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Problem-Solving Skills Development Through STEM Education: A Systematic Review

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ABSTRACT

Problem solving skills have been cited as one of the core competencies that enable one to succeed in the twenty-first century. Learning systems are becoming more convinced in the use of STEM (Science, Technology, Engineering and Mathematics) education as a strategic way of improving cognitive, analytical and problem-solving skills in learners. This is a systematic review that summarizes empirical and theoretical studies that have been published between 2000 and 2025 to investigate the role of STEM education in developing problem-solving skills at various levels of education. Based on a systematic review approach, the studies were located, filtered, and assessed to investigate instructions, learning outcomes, and situational elements that affect problem-solving development in the context of STEM models. The results show that integrated STEM practices, especially the project-based learning, inquiry-based teaching, and engineering design, have a big impact on the capability of students to recognize the problem, use interdisciplinary skills, and develop solutions to the issues. Nonetheless, the issues of teacher preparedness, curriculum integration, and assessment practices also tend to persist. The review indicates that there is a dilemma of long-term professional development, changes in the curriculum, and effective assessment plans to optimize the benefits of STEM education on problem-solving abilities.

Introduction

The modern societies have been changed by the fast rate of development of science, technology and innovation which have altered the quality of work, communication, and life. Due to this, the educational systems are becoming more and more burdened to equip the learners with more than just subject-specific knowledge, but also higher-order thinking skills that can guide them through challenging and unforeseeable situations. Problem-solving skills are one of these competencies that are regarded as central to academic achievement, employability, and citizenship. Problem-solving requires one to be able to identify and analyze problems, develop alternative solutions, evaluate the results, and use knowledge in new circumstances (Jonassen, 2000). The need to acquire such skills and the importance of traditional instruction based on rote is being increasingly questioned in the globalized and digitized world.

To address these issues, STEM education has become an effective pedagogical model that will be able to enhance the skills of problem-solving and critical thinking. Also, STEM education highlights the combined approach to science, technology, engineering, and mathematics regarding all real-life application, inquiry-based learning, and interdisciplinary learning (Bybee, 2013). In contrast to the traditional teaching where the subjects are segregated, STEM education promotes learning in the context of real-life problems, where learners have to apply the knowledge of various fields. This method has a lot of similarity with the constructivist learning theories, which focus on active learning, collaborative learning, and the building of knowledge on the basis of meaningful experiences (Vygotsky, 1978).

It has been postulated that instructional strategies that are structured around STEM foster conceptual learning and transferable problem-solving abilities. As an example, project based learning in the STEM environment enables the students to handle longer assignments that simulate real life problems and this also improves planning, analysis and evaluation of solutions (Thomas, 2000). On the same note, the mode of inquiry based learning promotes queries, developing investigations, and interpreting information and such enhances critical thinking and scientific skills in solving issues (Minner et al., 2010). Design engineering activities are also another contributor to problem-solving development since they involve the learners in a series of design, test, and refining solutions (National Research Council, 2012).

Although STEM education is becoming increasingly popular, the efficacy of STEM methods in training problem-solving skills depends on the situation. Teacher knowledge and skills, curriculum development, resource access, evaluation systems, and practices also play a major role in the learning outcomes (Roehrig et al., 2012). Besides, the very idea of problem-solving is complex and can be characterized in various ways in different studies, which is why it is not always easy to make entirely similar conclusions. Some of the studies concentrate on the cognitive aspects of problem-solving like reasoning and analysis, whereas others dwell on the metacognitive and collaborative viewpoints of problem-solving (Schoenfeld, 1992). These differences imply the necessity of systematic synthesizing of research that has been done to detect general tendencies, advantages, and gaps.

