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Review Article

A Decade of Science Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PjBL): A Systematic Literature Review

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Abstract
The fields of Science, Technology, engineering, and mathematics (STEM) have advanced significantly in Education. In various research in the world of education, STEM growth is frequently associated with project-based learning (PjBL). Combining STEM learning with PjBL is worth researching. This study's objective is to comprehensively investigate the link between STEM and PjBL, which covers the most advanced PjBL-STEM idea in academic units, implementation in various nations and educational levels, and the impact of STEM and PjBL relationships on the caliber of students. This analysis identified up to 168 Scopus-recognized papers between 2007 and 2022. This study used a systematic review with a four-step PRISMA-P. Finally, there were 35 articles included in this research. The analysis's findings demonstrate that STEM PjBL has successfully fostered active learning and student-centered instruction while enhancing 21st-century abilities (creativity, collaboration, problem-solving, creative use of technology, and higher-order thinking). The notion of STEM Subject, or the incorporation of STEM PjBL into activities, is the one that is researched the most in schools. The country that used PjBL STEM learning the most was the United States. In 2018, mixed research methodologies were used to study STEM-PjBL research the most. Secondary education STEM-PjBL studies and teachers are critical for children to become more interested in a STEM profession.

Keywords: Education, PjBL, project-based learning, science, technology, engineering, & mathematics, STEM

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1. INTRODUCTION

Given that the two methodologies and learning models have similar and complementary guiding principles, combining STEM learning with PjBL or vice versa merits consideration and research. STEM stands for Science, Technology, Engineering, and Mathematics. However, STEAM is also mentioned in certain publications (Diego-Mantecon et al., 2021). Adding the term "Art" represents a reform of educational disciplines aimed at raising students' appreciation of science and mathematics (Breiner et al., 2012). Other studies and more focused contexts refer to STEM or STEAM as the fusion of some disciplines to genuinely address challenges.

The importance of STEM in education is tied to the necessity to better the fields of mathematics and science to prepare students for the workplace and careers

(Brown & Merrill, 2011). Engineering is utilized to create breakthroughs and solve issues, and a technology course helps students better comprehend how tools operate (Bybee, 2010). PjBL, on the other hand, emphasizes students applying their knowledge through direct learning (learning by doing) that is done methodically and with the syntax: starting with questions to solve problems, followed by exploration activities through the inquiry process, forming scaffolding using technology or other learning resources, as well as creating and producing products as answers or giving reasons for problems (Krajcik & & Blumenfeld, 2006). PjBL uses genuine problem-solving, just like STEM, to link students' knowledge with what's happening in their surroundings (Bell, 2010).

1.1 Literature Review

It has been demonstrated that project-based learning (PjBL) in science can enhance students' learning results in both mathematics and science (Craig & Marshall, 2019a) until the social (Bascopé & Reiss, 2021). One of the educational revolutions in America that replaced the drawbacks of conservative-based learning is PjBL (Knoll, 1997). The qualities of project learning place emphasis on problem-solving, learning by doing, a relevant and meaningful curriculum for learners, and the role of educators as more than merely learning assessment agents and question writers (Merrynncole, 2019). PjBL links academic theory and practice, allowing students' knowledge, beliefs, and skills to be used in the workplace (Verma & Verma, 2011). According to Wilson (2021), STEM-based learning can assist PjBL in accepting kids interested in deep understanding. One such is the STEM-PjBL method of Education that integrates many academic areas utilizing robots (Kushnir, 2020).

The growth of science and technology catalyzes the modernization of civilization. The education department uses science, technology, engineering, and math (STEM) to innovate and replace the school system's long-standing teaching practices. STEM promotes students' creativity and intuition by applying information, planning, building, and developing a learning design (Li et al., 2019). Finding practical solutions is the basis for applying STEM, and one such method stresses learning via projects. The fact that there seems to be a process of incorporating pupils directly in learning sets STEM features apart from traditional ones (Aydin, 2020a). For students to thrive in STEM, they must have knowledge of and aptitude for solving problems, as well as the willingness to gather new information from project outcomes (Forawi, 2018).

1.2 Aim of the Study

The author is interested in examining the combination or relationship of these two learning styles in the field of Education after revealing some of the study's findings above. The formulations of the STEM-PjBL education-related concerns that will be examined in this study include the following:

RQ1. What concepts or fields have been researched in a decade?
RQ2. How is the application of STEM-PjBL from several countries at the education level?
RQ3. What are study methods often used?
RQ4. What is the output of the study on the effect of the STEM-PjBL approach on the quality of learners?

2. METHOD

2.1 Study Design

This study used a systematic review with a four-step PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses-Protocol) method (Moher et al., 2015). To locate 168 credible papers from 2007 to 2022 that concentrated on research findings by investigating, evaluating, and projecting information from research theme-related papers, research development is accomplished. The PRISMA-P procedure has four steps: 1) Identification of literature pertinent to the research, 2) analysis of criteria based on the author of the literature, 3) analysis of the author's use of codes and themes in the article, and 4) drawing of conclusions from the analysis's findings.

