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ORIGINAL RESEARCH

The implementation of the STEM PBL approach for students with disabilities: A literature review

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Abstract

The present systematic literature review (SLR) explores the successes and challenges of implementing the STEM project-based learning (PBL) approach for students with disabilities. By synthesizing findings from nine studies conducted in specialized and inclusive educational settings, this study highlights both the benefits and barriers of STEM PBL. The findings indicate that STEM PBL enhances student engagement, critical thinking, and learning outcomes. However, challenges such as accessibility issues, insufficient teacher preparedness, and resource limitations persist. These findings underscore the need for tailored instructional strategies and professional development programs to optimize STEM PBL for inclusive classrooms. Further research is essential to deepen the understanding of how students with disabilities engage with and benefit from STEM PBL. The study provides practical insights for educators, guiding the development of inclusive, effective STEM PBL models that foster meaningful learning experiences for all students.

Keywords: PBL · Qualitative approach · Quality education· STEM· Students with disabilities.

INTRODUCTION

Background of the Study

Bybee (2013) posited that during the 1990s, the National Science Foundation (NSF) defined STEM as "Science, Mathematics, Engineering, and Technology" (SMET), using the latter acronym to denote the Disciplines listed above. The STEM approach applies to all grade levels, both formal and informal, including preschool and postdoctoral levels (Gonzales & Kuenzi, 2012). As Bybee (2013) posited, the 21st Century calls for an educational system that equips the general workforce with 21st-century competencies, an advanced research and development workforce focused on innovation and a STEM-literate society. However, Gibson and Pick (2000) found that STEM education for young students is about providing them with opportunities to explore environmental materials. It is also about assisting them in developing concepts and guiding them through crucial experiences in students' early lives because they first want to know what they can do in the world.

As defined by Barell (2010), PBL constitutes an instructional model that emphasizes how students address contemporary issues and challenges, collectively devising strategies through

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collaborative problem-solving. Moreover, Kokotsaki et al. (2016) demonstrated that PBL is a student-centered learning approach that prioritizes student autonomy, constructive investigation, goal setting, collaboration, communication, and reflection in real-world practice. Furthermore, Wahyudi and Winanto (2018) determined that PBL is an invaluable pedagogical approach for the 21st Century. It is a comprehensive teaching strategy that motivates students to develop essential knowledge and competencies through a structured inquiry process centered on complex inquiries and meticulously designed learning materials and tasks (Wahyudi & Winanto, 2018). However, following the guidelines set forth by the Buck Institute for Education (2018), a high-quality PBL program is distinguished by six essential characteristics: intellectual challenge and accomplishment, authenticity, a tangible outcome, collaboration, project management, and reflection. Therefore, PBL is a strongly recommended instructional approach for developing student's technology, partnership, and problem-solving skills in the 21st Century (Bender, 2012).

STEM PBL signifies a contemporary pedagogical approach that places the student at the core of the educational process, employing an interdisciplinary, collaborative, and technology-based method of teaching and learning (Han et al., 2015). Furthermore, STEM PBL represents a distinctive pedagogical approach that offers significant advantages when implemented in a classroom setting (Han et al., 2015). Additionally, the STEM PBL approach is grounded in engineering design, which provides a framework for students to integrate their scientific, technological, and mathematical knowledge to address meaningful problems. In this context, Capraro and Slough (2013) posited that the integration of PBL and STEM fosters the development of crucial specialized learning connections between K-12 and post-secondary education, aligning with the demands of the future workplace.

Each STEM and PBL has a distinct role and set of benefits in assisting students in achieving their learning objectives, especially fostering critical thinking among students, thus enhancing their high-order thinking skills (Capraro & Slough, 2013). Moreover, Ash-shabira et al. (2024) posited that as the 21st century progresses, critical thinking has become an increasingly essential skill for individuals and organizations. However, critical thinking skills are crucial for current and future leaders to develop plans for creating a prosperous and long-lasting society (Muliakoswara et al., 2024).

In inclusive education, students with diverse backgrounds and abilities learn together in collaborative settings (Gollnick & Chinn, 2002). While some students excel, others require additional support to grasp instructional content. Soares and Vannes (2013) asserted that educators must provide equitable opportunities, ensuring all students can engage in meaningful learning experiences. STEM PBL, by design, facilitates differentiated instruction, allowing students with disabilities to work alongside their peers in structured yet flexible environments (Slough & Milam, 2013). The adaptable nature of PBL makes it particularly advantageous for students with diverse needs, enabling task customization based on individual competencies (Capraro & Slough, 2013). Noble et al. (2020) further emphasized that PBL fosters collaboration by structuring group work to encourage peer learning and mutual support rather than division of labor. However, its implementation in inclusive classrooms is often hindered by accessibility concerns, teacher preparedness, and resource limitations (Savery, 2006).

