit reported more significantically more excellent attitudes toward the classroom applications and career/future use of computing concepts.
7-	Li, Jie; Luo, Heng ; Zhao, Leilei; Zhu, Min; Ma, Lin; Liao,Xiaofang.	2022	16.	China	STEAM education in China's K-12 schools.	Article	Qualitative data.	STEAM; STEM; design-based research; cooperative teaching; China	This study proposes an innovative STEAM education model supported by cooperative teaching and project-based and collaborative learning theories. After two design, evaluation, and revision iterations, the proposed STEAM education model and a set of instructional design principles were validated.	The study results suggest that cooperative teaching can facilitate meaningful discipline integration and alleviate the STEAM faculty shortage. This study produced five proven instructional design principles for conducting STEAM education supported by cooperative teaching in primary schools.
12-	Petrosino, Anthony J; Shekhar, Prateek	2018	19.	United States	for K-12 engineering education. teachers with expert-level content knowledge	Article	Qualitative	Algebraic representations; Blind spots; Engineering practices; K-12 engineering education; Open-ended questions; Problem-solving process; Science and engineering; Teacher training.	These findings replicate and extend the EBS hypothesis that it developed subject matter knowledge, specifically, high content knowledge preservice and in-service educators predict students' problem-solving difficulty inaccurately. We found no significant differences in the mean scores between preservice and in-service teachers for all the six ranking task problems.	The findings suggest that EBS about algebraic problems is resilient to change despite teaching experience and training. Implications for K-12 engineering education and STEM integration are discussed.

4. Limitations

Our research question was addressed through a qualitative systematic review of existing literature. However, while systematic reviews thoroughly examine a substantial body of research, they come with some limitations that affect our findings. In our study, the search strategy involved two databases, namely Web of Science and Scopus, yielding only 17 relevant studies on our topic. Some of the implications of these limitations on the study's findings are that a limited pool of studies may have led to less generalized findings in response to the question about the effectiveness of using STEM strategy as a teaching method to improve problem-solving skills in K-12 students. It is crucial to acknowledge that the identified results may not represent the sole possibilities within the analyzed material. Although the authors diligently extracted utterances and descriptions, discussing each role is essential to recognize the potential for alternative interpretations. This study acknowledges a limitation concerning language, as the emphasis on English is due to the prevalence of research in this language. Translation challenges, hindering the complete translation of articles from other languages into English, further prompted this decision. Conducting research depending on only one language presents generalizability, cultural specificity, and inclusivity limitations. Findings may lack applicability to diverse populations, introducing biases rooted in linguistic and cultural nuances.

Additionally, the scope of this meta-analysis is narrowed to include studies published between 2018 and 2023. This timeframe is chosen to delve into contemporary trends, ensuring relevance to current issues. However, research within a limited time frame may compromise thoroughness, leading to potential oversights and incomplete findings. Short timelines restrict long-term observations and comprehensive analyses, potentially resulting in a narrower focus and smaller sample size. The selection of Web of Science and Scopus as databases stems from the guidance of our research supervisor, who recommended these platforms for their prominent standing in the education field. Nevertheless, limiting research to just two databases may lead to incomplete coverage, as different databases capture distinct literature sets. This restriction risks overlooking relevant studies, introducing potential bias, and limiting the overall quality and diversity of findings.

5. Future research directions

As a result of our extensive meta-analysis, exploring numerous articles on using STEM strategies as a teaching approach to enhance problem-solving skills in K-12 students, several compelling avenues for further in-depth analysis have emerged. Future research could delve into longitudinal studies to track skill development over time. Additionally, assessing innovative measurement methods and studying the effects on career aspirations, particularly in underrepresented genders, are areas warranting investigation. Examining parental involvement, the role of community engagement, and the adaptability of STEM strategies for online learning environments are also promising avenues. Insights from teacher and student perspectives and neuroscientific approaches to understanding the neural correlates of problem-solving skills in STEM education can contribute to a comprehensive understanding of the subject.