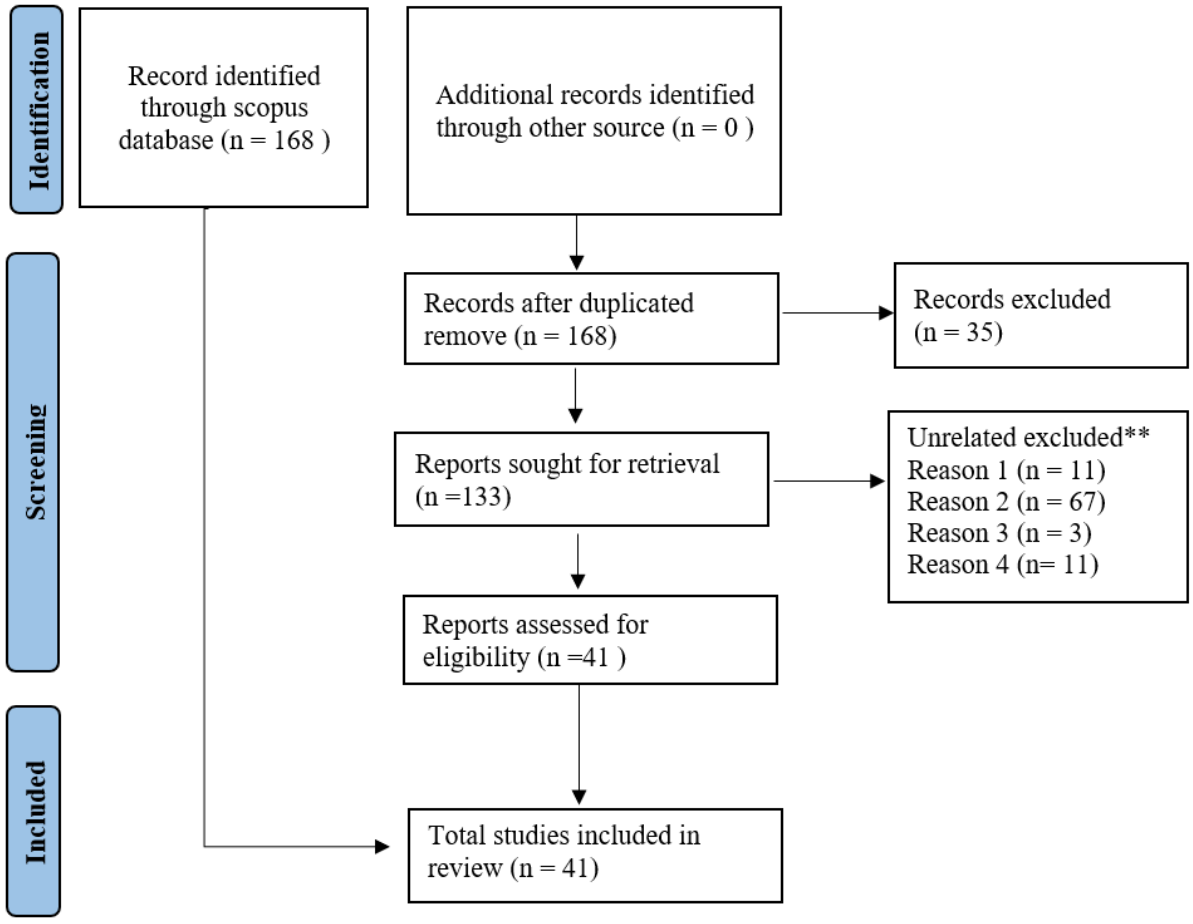

Figure 1. PRISMA Protocol

Because it is simple to look for an article or journal that has been accredited, Scopus identification is a source of literature search. The terms "project-based learning" or "PJBL " AND "STEM Education" are used in literature searches, with the review or article selection criteria. The article's year, author, document type, source, affiliation, country, and language are loaded with the search results in MS Word and MS Excel formats.

Checking every article data against the following screening criteria: (1) 2007 through 2022 for publications; (2) English-language articles that (3) do not come

from peer-reviewed journal publications and (4) are relevant to STEM, PjBL, and education issues at both the high school and collegiate levels.

Classification examines each of the 168 articles in depth, as indicated in Table 1, one by one. This limits the research that will be extensively studied about the connection between STEM and PjBL in Education. The classifications covered in the discussion include article type, research goals, nation, educational level, research design, and topics or information included in the study. Table 2 contains a list of the categorization outcomes for all the articles that have been examined.

Figure 1 describes the PRISMA Inclusion Process. The period of publications to be investigated was restricted to 2007 to 2022, and only fully accessible works were considered. According to the browser activity, 133 of the 168 items may have been downloaded.

There are 35 articles included in this research theme inaccessible from the Google scholar engine. The sum of the differences in reports that have been downloaded (n=133) is then checked individually and manually to group the article types, as shown in Table 1. From the examination results, 41 papers are included in the category for review analysis.