The opportunity to work alongside their typically developing peers provides students with disabilities who benefit from STEM PBL learning in an inclusive setting with an invaluable

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learning opportunity. Nevertheless, STEM PBL is regarded as a distinctive approach to learning, characterized by a supportive learning environment development that facilitates comprehension, encourages tangible reasoning, facilitates learning from peers, and cultivates self-reliance and a commitment to lifelong learning (Slough & Milam, 2013). Moreover, STEM PBL is an advantageous strategy for diverse learners due to the extensive nature of the project work, which allows for segmentation and customization of tasks to align with the students' competencies at different levels of achievement (Capraro & Slough, 2013). Moreover, Noble et al. (2020) suggested that, rather than a "divide and conquer" approach to group work, PBL provides group work activities where students can contribute to and benefit from the support or skills of their peers, thereby facilitating true collaboration. Because of these considerations, educators are implementing additional strategies designed to cultivate students' autonomy and equip them with the tools necessary to navigate the challenges associated with depending on others. (Noble et al., 2020). In alignment with Savery (2006), students with special needs and their typically developing counterparts can benefit from PBLs in an inclusive setting, particularly as they enhance their self-direction, self-regulation, and collaboration skills, regarded as the pivotal elements of the problem-based and project-based approach.

The UDL framework, introduced in the 1990s by the Center for Applied Special Technology (CAST), has gained significant recognition in the United States (Rose, 2002). The framework aims to support diverse student needs and to create equitable and accessible learning environments for all learners (Gordon et al., 2014; Orkwis & McLane, 1998; Rose & Strangman, 2007). According to Hartmann (2015), UDL is a diverse and sophisticated theoretical framework for learning, drawing on neuroscientific, educational, and technological research. Basham et al. (2010) implied that UDL aligns with the framework for inclusive STEM education by offering flexible, adaptable approaches to teaching and learning that cater to diverse student needs. Moreover, the UDL framework asserts that learners, including those with severe disabilities, should not be defined by their perceived impairments; Rather, they need support in accessing the accommodations necessary for effective learning (Hartmann, 2015).

In this context, UDL supports the STEM FOR ALL initiative by ensuring that all designed educational content, methods, and assessments can remove barriers and provide multiple pathways for students to engage with, understand, and succeed in STEM subjects, which promotes inclusion and equity in STEM education (Basham et al., 2010). By emphasizing multiple means of engagement, representation, and action/expression, UDL ensures that learning experiences are accessible and inclusive (Hartmann, 2015). UDL enhances the adaptability of STEM activities, allowing students with varying abilities to participate meaningfully in hands-on, inquiry-driven projects (Schreffler et al., 2019); thus, it applies to STEM PBL. This alignment fosters deeper engagement and equitable learning opportunities, as it addresses barriers to participation while promoting creativity, collaboration, and critical thinking. However, UDL ensures students can achieve better potential by developing key 21st-century skills (Rose & Meyer, 2006), particularly by integrating UDL into STEM PBL.

Article 26 of the United Nations (UN) Universal Declaration of Human Rights (1948) asserted that all individuals possess the inalienable right to education. Furthermore, Article 23 of the 1989 United Nations Convention on the Rights of the Child (CRC) established an affirmative obligation for signatories to the convention to furnish educational, vocational, medical, and rehabilitative services to children with disabilities. The increasing prevalence of

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students with disabilities, particularly in inclusive educational environments, presents educators and policymakers in the education sector with significant challenges (Wulandary & Kawai, 2024). Consequently, many countries have increased the number of proficient educators to achieve Sustainable Development Goal (SDG) 4, which prioritizes educational quality advancement (Tatto, 2021).

According to Saini et al. (2023), the SDG represents a pivotal element of global governmental initiatives designed to advance sustainable growth by implementing strategies to ensure prosperity, facilitate economic growth, enact environmental legislation, and encourage academic advancement. SDG 4 comprises seven goals about the quality of education at various stages of development. The objective is to guarantee that all individuals have access to an adequate and satisfying educational experience from early childhood to tertiary education (Johnstone et al., 2020). As an initiative in alignment with the 2030 Agenda, the current study concentrated on ensuring equal access to education for students with disabilities. This endeavor pertains to accessible and effective learning environment development for all students, with a particular emphasis on those with special needs as defined by SDG 4.5 and SDG 4.8. Considering the paramount importance of equality of opportunity, Ayverdi and Avcu (2023) have proposed that individuals with disabilities must be guaranteed access to STEM education. Accordingly, the objective of the present study was to provide a comprehensive synthesis of the existing literature on STEM PBL approaches, with a particular focus on their efficacy in addressing the needs of all students, including those with disabilities, in creating inclusive learning environments.