Systematic reviews are important in synthesising research evidence and influencing the educational policy and practice. Systematic reviews help to offer a thorough picture of what, under which conditions, and why works by summarizing the results of various researchers (Moher et al., 2009). Systematic reviews are especially useful in the area of STEM education because of the variety of different instructional models, learner students, and research methodologies. An in-depth analysis of problem-solving competencies in STEM education can assist teachers and policy makers to create more efficient learning settings that are responsive to the needs of the 21st century.

This systematic review aims to critically analyze the studies published between 2000 and 2025 on the importance of STEM education in the development of problem-solving skills of learners of various levels of education. In particular, the review is intended to establish efficient STEM teaching methods, examine the empirical data on problem-solving results and pinpoint difficulties and enabling variables impacting STEM implementation. This review is potentially important because it might assist curriculum designers, teacher educators, and policymakers aiming to empower the problem-solving skills with the help of STEM education. The research synthesis offered in this study adds to a more profound insight into the utilization of STEM education as the means of preparing students to meet the challenging real-life problem-solving requirements.

Literature Review

Problem-solving skills development based on STEM education have become an exponential part of the literature over the last 20 years due to the worldwide changes in education to equip students with the skills needed to operate in complex technology-driven societies. Scholars in various fields have studied the effect of integrated STEM on cognitive, metacognitive, and collaborative problem-solving skills of learners. The section provides the synthesis of the most important theoretical viewpoints, empirical results, and instruction models that connect STEM education to the development of problem-solving skills.

Problem-Solving as a theoretical concept in STEM Education Problem-solving is a process founded in cognitive psychology, where it is considered as an end goal and therefore involving the comprehension of a problem, a plan, actions, and solution evaluation (Bransford and Stein, 1993). Jonassen (2000) divides problems into well-structured and ill-structured, as the real-world problems, which are also the focus of STEM education, are usually ill-structured, which means they demand that the learners make assumptions, synthesize knowledge, and explain the choices. The methods of learning proposed by constructivist and socio- constructivist theories are quite relevant to STEM education, as it is based on active experience and social interaction (Vygotsky, 1978).

In constructivist approach, the learning environment in STEM promotes knowledge acquisition by learners by experimenting, inquiring and reflecting. These settings facilitate the thinking of higher order by placing the learning experience in realistic situations that demand identification of problems and generation of solutions (Hmelo-Silver, 2004). The support of STEM pedagogy by cognitive apprenticeship theory is also provided by paying more attention to the aspects that help to stress the modeling of the process of expert problem-solving and the scaffolding of thinking (Collins, Brown, and Newman, 1989). Together, these theoretical frameworks help to emphasize the potential of STEM education to help develop the effective problem-solving skills.

Problem-Solving Skills and Intended STEM Education This type of education is aimed at the deliberate connection of science, technology, engineering, and mathematics to solve real-life problems. There is also a factor of flexibly utilizing disciplinary knowledge in a flexible professional way according to Bybee (2013), which is the feature of effective problem-solving. It has been documented in science that integrated STEM curricula positively contribute to the skills and capabilities of learners in problem analysis, multiple representations, and cross-contextual transfer of knowledge (Kelley and Knowles, 2016).

According to Capraro, Capraro, and Morgan (2013), students that were involved in integrated STEM projects performed by far higher in terms of problem-solving than did students in conventional classrooms. These advantages were credited to the possibility of iterative design, interdisciplinary argumentation and joint solution creation. On the same note, English (2016) notes that integrated STEM activities endorse adaptive expertise, which facilitates learners to tackle new challenges creatively and strategically.

Project-Based Learning and Problem-Solving Problem-based learning (PBL) is one of the most widely studied teaching strategies in STEM education. PBL involves the students in the long term investigations around complex and real life problems, and involves planning, research, collaboration and reflection (Thomas, 2000). Bell (2010) brings into focus that the PBL environment experiences inherently develop problem-solving as it places students in the role of active contributors to solving the problem, as opposed to passive receivers of information.