Reason 1: bibliometric/systematic review article
Reason 2: proceeding/conference/forum
Reason 3: book
Reason 4: paper

Table 1. Types of Articles

Types of Articles	Total
Bibliometric/systematic literature review	11
Proceeding/conference/forum	67
Book	3
Paper	11
Research article	41

This review contains articles of five different sorts. The article is an exception due to the following reasons: Books and papers that do not explain the STEM-PjBL research methods used are 1) bibliometric or systematic literature review articles that are not the result of direct research in the field, 2) proceedings or conferences or forums that are only like displaying research results and designs, 3) Books and papers do not explain the STEM-PjBL research methods used, and 4) non-English papers.

2.2 Data Analysis

The aspects that can be produced in line with the formulation of the presented problem are discovered after classifying journal articles that fit into the study category. Study techniques, subject matter, and educational level are all particular to coding. Table 2 displays the outcomes of the coding data representation.

Table 2. Reviewed Articles in the Present Study

Country	Level	Methods	Discipline	Results
Turkey	Elementary school teacher	Case study	STEM subject	Understanding STEM (practical integration of disciplines stimulates student innovation), instructional excellence (developing critical thinking

Country	Level	Methods	Discipline	Results
				abilities, literacy, communication, and attitudes), instructional prerequisites (building context-specific assessment tools), and educational context (improvement of learning environment, teaching materials, curriculum, and expert staff) (Aydin, 2020b)
US	High school	Case study	Mathematics and science	STEM-PBL learning is suitable for every grade level, and the application of 'real life application' makes students understand science and mathematics. (Craig & Marshall, 2019a)
Australia	Secondary teacher	Case study	STEM subject	Innovative pedagogy, scaffolding ability, and multi-dimensional assessment (Wilson, 2021)
Chile	Elementary school	Ethnography	STEM subject	Collaboration and active participation to promote socio-ecological resilience (Bascopé & Reiss, 2021)
Slovenia	Teacher of STEM subject	Mix methods	STEM subject	There are differences in the beliefs of science/mathematics teachers and engineering/technology teachers due to knowledge of different disciplines (Vidic Andreja & Drobnič Vidic, 2017)
Japan	Middle school	Descriptive research	STEM subject	There is a development of students' critical thinking in solving contextual problems (Mutakinati *et al.*, 2018).
US	Teacher of STEM subject	Phenomenological and ethnography	STEM subject	Project learning is driven by students' experience and interest in science and environmental issues (Jorgenson, S.N. 2014).
Indonesia	Junior high school teacher	Qualitative descriptive	STEM subject	Barriers to STEM implementation: assessment time management, parental support, and learning implementation preparation (Winagun, M.M. & Kurniawan, D. 2019).
Ukraine	Teacher of natural science	Qualitative methods	Robotic Education	Introduction to education robotics course enhances educational innovation at the scientific and

Country	Level	Methods	Discipline	Results
				technological levels (Kushnir, 2020).
Malaysia	Secondary Students	Content analysis	Robotic	There is an increase in the higher-order thinking of students (Hussin.H. *et al.,* 2019).
US	Guru SMP & SMA	Quasi-experimental	STEM subject	No significant change in teacher attitudes toward interdisciplinary learning, teamwork, teaching satisfaction, or resistance to change (Salami *et al.,* 2015).
US	Secondary school	Grounded theory and comparative analysis	Physic	STEM Student on the Stage (SOS) helps students improve their academic and 21st-century skills (Sahin, A & Top,N. 2015).
Israel	Junior high school	Mix methods	Robotic course	Robotics creates an excellent and engaging learning environment for STEM-based learning and increases students' interest in education (Barak,M. & Assal, M. 2016).
US	College student	Quasi-experimental	STEM subject	Project-based learning influences students' perceptions of STEM career skills, usability, and aspirations (Beier *et* al., 2018).
Taiwan	High school	Mix methods	STEM subject	i-STEM (imagination, science, technology, engineering, mathematics) enhances the learning and creativity of high school students (Tsai *et* al., 2018).
US	Teacher pre-service	Qualitative methods	STEM subject	C-STEM PjBL (community-STEM-based learning project) allows students and teachers to connect and think critically about problems that exist in their society, culture, or institution (Nava, I. & Park, J. 2021)
Thailand	College student	Case study	Technology	PBL and CBL (community-based learning) methods improve students' knowledge, practical skills, presentation skills, and social skills in science and Technology (Prainetr *et* al., 2018).