Despite growing interest in STEM PBL and its application in inclusive education, there remains a significant gap in research specifically focusing on how STEM PBL implementation can effectively address the unique needs of students with disabilities. While many studies have explored the general benefits of STEM PBL, there seems to be limited attention devoted to identifying and overcoming the specific challenges faced by students with disabilities within specialized and inclusive educational settings. Additionally, a lack of comprehensive frameworks exists to guide the integration of STEM PBL with inclusive practices, particularly for students with disabilities. UDL provides a potential solution by offering a flexible framework that ensures all students, including those with disabilities, can engage with, understand, and succeed in STEM PBL activities. UDL emphasizes multiple means of engagement, representation, and expression, creating a more inclusive learning environment that caters to diverse needs and abilities. As a result, a gap in understanding remains regarding how these students engage with, benefit from, and participate in STEM PBL activities. This study aims to fill this gap by investigating the practical applications, challenges, and advantages of STEM PBL for students with disabilities, providing insights into how it can be adapted to meet their diverse learning needs.

Research Questions

This study investigates two key research questions concerning the implementation of STEM PBL for students with disabilities in both special schools and inclusive educational settings. It aims to explore how STEM PBL can be adapted to meet the specific learning needs of students with disabilities and assess its effectiveness in addressing their unique educational challenges. Furthermore, the study examines the obstacles encountered in STEM PBL implementation,

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identifying structural, pedagogical, and contextual barriers that may hinder its success. Through this inquiry, the study seeks to provide a nuanced understanding of both the potential and limitations of STEM PBL for students with disabilities.

Research Objectives

The primary objectives of this study are to evaluate the effectiveness of STEM PBL in addressing the diverse learning needs of students with disabilities and to investigate the challenges associated with its implementation in specialized and inclusive educational settings. By synthesizing empirical findings, the study aims to generate insights that can inform evidence-based instructional practices and policy development. Ultimately, this research seeks to contribute to the advancement of equitable and high-quality STEM education for all learners, particularly those with disabilities.

METHOD

Research Design

The current study utilized a qualitative design within a systematic literature review (SLR). The primary objectives of this study are to evaluate the effectiveness of STEM PBL in addressing the diverse learning needs of students with disabilities and to investigate the challenges associated with its implementation in specialized and inclusive educational settings. By synthesizing empirical findings, the study aims to generate insights that can inform evidence-based instructional practices and policy development. Ultimately, this research seeks to contribute to the advancement of equitable and high-quality STEM education for all learners, particularly those with disabilities.

Data Collection

The authors employed a systematic approach to data collection, integrating digital literature searches with targeted sampling techniques. The search process was structured around the use of relevant keywords aligned with the research focus, ensuring a comprehensive identification of studies related to STEM PBL implementation for students with disabilities. Additionally, the snowball sampling method was utilized to expand the search scope by examining references cited in the initially retrieved studies, allowing for the identification of further relevant literature (Van Saane et al., 2003).

The selection process adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a structured framework for enhancing the transparency, rigor, and replicability of systematic reviews (Page et al., 2021). PRISMA facilitates a methodologically sound review process by outlining standardized procedures for study identification, screening, inclusion, and exclusion (Zhang et al., 2025). In accordance with these guidelines, the present study systematically applied these procedures to ensure methodological rigor in selecting and analyzing the included literature.

During the identification and screening processes, the authors utilized digital databases for this comprehensive literature review, including Google Scholar, ResearchGate, and JSTOR. The authors constructed the search using a combination of synonyms and related vocabulary relevant to the research focus to maximize the breadth of results (Van Saane et al., 2003). Specifically, the primary search terms employed were "STEM PBL in students with

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disabilities" and "STEM PBL in students with special needs," targeting studies that explored the implementation of STEM PBL for students with disabilities.

The identification and screening phases were conducted using established digital databases, including Google Scholar, ResearchGate, and JSTOR, to ensure access to a broad range of peer-reviewed literature. The search strategy incorporated a combination of synonyms and related terminology to maximize the scope of retrieved studies (Van Saane et al., 2003). Primary search terms included "STEM PBL in students with disabilities" and "STEM PBL in students with special needs," specifically targeting research that examined the implementation and impact of STEM PBL for students with disabilities.