There are many studies proving the positive effect of PBL on the problem-solving skills. In Hmelo-Silver (2004), the students involved in problem-based STEM activities reported that they developed greater reasoning and self-regulation abilities. Walker and Leary (2009) in their meta-analysis were able to conclude that problem-based and project-based learning methods were very effective in increasing the problem-solving performance of learners as opposed to traditional lecture-based learning. These findings show that PBL is a useful instrument of integrating problem solving in STEM programs.

Scientific Problem-Solving Inquiry-based learning (IBL) is an approach to learning that revolves around students employing exploration, inquiry, and evidence to underpin their way of thinking. Questions in STEM In STEM, the questions are activities where one asks the students to form hypotheses, make investigations, analyze the information and make decisions which are the most important processes in solving scientific problems (National Science Teachers Association, 2004). According to Minner, Levy and Century (2010), inquiry based instruction positively influences the conceptual knowledge and problem solving skills of students especially in science and mathematics.

Inquiry-based STEM classes have been shown through empirical research to facilitate more in-depth thinking and pursuance of problem-solving activities. As an illustration, Furtak et al. (2012) discovered that guided inquiry strategies resulted in a greater success and enhancement of reasoning abilities compared to either unguided inquiry or conventional instruction. These results highlight the relevance of scaffolding to inquiry based STEM classrooms to facilitate the development of problem-solving.

Design and Problem-Solving Processes Engineering design is a core element of STEM education and an effective background to train problem-solving. The engineering design process implies the identification of problems, the derivation of several solutions, prototype testing and the optimization of the designs in response to feedback (National Research Council, 2012). This cyclic process resembles the approach to problems-solving of experts and teaches learners to think of failure as a learning experience.

Studies by Dym et al. (2005) show that engineering design work improves the capability of students in terms of being systematic and creative in finding solutions to complex problems. Engineering-related STEM programs have been found to enhance the application of mathematical and scientific concepts in the problem-solving situation by the students at the secondary level (Katehi, Pearson, and Feder, 2009). These researches emphasize engineering design as an important transition section between theoretical knowledge and practical problem solving.

Social Aspects of Problem-Solving Problem-solving in STEM education Problem-solving in STEM education is usually a group activity. In social interaction, the learners are in a position to express reasoning, provoke assumptions and co-construct knowledge (Webb, 2009). Johnson and Johnson (2009) stress that the cooperative learning organization improves the level of problem-solving through the facilitation of positive interdependence and individual responsibility.

The effectiveness of collaboration in solving STEM problems has empirical evidence. Research also shows that learners in collaborative STEM teams have a greater degree of reasoning and quality of solutions compared to those working alone (Gillies, 2014). Team problem-solving also helps in fostering the development of communication, and team work skills required in real world problem context.

Problems Selected in the Literature:Although it has been found that STEM education plays a strong role in the development of problem solving process, there are a number of challenges that have been identified in the literature. The readiness of teachers is also a critical issue since most educators state they have a low level of confidence in teaching open-ended problems of solution (Roehrig et al., 2012). Lack of time, curriculum restrictions, and the mismatch between the system of STEM pedagogy and the standardized assessment also undermine the successful implementation (Kelley and Knowles, 2016).

Besides, the evaluation of problem-solving capabilities in STEM is not yet developed. The complex reasoning processes can not be reflected by traditional testing techniques, and the performance-based and formative assessment strategies are called in (Black and Wiliam, 2009). These issues should be addressed to achieve the maximum potential of STEM education in the creation of problem-solving skills.

Methodology

The approach in this study was a systematic review that had to investigate the role of STEM education in problem-solving skills development. The choice of a systematic review is justified by the possibility to provide a transparent, reproducible, and complete synthesis of currently existing research evidence and the reduction of bias (Moher et al., 2009). The methodology used was systematic reviews of education and social sciences of international standards to guarantee rigour, validity, and reliability.