Country	Level	Methods	Discipline	Results
US	Teacher	Quantitative	STEM subject	STEM learning supports work interest in STEM fields (Havice *et al.,* 2018).
US	Middle and secondary teacher	Survey	STEM subject	Project-based learning and accurate data collection create STEM curriculum innovations. This has a positive impact on students' interest and motivation in STEM fields (Birney *et* al., 2021)
Malaysia	Secondary school	Mix method	STEM subject	There has been a significant improvement in 21st-century skills in digital literacy, innovation, communication, and spiritual values (Husin *et* al., 2016).
US	High school and graduate	Mix methods	Robotic	FIRST (for inspiration and recognition of science and technology) increases confidence and career choice in STEM domains. There is a substantial, significant, and positive correlation of interpersonal skills, career choices, family support, schooling, and external motivation for STEM success (Yoel & Dori. 2022).
Turkey	College student	Mix method	Chemistry	Improve academic achievement and reduce student misconceptions (Gunter & Alpat. 2013).
US	Secondary school	Quantitative methods	STEM subject	PBL's STEM-integrated curriculum affects mathematics academic achievement and improves communication and collaboration skills in the classroom (Han *et al.,* 2016).
US	Teacher	Case study	STEM subject	PD (professional development) is effective in communicating essential concepts of STEM PjBL (Han S. *et al.,* 2014).
US	High school	Quantitative methods	Engineering	Engineering design projects created in the Creative Engineering Design course enhance students' attitudes toward community service and efficacy through engineering skills (Zarske *et al.,* 2012)

Country	Level	Methods	Discipline	Results
Taiwan	College student	Mix methods	Engineering	STEM PjBL increases motivation, self-study efficacy, STEM learning pleasure, and knowledge of the usefulness of STEM in future career development, particularly in engineering (Kuo *et al.,* 2018).
Taiwan	High school	Mix methods	STEM subject	STEM-Imagination project-based learning can promote students' diverse abilities and increase their imagination in project activities (Lou *et al.,* 2014).
Spain	College Student	Qualitative methods	Computer	The use of GbPExplorer allows students to actively learn to understand theory in real-time with the integration of disciplines of several sciences (Sabate *et al.,* 2020).
Italy	Secondary school	Questionnaire	Robotics	Innovative learning, such as practical projects in STEM and robotics disciplines (Cesaretti *et al.,* 2017).
Malaysia	Middle school	Mix methods	Technology	The quality of classroom teaching and learning affects STEM success (Shahali *et al.,* 2018).
US	Elementary teachers	Mix methods	Technology	3D printing technology that explores engineering, technology, and science can spark student interest in STEM (Novak & Wisdom. 2018).
Taiwan	College student	Mix methods	Engineering and Technology	Students experience a significant change in attitude, realizing STEM plays a vital role in careers, and technology improves the efficiency of human life (Tseng *et al.,* 2013).
US	Middle and high school	Qualitative methods	STEM subject	Multisensory Technology and experiences help students with visual impairments get involved in STEM (Tsinajinie. 2020).
Spain	Teacher	Qualitative methods	Mathematics	Math teachers avoid transdisciplinary projects to deepen math in depth (Mantecon *et al.,* 2021).
US	Secondary school	Quantitative methods	STEM subject	PSB (problem-solving beliefs) results show that significantly positive PjBL STEM activities improve

Country	Level	Methods	Discipline	Results
				students' perceptions of maples and future STEM careers (Kwon *et al.*, 2021).
Indonesia	Secondary	RnD	Physic	STEM prototype-based teaching materials developed with project models enhance students' higher-order thinking skills (Ngadinem *et al.*, 2020).
Malaysia	Secondary	Quasi-experimental	STEM subject	There has been a positive change in interest in STEM careers and interest in STEM maples (Shahali *et al.*, 2017).
Taiwan	College student	Mix methods	Engineering	The operation of thinking design and the lack of critical thinking processes, as well as evaluation, are problems that are often faced by university units (Chan & Nagatomo. 2021),
Malaysia	High school student and teacher	Questionnaire	STEM subject	PBL's STEM adaptation curriculum has a positive impact on learning activities in the school environment and has the potential to increase multidisciplinary capacity and integrate technical and nontechnical skills (Tauro *et al.*, 2017).
Taiwan	High school	Mix methods	Technology	The application of 3D printing in STEM projects helps students elaborate on the concepts of modeling and feasibility analysis (Lin *et al.*, 2018).
Indonesia	Teachers' Junior high school	Mix methods	Biology	Integrasi projek STEM dalam lembar kerja digital meningkatkan pengetahuan konseptual dan pemikiran kritis siswa dalam subjek interdisiplinner (Widiyawati *et al.*, 2020).

3. RESULTS

3.1 Subject

The findings from the analysis of 41 articles are presented in Table 2, together with information on the nation, educational level, and critical ideas covered in each report. Utilizing STEM-PjBL, nine material ideas were constructed, covering math and science, robotics, STEM subjects, physics, chemistry, technology, engineering, computer science, and biology (see Figure 2). The most advanced research material notion is in the STEM fields. The idea of a STEM topic has to be clarified further in light of the analysis's findings. For example, C-STEM PjBL (Community focused STEM project based learning), i-STEM (imagination-Science, technology,

engineering, and mathematics), and others are examples of learning using STEM and PjBL approaches that are combined, modified, or integrated with an application, activity, or learning creativity developed by the researcher himself. Because of this, the name and description of other article content can be used to understand its meaning.