The authors initially identified a total of 120 articles through database searches. After removing 30 duplicates, 70 titles, and abstracts were screened for relevance. Of these, the authors evaluated 20 full-text articles against the inclusion and exclusion criteria, and nine previous studies were deemed eligible for inclusion in this review. These nine selected studies were subsequently analyzed and synthesized to address the research questions, providing insights into trends, challenges, and opportunities in the STEM PBL implementation for students with disabilities. The data collection procedures according to PRISMA guidelines are listed in Figure 1.

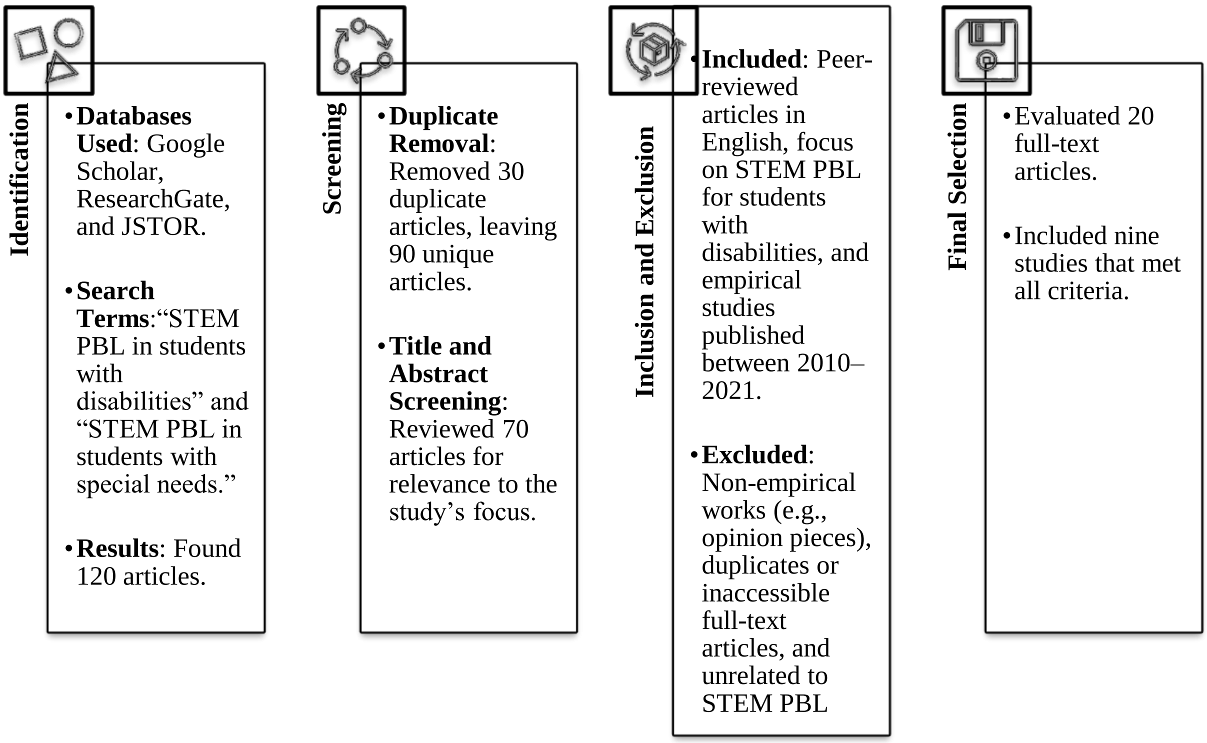

Figure 1 Data Collection Procedures

Data Analysis

The current study involved a systematic and rigorous analysis of literature retrieved from online databases, ensuring a methodologically sound synthesis of existing research. The analytical process encompassed a structured review of selected studies, with key findings and summaries systematically organized in a tabular format. Each entry in the table included detailed bibliographic information, such as author(s), research titles, year of publication, journal name,

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and research methodologies employed. This structured documentation facilitated a comprehensive comparative analysis of methodological approaches, thematic patterns, and reported outcomes across the selected studies.

Validity and Reliability

The concepts of validity and reliability serve as fundamental criteria in evaluating the methodological rigor of scientific research (Chetwynd, 2022). In the context of systematic literature reviews (SLR), these principles ensure the selection of credible and methodologically sound sources (Ediyanto et al., 2024). To enhance validity, this study adhered to predefined selection criteria and PRISMA guidelines, ensuring that only empirically substantiated research was included. Reliability was reinforced through a structured and replicable process of summarizing and analyzing articles, ensuring consistency in the interpretation of findings (Ediyanto et al., 2024). By maintaining transparency in data extraction and analysis, this study upholds the methodological rigor necessary for deriving robust and generalizable conclusions.