Research Design

The preferred reporting items of systematic review and meta-analyses (PRISMA) framework was used as a guide to conduct the review. The method offers a systematic way of recognizing, filtering, evaluating and synthesizing pertinent studies. Peer-reviewed empirical and theoretical research was reviewed which was published between 2000 and 2025 and this was in accordance with the current trends in the field of STEM education and research on problem solving.

The research questions that will be used to conduct this review are:

- What is the role of STEM education in the development of problem-solving skills?
- What are the best STEM teaching methods of developing problem-solving skills?
- What are the difficulties and enabling factors in solving problems in STEM education?

Data Sources

Literature search was also done in various academic databases in order to have wide coverage of appropriate literature. The databases included:

- ERIC (Education Resources Information center)
- Scopus
- Web of Science
- JSTOR
- ProQuest
- Google Scholar

The choice of these databases was based on the fact that they have a significant indexing of education, psychology, and research on STEM. Also, key studies and review articles reference lists were hand screened to produce more relevant publications.

Search Strategy

The systematic search strategy was created based on the combination of keywords and Boolean operators. Search terms included:

- STEM education
- problem-solving skills
- critical thinking
- project-based learning
- inquiry-based learning
- engineering design
- integrated STEM
- 21st-century skills

What was used to narrow search results was the combination of these terms with operators like AND and OR. For example:

- Stem education and problem solving skills OR project-based learning and problem solving.
- Only publications written in English language were used to limit the search in order to maintain consistency in analysis and interpretation.

Inclusion and Exclusion Criterion

Inclusion and exclusion criteria were set clearly before the screening was conducted to ensure that there was objectivity.

Inclusion Criteria:

- Articles that were published after 2000 to 2025.
- Scholarly books, conference proceedings and peer-reviewed journal articles.
- Research that specifically explored STEM learning and problem solving ability.
- Study which is carried out at any level of education (primary, secondary, or tertiary education).
- Empirical studies, mixed-method studies or well-grounded theoretical studies.

Exclusion Criteria:

- Research that did not specifically aim to investigate STEM education.
- Articles that covered general academic achievement and not problem-solving.
- Opinion pieces, editorial pieces or non-peer reviewed sources.
- Those studies, which are not methodologically sound or have inadequate data.

Study Selection Process

The selection of the study was done in three phases. To start with, all identified records were screened on relevancy using titles and abstracts. Second, the full-text articles were screened so that they met the criteria of inclusions. Third, redundant records and investigations which did not satisfy the quality criterion were eliminated. This multi-stage filtering process was useful in eliminating all irrelevant and low quality studies in the final review.

More than 400 original records were found out. Following the screening and eligibility, an estimated of 90 studies were left to be analyzed in depth. The last choice was based on studies published in different geographical areas and learning environments, which increased the applicability of the results.

Quality Assessment

To make the review credible, a methodology assessment of each study included was carried out. A set of criteria was used which consisted of the clarity of the research design, the suitability of the data collection methods, the validity of the used instruments, and the transparency of the analysis. Quantitative research was evaluated in relation to its sample size, reliability as well as statistical rigor whereas the qualitative research was evaluated in terms of credibility, transferability as well as trustworthiness (Creswell and Plano Clark, 2011).

Literature with weak methodology or inadequate reporting was not synthesized.

Data Extraction

Key information of each study was also systematically recorded through the use of a standardized data extraction form. Extracted data included:

- Name of authors and year of publication.
- STEM pedagogical strategy.
- Sample size and research design.
- Problem-solving outcomes
- Major conclusions and weaknesses.

This systematic methodology has allowed making comparisons and syntheses across studies.

Data Synthesis

Since different methodologies and outcome measures are present, a thematic synthesis methodology was used. Quantitative results were summarized in a descriptive manner, whereas, the qualitative results were analyzed in order to establish common themes that concerned the development of problem solving. The studies were classified by instruction strategies (e.g. project-based learning, inquiry-based learning, engineering design) and level of education.