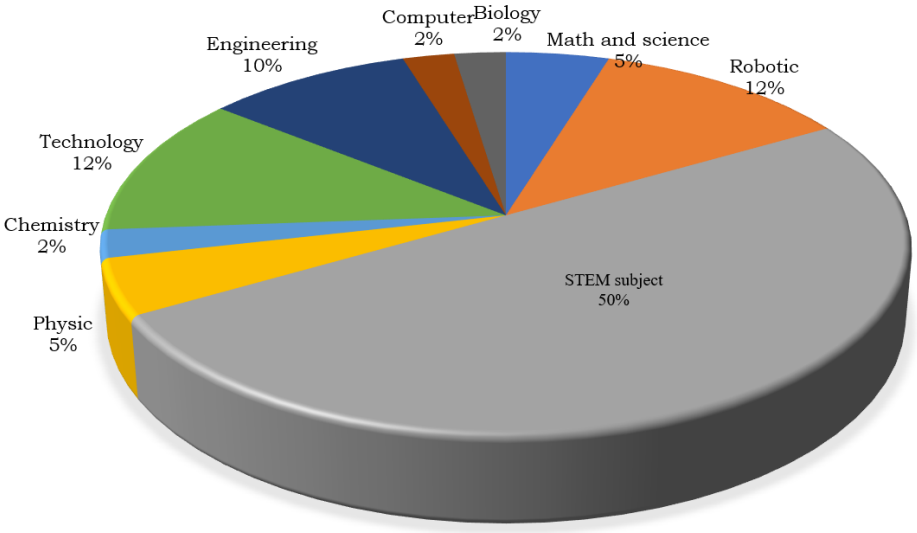

Figure 2. Percentage of Articles by Subject

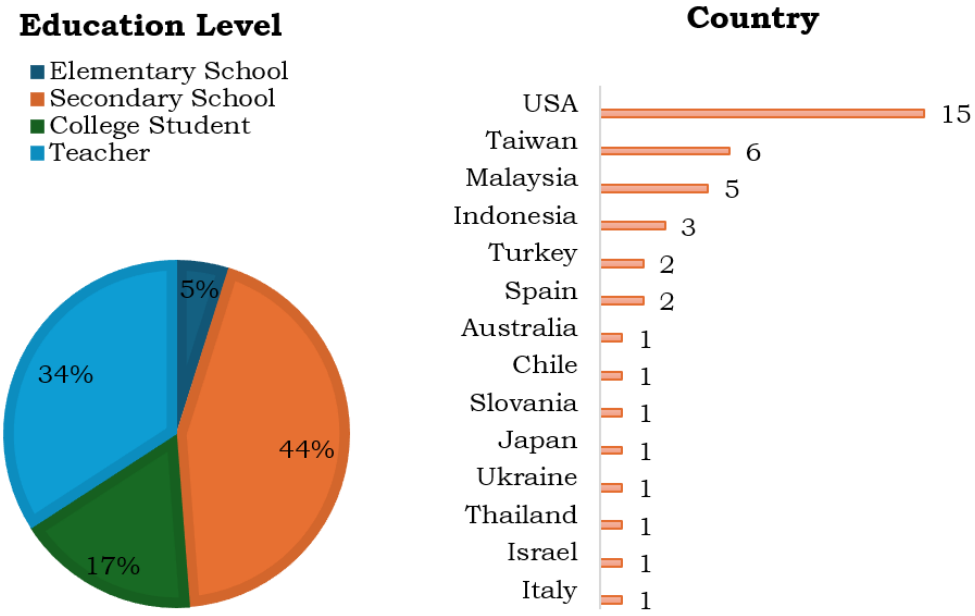

Figure 3. Percentage of Articles by Education Levels and countries

3.2 Country and Education Level

In the past ten years, STEM-PjBL has been studied the most in the United States. Taiwan, Malaysia, Spain, Italy, Turkey, Thailand, Israel, Ukraine, Japan, Slovenia, Chile, and Australia are some nations that have agreed to use STEM-PjBL (see Figure 3). The four groups of education levels include elementary school, high

school, university, and teacher occupations. Middle school, secondary school, or high school are some of the phrases used in the article that have been evaluated for the secondary school education level. The teacher education level is also included for elementary and secondary school instructors.

3.3 Publication and Methods

2018 was the most prolific year, with 9 STEM-PjBL research publications published. After 2020, 2021, 2017, 2019, 2016, 2014, 2015, 2013, 2022, and 2012, there will be a total of 7, 6, 4, 3, 3, 3, 2, 2, 1, and 1 articles published. Mixed qualitative and quantitative research approaches are used in the study.