RESULT AND DISCUSSION

Results

In the current study, the authors arranged the analyzed literature in the table, which includes the author(s) name, publication year, research title, and the main findings of each study. The findings presented in the table include the advantages of STEM PBL in influencing the performances of students with disabilities and the challenges that arose during the implementation of STEM PBL on students with disabilities. The literature and each finding are listed in Table 1.

Table 1. Table Caption Usage

Author(s), Year, Title	Findings
Marino et al. (2010). *An Analysis of Factors That Affect Struggling Readers' Achievement during a Technology-Enhanced STEM Astronomy Curriculum*	This study explored factors influencing STEM achievement in students with reading difficulties using a UDL-based astronomy curriculum. The data collected from 1,153 middle school students revealed that a subset of low-reading-ability students demonstrated performance levels comparable to those of proficient readers. Key factors enabling this success were identified, emphasizing the value of inclusive STEM instruction and suggesting areas for further research.
Capraro. (2012). *The development of a teacher observation instrument for PBL classroom instruction.*	This literature introduced an instrument to assess the enactment of key elements in STEM PBL activities within classrooms. The chapter details the steps involved in developing the instrument, providing a framework for how it can be used to evaluate the effectiveness of STEM PBL instruction. Additionally, the chapter offers follow-up suggestions for educators and institutions involved in STEM professional development, including school districts, educational academies, service centers, and university partners, to help them integrate the instrument into their training and assessment processes for improved STEM education outcomes. Nevertheless, the evaluation of specific pedagogical approaches necessitates the utilization of an adequately constructed observation instrument.
Soares & Vannest (2013). *STEM Project-Based Learning and Teaching for Exceptional and Learners.*	This literature examined the efficacy of PBL in addressing the needs of this particular learner group. While PBL benefits all learners, it is especially crucial for those with special conditions, as it promotes successful participation and learning. This source elucidates the characteristics of exceptional and diverse learners, outlines the fundamental elements of STEM-focused PBL, and illustrates how these elements can enhance learner engagement and performance when applied effectively to foster an inclusive learning environment that benefits all students.

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Zech. (2014). *Efficacy of STEM Initiatives Utilizing Project-Based Learning with Inclusion Students in an Urban High School.*	This study explored the impact of combining STEM education and PBL in inclusion classrooms at an urban high school, focusing on students with disabilities. Guided by motivational and choice theories, the research assessed effects on academic achievement, behavior, and attendance. Teacher surveys showed positive impacts of STEM-PBL, though concerns about its rigor for students with disabilities and the need for more professional development were raised. Quantitative analysis of test scores, behavior referrals, and attendance revealed improvements in math, reading, and attendance from 2008-2012 but no significant changes post-implementation. The study highlighted the need for additional professional development to implement STEM-PBL strategies better, offering a model for improving inclusive education outcomes.
Han et al. (2015). *How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement.*	This study investigated the impact of STEM PBL on students with varying performance levels and the influence of individual factors on their mathematics achievement. Teachers from three high schools participated in sustained professional development and implemented STEM PBL activities every six weeks for three years. The study included 836 high school students who took the Texas Assessment of Knowledge and Skills (TAKS) test. Using hierarchical linear modeling, the analysis found that STEM PBL positively affected student achievement, particularly for low-performing students, who showed significantly higher growth in math scores compared to middle and high performers. Ethnicity and economic status were also strong predictors of achievement. The findings suggest that STEM PBL benefited low-performing students more, helping to reduce the achievement gap.
Hwang & Taylor. (2016). *Stemming on STEM: A STEM Education Framework for Students with Disabilities.*	This article addressed the challenges faced by students with disabilities in STEM education, noting that they typically perform below their peers without disabilities in math and science. The authors propose a new framework for STEM education incorporating the arts, transforming STEM into STEAM to enhance accessibility and engagement for students with disabilities. They outline a comprehensive approach for special education classrooms that includes teaching problem-solving skills in science, applying them through hands-on engineering activities, integrating art and music to increase motivation, using various technologies, and connecting lessons to real-world applications. This framework aims to provide students with disabilities authentic learning experiences, promoting flexibility and creativity while helping them develop the knowledge and skills necessary to solve complex, real-world problems.
Lambie. (2020). *Project-based learning (PBL) in science, technology, engineering, and mathematics (STEM): Perspectives of students with special education needs (SENs).*	This study examined how students with Special Educational Needs engage with STEM subjects when taught through a STEM PBL approach. Qualitative and quantitative data were collected to assess students' and the teacher's perspectives on STEM, understanding, engagement, and changes in STEM skills. The findings revealed that students had improved perceptions of certain STEM subjects and were academically successful, engaged, and enjoyed the STEM PBL environment. Both students and the teacher showed improvements in STEM skills throughout the study. Despite lacking prior experience with STEM PBL, the teacher improved their ability to teach using this method. The study highlights the positive effects of STEM PBL on students with SENs and the potential for teacher development through its implementation.
Noble et al. (2020). *A Mixed-Methods Approach to Understanding PBL Experiences in Inclusive STEM High Schools*	This study explored the implementation of PBL in inclusive STEM high schools, which aims to foster 21st-century skills, promote academic success, and encourage students to pursue STEM careers. While PBL is central to these schools' goals, there needed to be a prior detailed description of its application. The study draws on classroom observations and teacher interviews to identify instructional practices and classroom behaviors during PBL. The results show that PBL implementation is multifaceted and consistent across various schools. Quantitative data also indicate an increased use of specific strategies in PBL classrooms compared to non-PBL classes. The study provides valuable insights into PBL practices in inclusive STEM schools and offers important implications for future research and the effective use of PBL in education.
Lu et al. (2022). Evaluation of disabled STEAM-students' education	This study examined the impact of a STEAM PBL curriculum on students with learning disabilities, focusing on their learning outcomes and creativity. Over 10 weeks, three primary school students participated in 12 STEAM lessons, using