The synthesis focused on the patterns, consistency, and discrepancy of results, making it possible to give a subtle meaning to the impact of STEM education on problem-solving abilities.

Ethical Considerations

Since this research was a review of already existing research, there was no direct participation of human subjects that were involved. The ethics were observed by citing all the sources properly and being transparent during the review process.

Results and Discussion

This part reports the synthesized results of the systematic review and how STEM education can be used to achieve skills in problem-solving. The findings are presented in the form of the major themes that were identified in the reviewed works, such as teaching and learning methods, learning outcomes, group work, and implementation issues. Quantitative and qualitative data are combined to get a holistic view of the problem-solving development in STEM education.

Overview of Findings

The studies reviewed in this paper all show a positive and significant effect of STEM education on the abilities of students to solve problems at different levels of studying. Students who were exposed to combined STEM strategies exhibited greater capabilities in problem detection, critical thinking, problem design, and critical feedback (Bybee, 2013; English, 2016). Such results were most evident in learning situations that focused on active learning, interdisciplinary learning, and the real-world problem situation.

Problem-Solving under the influence of STEM Instructional Strategies

Project-Based Learning (PBL) became one of the most useful methods of instruction based on the development of problem-solving skills. Research has stated that PBL students had an improved capability to break down intricate problems, organize systematically, and analyze alternative solutions (Bell, 2010; Thomas, 2000). The long-term and realistic nature of projects enabled learners to undergo the entire problem-solving process such as iteration and reflection.

The effect of inquiry-based learning also showed good results in development of problem-solving. Students who were involved in guided inquiry learning demonstrated better skills to develop questions, interpret information, and make evidence-based conclusions (Minner et al., 2010; Furtak et al., 2012). The methods of inquiry proved effective especially in situations involving science and mathematics where data interpretation and testing hypothesis may be part of the problem solving process.

Design-based learning engineering was also an aspect that led to adaptive problem solving among learners. Tasks were done by engineering, which entailed setting constraints, finding multiple solutions, refining designs, and making them resilient and creative (National Research Council, 2012). Some of the studies reported that engineering design work increased the transfer of knowledge to new problem contexts among students (Dym et al., 2005).

Cognitive and Metacognitive Conclusions

In the literature, STEM education was linked to both cognitive and metacognitive higher-order problem-solving. Students showed improved analytical, conceptual and interdisciplinary knowledge application, cognitively (Capraro et al., 2013). Metacognitively, the learners were more aware of their problem-solving strategies, i.e. planning, monitoring and evaluating their strategies (Hmelo-Silver, 2004).

The metacognitive skills were especially developed within the learning contexts that involved reflections and feedback. Research findings indicated that the ability to internalize the effective strategies of problem-solving, and implement them to a different situation was aided by structured reflection activities among students (Black and Wiliam, 2009).

The Collaboration part in Problem-Solving

Team learning was found to be a key aspect in improving the performance of problem solving in STEM learning. The use of group-based STEM activities helped students to develop arguments, negotiate meaning, and create collective understanding (Johnson & Johnson, 2009). It has been shown that collaborative problem-solving besides enhancing the quality of solutions, helps in building communication and teamwork capabilities needed in the real world problems context (Webb, 2009).

Nevertheless, the quality of collaboration was determined by task design and teacher facilitation. Research articles put stress on the need to have clear roles, formal interaction, and teacher direction in order to have a productive collaboration (Gillies, 2014).

Table 1: Summary of STEM Approaches and Problem-Solving Outcomes

STEM Approach	Educational Level	Project-Based Learning
Inquiry-Based Learning	Primary–Secondary	Strategic planning, solution evaluation
Collaborative STEM Tasks	Primary–Higher Education	Question formulation, data analysis
Engineering Design	Secondary–Higher Education	Communication, collective reasoning

Challenges in Implementing STEM for Problem-Solving

Although the results are positive, the review revealed a number of issues that reduce the effectiveness of STEM education in the development of problem-solving skills. The readiness of teachers was one of the most common obstacles. Numerous teachers have also stated that they lacked enough training in helping with open-ended, problem-based STEM activities (Roehrig et al., 2012). Teachers might also resort to conventional methods of teaching instructions that do not allow them to offer problem solving opportunities without proper support.