6. Conclusion

This paper outlines the planning and execution of a STEM strategy as a teaching method to improve problem-solving skills in k-12 students by collecting information from different databases that helped students acquire critical problem-solving skills and important physics information. The study included qualitative analysis. The qualitative study examined the perceived barriers and training requirements of STEM students and how STEM strategies enhance students' learning abilities in grades K–12; the research shows that cooperative teaching in high schools improves STEM education by integrating project-based learning, increases discipline integration, and addresses teacher shortages.

The following points will serve as a summary of our key results regarding the characteristics of research on the efficacy of STEM strategies on K–12 students in improving problem-solving to answer our question:

1. The lack of empirical studies across all countries and context categories suggests a lack of development in the field of study. Most of the studies have comparable research methodologies that have aided one another in demonstrating how effective STEM education is in helping K–12 students solve problems (Alsoliman, 2022; Li et al., 2022; Folger et al., 2022) and writing discussions. As well as the researchers also discovered that attending engineering work significantly increased the confidence of secondary STEM teachers in engineering pedagogy, demonstrating engineering's potential as a tool for improving critical thinking and problem-solving skills.
2. The STEM approach is evident in several studies. Other than the research by (Boaler et al., 2022, and Christian et al., 2021), the study focuses on students' usage of project-based learning in STEM strategy by (Li et al., 2022).
3. Even though the STEM approach works to help K -12 students solve problems in group projects (Boaler et al., 2022; Li et al., 2022), it also encourages students to cooperate and communicate with one another.
4. Further highlighting the beneficial relationship between engagement and learning by (Leitner et al., 2023), the integration of well-designed game-based learning environments presents a viable path for including A.I. principles in high school STEM teaching.
5. These studies (Bhuyan et al., 2020; Ziaeefard et al., 2017) examine a program that uses the creative usage of aerial drones to improve minority kids' critical thinking abilities and spark their interest in STEM fields.
6. Kilty et al.'s 2021 study offers suggestions for improving K -12 students' problem-solving abilities using practical STEM techniques, focusing on designing flexible learning environments consistent with STEM's dynamic character.
7. Kilty et al. (2021) offer suggestions for improving K -12 students' problem-solving abilities using practical STEM techniques, focusing on designing flexible learning environments consistent with STEM's dynamic character.
8. Neuroscientific techniques to understanding the brain correlates of problem-solving abilities in STEM education and neuroscientific approaches to understanding the neural correlates of problem-solving skills, in general, can all contribute to a thorough understanding of the issue.
9. Researchers developed a game-based learning environment with AI integration for high school STEM education, positively impacting K-12 children's problem-solving skills development.

To summarize, all studies attempted to pay special attention to the use of STEM strategies in k-12 students with the ability to improve problem-solving skills, which explains how the findings address this research question. Firstly, implementations required teachers to practice using STEM with students as a teaching approach, and the study demonstrated that STEM impacts student cooperation, improving their cooperative skills while using STEM as a teaching method.

Additionally, cooperative skills provide students with the opportunity to experience project-based learning, which has a high impact on cooperation between students by sharing ideas, allowing 12 students to solve all problems that arise during their learning time, a theoretical framework of project-based learning PBL helpful in making Chinese K-12 students more adaptable in problem-solving following the pandemic period, Through experiential, inquiry-based learning, collaborative activities, and group projects, STEM techniques help students develop problem-solving abilities. These activities promote critical thinking, data analysis, and real-world problem-solving while improving communication and creativity. Additionally, studies have used A.I. to design game-based learning for high school STEM education, and it has a positive impact on increasing problem-solving skills for k-12 students.

Declaration of Generative A.I And A.I.-Assisted Technologies in the Writing Process

Throughout the development of this work, the authors employed Chat GPT to receive recommendations on condensing paragraph lengths and enhancing linguistic performance. Following utilizing this computational tool, the authors systematically scrutinized and revised the content as deemed necessary, thereby assuming unequivocal responsibility for the substantive content presented in the publication.

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