learning outcomes and creativity under the UN sustainable development goal: project-based learning oriented STEAM curriculum with micro: bit.	tools like micro: bit and paper cutting. The results showed that the PBL-oriented curriculum improved students' creativity and academic performance, with positive immediate and retention effects. The study suggests that a tailored STEAM curriculum can enhance problem-solving abilities and build confidence in students with disabilities, aligning with SDG4 targets for quality education. It also highlights the need for curriculum designs that consider students' interests and needs, with further research recommended to explore broader applications.

How STEM PBL met the unique needs of students with disabilities

The literature underscores the efficacy of STEM PBL in addressing the educational needs of students with disabilities by enhancing academic performance, fostering creativity, and increasing engagement in inclusive settings. Empirical studies highlight its potential to bridge learning gaps and support diverse learners through accessible, inquiry-based instruction.

Marino et al. (2010) examined a UDL-based astronomy curriculum, revealing that students with reading difficulties performed at levels comparable to their proficient peers. This outcome underscores the significance of inclusive curriculum design in mitigating learning barriers and enhancing STEM accessibility. Similarly, Han et al. (2015) investigated the impact of STEM PBL on mathematics achievement among high school students, demonstrating that lower-performing students exhibited significantly greater score improvements, thereby contributing to closing the achievement gap. Zech (2014), in a study of urban high school inclusion settings, reported that STEM PBL not only enhanced academic achievement, behavior, and attendance but also raised concerns among educators regarding its rigor for students with disabilities, emphasizing the need for additional professional development.

The integration of arts into STEM conceptualized as STEAM, has been proposed as an inclusive strategy to enhance engagement. Hwang and Taylor (2016) developed a STEAM framework incorporating practical engineering tasks, creative pursuits, and pragmatic applications, facilitating accessibility and fostering problem-solving skills, confidence, and creativity. Lu et al. (2022) further demonstrated that a tailored STEAM curriculum significantly enhanced both immediate and long-term learning outcomes for students with learning disabilities, reinforcing the role of interdisciplinary approaches in inclusive STEM education.

Beyond academic achievement, STEM PBL has been shown to influence students' attitudes toward STEM disciplines. Lambie (2020) found that students' perceptions of STEM subjects improved, alongside the development of critical STEM skills and an increased enjoyment of the PBL environment. Teachers, despite initial challenges, became more proficient in implementing STEM PBL over time. Observations of inclusive STEM high schools further validated the effectiveness of consistent PBL strategies in fostering 21st-century competencies, academic success, and interest in STEM careers (Noble et al., 2020).

Despite these promising outcomes, challenges persist. Studies by Capraro (2012) and Zech (2014) identified the need for enhanced professional development and curriculum refinement to better accommodate the specific learning needs of students with disabilities. Capraro (2012) introduced an assessment instrument for STEM PBL implementation, emphasizing the importance of structured evaluation mechanisms to improve instructional strategies.