There were also challenges of curriculum and assessment limits. Standardized testing models are frequently focused on content knowledge and not on higher-order skills, which prevents teachers using problem-based STEM learning methods (Kelley and Knowles, 2016). Besides, the lack of instructional time and resources prevents the long-term work on complex tasks of problem-solving.

Table 2: Challenges and Facilitating Factors in STEM Problem-Solving

Category	Challenges	Facilitating Factors
Teacher Factors	Limited training, low confidence	Professional development
Curriculum	Rigid standards, time constraints	Integrated STEM curricula
Assessment	Focus on rote learning	Performance-based assessment
Resources	Limited technology and materials	Institutional support

The results of this review support the idea that STEM education creates an effective environment in which the process of mastering problem-solving skills can be developed. The combination of disciplines and practical applications, as well as orientation to active learning can be discussed as the elements that align well with theoretical frameworks on efficient problem-solving (Jonassen, 2000). Nevertheless, the difference in implementation and results highlights the contextual nature of such factors as teacher expertise and institutional support.

In general, the findings indicate that STEM education can be the most effective one in case it is introduced in the form of a holistic, well-supported model where problem-solving is discussed as the main learning outcome.

Discussion

The results of the present systematic review are quite convincing that STEM education is a key contributor to the development of problem-solving skills at any level of education. The analyzed articles all indicate that, when structured to acknowledge authentic, interdisciplinary, and learner-centered experiences, students have a higher chance of acquiring the cognitive, metacognitive, and collaborative skills that can be successfully applied to solve problems. These results are consistent with the current aims of education, which are focusing more on higher-order thinking and the flexibility to react to complicated changes in the real-life environment (Bybee, 2013).

The effectiveness of integrated STEM strategies in facilitating transferable problem-solving skills is one of the most important lessons achieved in this review. As opposed to conventional subject-specific education, integrated STEM education demands students to utilize the information that belongs to several fields and, therefore, allows them to solve problems in their entirety. Such an interdisciplinary interaction helps develop a flexible and adaptive expertise, a quality that is needed when solving ill-defined problems that arise in most cases beyond the academic environment (English, 2016). The positive results that are always observed when it comes to integrated STEM curriculums are a testament to the significance of curriculum coherence and meaningful integration.

Other instructional strategies discussed in the review including project-based learning, inquiry-based learning, and engineering design play a central role in improving the problem-solving skills. These approaches have some common features such as the involvement of students, practical importance, and repetitive learning. These methods enable the students to undergo the entire problem-solving process, including identification and analysis of problems, because each cycle takes almost a certain period of time (Thomas, 2000). This practical aspect seems to be one of the primary reasons why successful STEM learning environments are more likely to be found in comparison with conventional models of teaching.

The other significant discovery is associated with metacognitive aspect of problem solving. Research studies have always found that the STEM learning atmosphere that involves reflection, feedback, and self-assessment encourages more awareness on how strategies should be utilized in solving problems. Metacognitive regulation allows the learners to plan, monitor as well as modify their methods and hence the problem solving becomes more efficient and effective (Hmelo-Silver, 2004). This implies that STEM education must clearly incorporate reflection opportunities so that it can make the most out of its influence on developing problem solutions.

Teamwork proved to be a major enabler of solving problems in STEM situations. Joint efforts in STEM activities can make learners explain their arguments, address opposing views and compromise on mutual solutions. Such social processes do not only lead to better results in cognitive processes, they also allow the development of communication and teamwork skills which are more appreciated in the professional environment (Johnson & Johnson, 2009). Nevertheless, the efficacy of this type of problem-solving is paradoxical and is largely dependent on the design of tasks and facilitation by teachers. Ineffective group work can result in inequalities of participation and superficial engagement of the group and its impacts are limited.