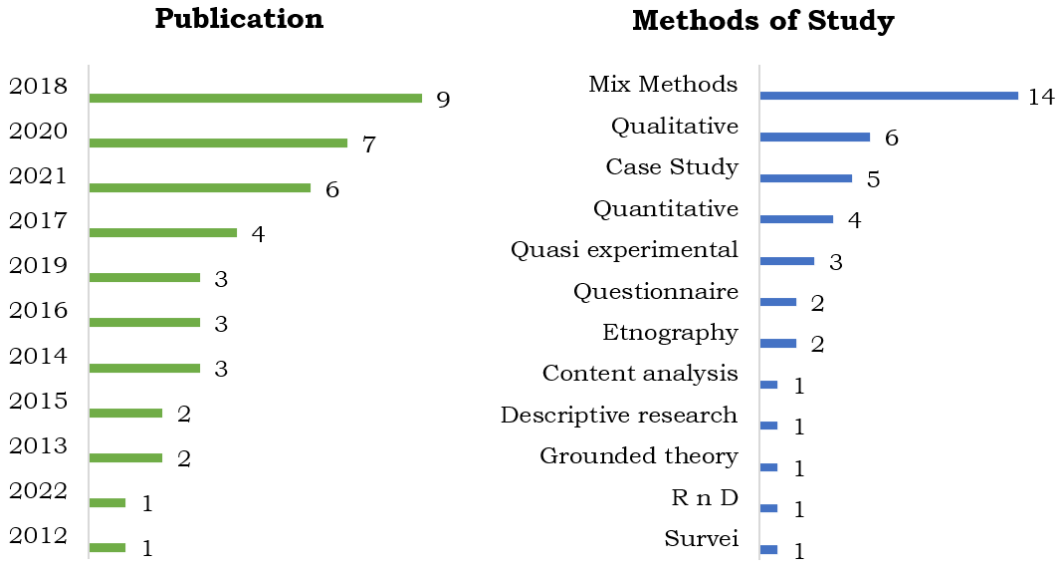

Figure 4. Publication and Study Method

4. DISCUSSION

4.1 Content

According to the review analysis's findings, STEM subjects are the ones that get the most discussion. A description of the STEM subject and other information is provided below.

4.1.1 STEM Subject

According to the findings, a STEM subject is an application of PjBL that combines, modifies, or incorporates STEM in research concepts and activities. The following is a description of the analysis's STEM subject.

1) The acronym i-STEM stands for imagination, science, technology, engineering, and mathematics learning (Tsai et al., 2018; Lou et al., 2014). In the learning process, this i-STEM paradigm blends STEM education with creative Education. Students' connections between real-world experiences and the six stages of STEM instruction—exploration, initiation, development, word alternatives, and presentation—define the idea of imagination and STEM.
2) C-STEM-PjBL is an acronym for community STEM project-based learning (Nava & Park, 2021). This material is designed for aspiring math and science instructors who will be working with students in the neighborhood so that they can really carry out assignments, reflections, and social-emotional learning activities.

3) The acronym BOP-CCERS refers to The Billion Oyster Project and Curriculum and Community Enterprise for Restoration Science (Birney et al., 2021). In order to collect accurate data through port restoration activities, the program uses project-based learning to involve students and instructors. Around the port, the coral reefs' rehabilitation is a subject connected to the STEM idea.
4) POPBL STEM stands for Project Oriented Problem-Based Learning STEM, also known as the BITARA STEM curriculum, in the study by Husin et al. (2016). Four intervention and activity modules are carried out using a STEM approach and project-based learning.
5) Outside of points 1-4, other articles, especially those in STEM fields, frequently utilize the term "STEM-PjBL." A project-based learning approach is used to teach STEM subjects.

4.1.2 Robotics

The robot idea investigated with STEM-PjBL uses the Simple & Power Machines kit, MBot, LEGO® Mindstorms, and Lego EV3 software (Hussin et al., 2019; Kushnir et al., 2020; Cesaretti et al., 2017). The notion of robots may be used to teach students how to operate robots, write programs, take measurements by varying parameters, show findings in tables and drawings, determine the robot's speed, and more. Robotics projects empower students to take ownership of their actions, create using physics and math principles, engage in programming activities, and deal with the documentation and presentation of outcomes. Robot learning initiatives are non-formal and multidisciplinary and integrate STEM knowledge alongside other subjects, including physics, computers, science, and technology. Robot education is a crucial element of contemporary society, embodied in the intellectual development of personality, particularly in the development of students' capacity for logical, algorithmic, and creative problem-solving, information culture, memory, attention, and scientific intuition.

Robotics offers a variety of teaching opportunities for STEM ideas, enhancing and completing but not replacing the function of science and math principles.

4.1.3 Technology

Electrical Technology, 3D printing technology, intelligent wireless communication, WiFi, and digital technology are some of the technological ideas covered in class (Prainetr et al., 2018; Shahali et al., 2018; Novak & Wisdom. 2018; Tseng et al., 2013; Lin et al., 2018). Technology enhances technological literacy, affecting instruction effectiveness and the instructors' confidence.