Collectively, these studies highlight STEM PBL’s transformative potential for students with disabilities while underscoring the necessity of intentional curriculum design, teacher training, and inclusive pedagogical approaches. The findings suggest that equipping educators

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with the tools and knowledge to implement accessible, creativity-driven, and student-centered STEM PBL is critical to fostering engagement, academic success, and long-term interest in STEM fields among diverse learners.

Challenges in implementing STEM PBL on students with disabilities

Implementing STEM PBL for students with disabilities presents both opportunities and challenges. While research underscores the benefits of inclusive pedagogical models such as Universal Design for Learning (UDL)—which has enabled students with lower reading abilities to perform comparably to proficient readers in STEM subjects (Marino et al., 2010)—effective implementation requires structured evaluation tools to assess and refine instructional strategies. STEM PBL fosters active participation and academic achievement among diverse learners, yet its multifaceted nature complicates uniform application across educational contexts.

One of the primary concerns in STEM PBL implementation is ensuring rigor and accessibility for students with disabilities. While studies confirm that STEM PBL enhances students' engagement, perceptions, and problem-solving skills, barriers persist for low-performing or at-risk learners, particularly in terms of cognitive load, instructional pacing, and accessibility of learning materials (Han et al., 2015). Additionally, broader socioeconomic and demographic factors, such as economic status and ethnicity, further influence students' academic performance, complicating efforts to close achievement gaps in STEM education (Han et al., 2015).

Efforts to adapt STEM PBL to diverse learners have led to interdisciplinary approaches such as STEAM, which integrates the arts into STEM curricula to enhance creativity and real-world problem-solving (Hwang & Taylor, 2016). Although STEAM-based strategies have shown positive learning outcomes, their implementation demands well-structured curriculum design and comprehensive teacher training. A persistent challenge is teacher preparedness, as many educators lack prior experience in integrating STEM PBL into inclusive classrooms. Despite evidence suggesting that sustained professional development improves instructional effectiveness and positively impacts student learning, barriers such as limited institutional support, resource constraints, and the absence of standardized models continue to hinder large-scale implementation.

To maximize the potential of STEM PBL for students with disabilities, greater investment in teacher training, adaptable instructional models, and curriculum flexibility is required. While the approach has demonstrated success in enhancing academic outcomes, fostering 21st-century skills, and increasing engagement, its long-term effectiveness and scalability necessitate further empirical research and refinement (Han et al., 2015; Hwang & Taylor, 2016; Lambie, 2020; Soares & Vannes, 2013). Addressing these challenges will be critical in ensuring that STEM PBL remains an equitable, accessible, and effective learning framework for all students, regardless of ability.

Discussion

The findings from the reviewed studies hold significant implications for educational practice, policy development, and future research, particularly in the context of inclusive STEM PBL for students with disabilities. The integration of Universal Design for Learning (UDL) with STEM education has demonstrated the potential to address diverse learning needs, particularly for

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students with reading difficulties. Marino et al. (2010) found that students with low reading proficiency performed at levels comparable to their peers when supported by a UDL-based astronomy curriculum, highlighting the importance of accessible instructional design in STEM education. This study underscores the necessity of developing STEM curricula that accommodate diverse learning styles and cognitive abilities, thereby encouraging educators to incorporate UDL principles into STEM instruction to bridge achievement gaps and enhance academic success for students with disabilities. Furthermore, the integration of PBL in inclusive classrooms has shown positive effects on academic achievement, behavior, and attendance, particularly among students with disabilities. However, the findings also indicate that educators often face difficulties in implementing these methodologies effectively. This underscores the importance of ongoing professional development to equip teachers with the requisite pedagogical strategies to successfully integrate STEM PBL in inclusive classrooms.

From a policy perspective, these findings provide critical insights for shaping inclusive education reforms. The combined use of UDL and PBL in STEM education could serve as a foundation for policy initiatives aimed at enhancing educational accessibility and equity for students with disabilities. Policies should prioritize teacher training, resource allocation, and curriculum adaptation to ensure that STEM PBL is effectively implemented in diverse learning environments. Furthermore, the need to develop adaptable and student-centered STEM and STEAM curricula is evident, particularly to support the varying needs of students with disabilities. Educational policies should mandate the integration of diverse learning strategies to foster equitable learning opportunities, ensuring that all students, regardless of ability, have access to high-quality STEM education.