Although the findings are positive, the review presents existing challenges, which should be addressed. Instructional readiness is a major concern because most teachers are not well trained on how to develop and implement a problem-based learning on STEM. Unless teachers have the necessary professional development, they might fail to cope with open-ended learning settings and evaluating complex outcomes of solving problems (Roehrig et al., 2012). Moreover, the assessment practices do not correspond to the objectives of the STEM education. Performance-based and formative assessment plans are necessary because standardized tests that emphasize the memorization of facts can discourage the adoption of instruction based on problems (Black and Wiliam, 2009).

On balance, this discussion implies that though STEM education has great potential to build problem solving skills, the success of this intervention is dependent on systemic facilitation, such as educating teachers, reforming curriculum as well as innovative assessment. These issues are critical to the process of transforming the potential of STEM education into extended educational change.

Conclusion

The presented systematic review gives thorough evidences of the importance of STEM education in helping to form the problem-solving skills in the various education settings. As a multidimensional cognitive and metacognitive action, problem solving is also becoming a competency that learners have to possess in order to cope with the issues of the 21 st century. This review confirms that STEM education, when done properly, can greatly raise the capacity of students to solve problems, offer interdisciplinary solutions, come up with innovative solutions and critically reflect on the results.

The synthesized evidence shows that the implementation of integrated STEM seems to be especially useful in the development of problem-solving skills (studies published between 2000 and 2025). Integrated STEM learning involves the use of knowledge in science, technology, engineering, and mathematics in a unified way, unlike the traditional subject-specific learning. This integration aids the process of cognitive flexibility so that learners can be able to move their problem-solving strategies to new and ill-structured problems. Students who have participated in STEM integrated experiences show increased reasoning skills and analytical thinking and the capacity to consider several possible solutions, which speaks to the transformative nature of the instructional model (Bybee, 2013; English, 2016).

The concept of project-based learning (PBL) appeared to be one of the most effective in the field of STEM education. PBL also offers learners long periods of time to work on real-world problems, which encourages them to be strategic, test over time and reflect (Thomas, 2000; Bell, 2010). It has been demonstrated empirically that students who participate in the activities of PBL-based STEM programs demonstrate more problem-solving performance relative to the performance of their traditional classroom counterparts, especially in interdisciplinary-based tasks involving the need to be innovative (Capraro et al., 2013). On the same note, inquiry-based learning has been evidenced in enhancing the capacity of students to ask questions, analyze facts as well as make evidence-based conclusions, which promotes a better comprehension of scientific concepts and reasoning (Minner et al., 2010; Furtak et al., 2012).

Design-based learning is a unique approach to the development of problem-solving skills as it exposes learners to the process of solving problems, which is iterative and focused on solutions. The engineering tasks involve the students to recognize constraints, create various solutions and refine the prototypes based on the evaluation and feedback. This hands-on methodology is an analogy of real-world problem solving in professional STEM education and provides flexibility and imagination in learners (National Research Council, 2012; Dym et al., 2005). In these instruction strategies, the presence of reflection and feedback tools was demonstrated to profoundly empower metacognitive elements of problem solving and allow students to keep track of, assess and modulate their strategies successfully (Hmelo-Silver, 2004).

Teamwork has been identified as a decisive aspect of efficient STEM-based problem-solving. Group work also promotes reasoning and negotiating towards mutual understanding and collaboratively constructing solutions, which results in both mental and social gains (Johnson & Johnson, 2009; Webb, 2009). Team problem-solving is not only effective in enhancing the level of solutions it also enhances communication, cooperation, and interpersonal abilities, which are needed to be a successful professional in STEM career. Nevertheless, the effectiveness of collaborative learning relies upon the task organization, the definition of the roles, and teacher facilitation, which means that it is necessary to design instructions carefully.