4.1.4 Engineering

Engineering research focuses on (1) Human-Computer Interaction (HCI), which includes methods for bettering target user comprehension, enhancing product ergonomics and aesthetics, and creating service-oriented product designs (Kuo et al., 2018), (2) Ingenious Engineering, (3) Multi-function electric vehicle explores mechanical engineering (Tseng et al., 2013); (4) Design-based task of creating and developing prototypes of things in the surrounding environment (Chan & Nagatomo, 2021).

4.1.5 Mathematics and Science

The concepts of mathematics and science are as follows: (1) mathematics: functional relationship, properties and attributes of function, linear function, linear equation and inequalities, quadratic and other nonlinear function, geometric and

spatial reasoning, 2D and 3D representation, measurement, percent, proportion, probability, statistic, mathematical processes, and tools; science concepts: nature of science, organization of living systems, the interdependence of organisms, structure (2) Mathematical use and theory (Mantecon et al., 2021).

4.1.6 Physics

Newton's third law and the rule of conservation of momentum are used in physics (Ngadinem et al., 2020); the Bernoulli principle is second (Sahin & Top, 2015). Ship prototypes are used to study STEM-PjBL physics.

4.1.7 Chemistry

Electrochemistry is a chemical concept (Gunter & Alpat, 2013). Through case studies of various activities created by researchers in which students use electrochemical ideas to conduct investigations to discover solutions to a situation, STEM-PjBL is investigated.

4.1.8 Biology

Bioacoustics is a biological concept (Widiyawati et al., 2020). STEM-PjBL Students studying bioacoustics respond to inquiries regarding vibration, living things, and airwaves in electronic books.

4.1.9 Computer

Graph-based Problem Explorer (GbPExplorer) is a computational notion (Sabate et al., 2020). Computers help students and teachers become better programmers.

4.2 Country and Education Level

The country that adopted STEM and PjBL-based learning the most was the United States. This may be because, according to the OECD (2012), the United States is placed 27th out of 34 nations in terms of developing new businesses, industries, and ideas in the STEM sectors to support economic development and stability. Reforms are being considered for this circumstance to equally implement the STEM approach throughout all educational levels (Craig & Marshall, 2019b). By registering its development program with the independent educational organization National Science Foundation (NSF) and undergoing ongoing monitoring, the US government is genuinely implementing STEM instruction in schools (Havice et al., 2018). The growing number of people working in STEM disciplines, together with the number of graduate students pursuing STEM as their area of study, is proof of the effectiveness of the STEM strategy. According to Carnevale et al. (2011), the expected 10% growth in employment between 2008 and 2018 from 148 million to 162 million caused the US GDP to grow by 17%. The American Community and Current Population survey data from the US Census Bureau indicate that the STEM workforce is expanding and will soon dominate American economic development (Langdon et al., 2011).

The analysis's findings indicated that, with a percentage of 46%, high school students applied STEM PjBL the most frequently, followed by teachers with a ratio of 32%, students in higher Education with a proportion of 17%, and students in primary schools with a ratio of 5%. The topic or features of the curriculum utilized may be used to understand the connection between the utilization of STEM-PjBL and the degree of Education in secondary schools. In Craig and Marshall (2019b), samples were chosen based on their ability to participate in STEM projects with their parent's permission and their aptitude for science and math. Pengaplikasian STEM-

PjBL dikurikulum sekolah menengah sudah terkhusus pada Compared to primary schools, which focus more broadly on a single science, more specialized fields. Cesaretti et al. (2017) emphasized that high school reform needs to set up coherent and adaptable governance for vocational schools to guarantee that students can adjust to society's demands and the quickly changing economic consequences via learning that prioritizes skill development. Higher education programs and the future of student work benefit from the secondary education students get. Therefore, STEM is anticipated to boost students' interest in their future occupations to cultivate attitudes and raise metacognitive awareness of the learning experiences produced by high schools through the project learning model. In addition to helping students develop their critical, creative, collaborative, and communication abilities, STEM is also anticipated to help high school students build their 21st-century competencies. It also allows kids to develop higher-order thinking skills (HOTS) (Ngadinem et al., 2020). According to Kwon et al. (2021), the lack of STEM workers hindering the realization of the production of high-tech glass, semiconductors, and photovoltaic cells in North American nations, is evidence that schools must become present in the STEM-related job market to compete in the global economy. Essentially, the application of STEM-PjBL at the secondary school level intends to train students to be ready for the world of work in STEM sectors to boost the nation's economy, based on numerous of the reasons listed above and via the analysis's findings.