Despite the valuable insights provided by the reviewed studies, several research gaps remain, necessitating further empirical investigation. Future research should focus on adapting STEM and STEAM curricula to better support students with disabilities, particularly those struggling with reading difficulties and other cognitive challenges. Additionally, longitudinal studies would provide a deeper understanding of the long-term impact of STEM PBL on the academic and social development of students with disabilities. Another essential avenue for research involves evaluating the effectiveness of professional development programs for teachers, ensuring that they are adequately trained to implement inclusive STEM PBL strategies. Moreover, exploring the scalability and sustainability of these educational programs in varied educational contexts will be critical in determining best practices for long-term implementation.

While this systematic review provides valuable insights, it is important to acknowledge certain limitations. First, the exclusive focus on English-language studies may have excluded relevant research published in other languages, thereby limiting the scope and diversity of perspectives. Additionally, the temporal limitation to studies published within the past decade may have excluded earlier foundational research, restricting the historical breadth of the analysis. Some of the included studies had limited scope or small sample sizes, which may affect the generalizability of the findings. Furthermore, the review primarily examined academic outcomes, with less emphasis on social, emotional, and behavioral development in STEM PBL contexts. Future research could expand on these dimensions to provide a more holistic understanding of the impact of STEM PBL on students with disabilities.

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CONCLUSION AND RECOMMENDATIONS

Conclusion

The integration of STEM PBL into inclusive education offers significant advantages for students with disabilities, including enhanced engagement, motivation, and academic performance, particularly in STEM-related subjects such as mathematics. By fostering problem-solving, collaboration, and creativity, STEM PBL provides an adaptable framework that accommodates diverse learning needs. Its real-world applicability enables differentiated instruction, ensuring that students can engage with content in ways that align with their individual abilities and interests. However, despite these benefits, challenges remain. Educators frequently perceive STEM PBL as complex and resource-intensive, requiring specialized training, professional development, and institutional support. Additionally, successful implementation depends on the availability of adequate resources, administrative backing, and structured scaffolding to assist students who may struggle with the independent and collaborative aspects of PBL. Addressing these challenges is crucial for ensuring that STEM PBL remains an effective and sustainable educational approach for all learners.

Recommendations

To enhance the effectiveness of STEM PBL for students with disabilities, several key recommendations emerge from the reviewed studies. First, teacher training and professional development must be prioritized. Research consistently highlights the need for educators to be equipped with the necessary skills to implement STEM PBL effectively, particularly in inclusive settings. Continuous professional development should be provided to support teachers in adapting STEM PBL to diverse learning needs, ensuring accessibility and effectiveness for students with varying abilities.

A second crucial recommendation is the adoption of inclusive teaching methodologies, particularly through the integration of Universal Design for Learning (UDL) and STEAM approaches. By incorporating arts into STEM and emphasizing hands-on, inquiry-based learning, educators can create engaging, creative, and accessible learning environments that benefit students who struggle with traditional, lecture-based instruction.

Further, the research indicates that low-performing students benefit significantly from STEM PBL, suggesting that targeted interventions should be developed to support students at risk of academic failure. Schools should emphasize structured support systems that allow these students to engage with STEM content meaningfully while addressing their unique learning challenges. Additionally, promoting student engagement and motivation is essential. STEM PBL has been shown to enhance academic achievement and enjoyment of learning, making it imperative for educators to create inclusive, student-centered learning environments that foster active participation.

Another recommendation is the customization of curriculum design to accommodate diverse learners. The curriculum should be differentiated to align with students' varying skill levels, learning preferences, cultural backgrounds, and life experiences. A flexible and adaptable approach ensures that students with disabilities receive the support necessary for meaningful engagement with STEM concepts. Additionally, schools should implement systematic monitoring and assessment mechanisms to evaluate the impact of STEM PBL. Using

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structured instruments to track student achievement, engagement, and behavior will provide educators with empirical data to refine and improve instructional practices.

Finally, sustained investment in teacher development is essential. Educators, particularly those new to STEM PBL, require structured training programs that build confidence and competence in integrating PBL strategies into their teaching. Supporting teacher development not only enhances the effectiveness of STEM PBL but also ensures long-term sustainability in inclusive classrooms.

In conclusion, the reviewed studies reinforce the pedagogical efficacy of STEM PBL in inclusive education, yet they also highlight the need for continuous professional development, curriculum adaptation, and ongoing research to refine its implementation. Future research should explore how STEM and STEAM curricula can be further optimized to meet the diverse needs of students, ensuring equitable access to high-quality education and fostering critical 21st-century competencies among all learners.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. This study was conducted independently, with no financial or personal relationships influencing the research outcomes.

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