Regardless of the evident positive aspects of the collaboration of STEM education to problem-solving, there are still a number of challenges. The biggest obstacle to teacher preparedness is the lack of confidence and training as reported by many teachers to facilitate open-ended and problem-solving-oriented STEM instruction (Roehrig et al., 2012). Without proper professional growth, educators might go back to using the old-fashioned didactic methods, which will restrict the performance of STEM interventions. The rigidity of the curriculum and lack of time is also problematic, and so are standardized tests that focus on memorizing the material rather than encouraging critical thinking (Kelley and Knowles, 2016; Black and Wiliam, 2009). There are also resource constraints such as lack of access to technology, laboratory resources and instruction materials that further impede the realization of the problem-solving-based STEM education.

The results of this review have significant implications on the side of educator, policy and curriculum designers. Second, one should put emphasis on teacher professional growth, focusing on content-related issues, and pedagogical mechanisms of solving problems in STEM. Teachers should be equipped in training programs to facilitate inquiry-based, project-based, and engineering design tasks, and ways of promoting metacognition and reflection.

Second, the curriculum models would have to be redesigned in a way that would bring together the STEM disciplines in a unified manner, with a clear focus placed on problem-solving outcomes. Real, interdisciplinary assignments are to be integrated on grade levels so as to make the processes of problem-solving persistent. Third, the practices of assessment should develop to capture the process and product aspects of problem-solving. Performance-based evaluation, portfolios, and reflective journals are also suggested as the means that give an overall picture of the abilities of learners.

Lastly, there is the institutional and policy support to facilitate access to required resources, time allocation and infrastructural support. Problem-solving skills in STEM situations can also be intensified through collaboration networks, working with industry, and access to learning environment that is enhanced by technology.

Although the review indicates that STEM education has proven useful in problem-solving development, researchers still have gaps. Future studies are required to investigate the applicability of STEM to non-STEM problems such as social, ethical, and entrepreneurial problems. This requires longitudinal studies of how problem-solving skills gained with time. Besides, the effectiveness of the intervention based on STEM-related problem-solving is still to be investigated further regarding the impact cultural, socio-economic, and contextual factors impose.

The application of powerful evaluation tools to assess both cognitive and metacognitive domains of problem-solving is a high research requirement. Lastly, there should be research done on the scaling of successful STEM teaching methods to various educational systems, especially in under-resourced ones.

To sum it up, this systematic review proves that STEM education has become a very effective method of problem-solving skill development. Project based learning, inquiry based learning, engineering design, and collaborative activities enable learners to develop cognitive and metacognitive skills that they require in solving complex problems. Although the issues of teacher readiness, curriculum limitations, and evaluation constraints persist, specific interventions and support of the policy can increase the effect of STEM education on problem-solving outcomes. With the modern societies still grappling with the multifaceted and fast changing challenges, imparting problem solving skills by means of STEM education has been a burning issue to equip learners with the needs of 21st century.

Recommendations

According to the results of this systematic review, the following recommendations are offered to improve skills in problem-solving with the help of STEM education:

1. Conduct regular training programs on the pedagogy of the STEM curriculum and problem solving.
2. Integrate STEM disciplines in an integrated way through explicit objectives of problem solving.
3. Implement performance based execution of the processes and solution quality.
4. Provide laboratories, technology and instructional materials to facilitate STEM.
5. Provide the access of online STEM tools and virtual laboratories in remote learning situations.
6. Promote systematic team activity with the roles and duties.
7. Develop policies that put emphasis on STEM education and skill development in problem solving.
8. Carry out longitudinal research to determine the effect of STEM education on problem-solving in the long term.
9. The educational technologies that should be used to improve the experiences of problem-solving include simulations, virtual laboratories, and interactive programs.

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