One of the essential factors in research on the use of STEM-PjBL in Education is the teachers' education level. Teachers themselves play a key role in the implementation of STEM-PjBL in classrooms. Educators must develop lesson plans, make assessment materials, carry out assessments, and evaluate the outcomes and outputs of STEM projects. It is imperative to build assessment tools since insufficient ones will make it impossible to gauge students' comprehension of STEM applications (Tauro et al., 2017). To incorporate PjBL learning into the contextual notion that occurs in real life, teachers also need to look for ideas and issues from everyday life. Based on the learner's background, prior knowledge, and experience with the topic to be applied, authentic questions that trigger a high-level understanding of ideas are developed. Teachers must prepare for STEM-PjBL in various ways, but the fundamental need is to understand the ideas and keep up with the most recent content theory. Collaboration enhances teachers' communication and cooperation abilities (Aydin, 2020a). Teachers must practice a lot, especially in science, to combine many disciplines, which is problematic. By collaborating and communicating as a team, teachers may overcome challenges in imparting STEM knowledge in the classroom.

4.3 Publication Year and Methods

168 papers mention STEM-PjBL, according to an examination of reviews from 2007 to 2022. 133 publications may be downloaded, some of which are books, conferences, reports, and other things rather than research articles (see Table 1). The release of peer-reviewed research publications was postponed from 2012 to 2022. Within a decade, investigations on STEM-PjBL were regularly published in journals with a Scopus index. 2018 (9) had the most STEM-PjBL articles published, followed by 2020 (7) and 2021. (6). Over the past three years, several STEM concepts and disciplines in engineering, robotics, and technology have been investigated. This is supported by the publication of the results of studies on the stem, and PjBL indexed by the most influential Scopus from 2016 to 2020 (Conde et al., 2021; Yunita et al., 2021).

Regarding the approach, each article has a distinct personality and goal; thus, to make the task easier, an analysis is done based on each article's research methodology. According to the findings that have already been provided, twelve different study methodology types have been employed. The paradigm divides the twelve research approaches into mixed, quantitative, and qualitative methods. Surveys, quasi-experimental, descriptive research, research and development (RnD), content analysis, questionnaire, and quantitative methodologies are all covered in this category. Case studies, grounded theory, and ethnography are also a part of the qualitative technique. The following is a description of each methodology's data-gathering methods:

4.3.1 Mixed Methods

An overview of the entire article reveals a mixed approach to gathering data, using both qualitative techniques such as open-ended and semi-structured interviews, observation sheets, documents in the form of photos, discussion results, and reflection journals, as well as quantitative methods such as questionnaires, t-tests, surveys, pre-post surveys, and quasi-experimental (pre-post-tests). Due to the advantages of complex data, which increase the study's accuracy, this approach has been developed the most. The initial data are statistically analyzed using quantitative methods, and the interpretation of the data and support for the study's findings are deepened using qualitative approaches.

4.3.2 Quantitative Methods

Articles that include motivational surveys as part of their survey technique. Articles employing surveys and questionnaires as part of a quasi-experimental technique Worksheets and observation logs are used in the descriptive research process. The R n D technique involves product validation forms and surveys. A pre-testing and post-testing content analysis approach. Additionally, the quantitative method using survey forms and pre-post testing is used. Surveys used the Likert scale, and average quantitative analysis (pre-post test, questionnaire) used ANOVA.

4.3.3 Qualitative Methods

Data gathering strategies for case study articles include journal notes (researchers' diaries and research samples), workbooks, performance sheets, evaluation rubrics, thematic analysis, Nvivo 10 soft analysis, and interviews. Using interviews and observation logs to develop a grounded theory. Using semi-structural interviews, fieldwork, artifact collections from the classroom, and other ethnographic techniques.

4.4 What Conclusions Did the Research on the Impact of the STEM-PjBL Strategy on Learning?

According to the research, learning goals with a STEM approach have always been connected to 21st-century skills, active learning, and student-centeredness. Computer science, engineering, technology, and artificial intelligence are STEM fields related to 21st-century capabilities. Through problem-based models or methods and inquiry, which in this study is referred to as project-based learning, active learning and student-centered learning are implemented. PjBL is compared as a motivating factor for achieving STEM learning objectives where the design of the instructional process is described in depth. Doing projects requires staff and specialist trainers from other disciplines, in addition to educators' thoughts and student needs, to carry out maps and learning objectives in keeping with educational institutions' goals. The selection of project kinds that suit the learning subject can help schools link STEM-

based Education, despite its challenging and crucial nature (Bascope & Reiss, 2021). Activities may be created using anything about the student's cultural background, interest in STEM, and environmental challenges (Vidic Andreja & Drobnič Vidic, 2017). Faculty-designed STEM-PjBL projects are experiential and purposefully related to current events and potential futures in the hopes that students would find them fascinating and relevant. However, in particular studies, only a small number of students can complete new topic assignments independently. Therefore, it is necessary to employ hands-on learning to help students develop knowledge and abilities before they can handle challenging projects. Educators and specialists must also create more applicable and practical lessons and consider which critical skills will be helpful in different 21st-century job domains. The capacity to compete in a new era is built through STEM literacy, which can only be developed through the impact of schools, communities, and international businesses (Hussin et al., 2019). The findings of the analysis show that an average study spends a minimum of three months and a maximum of 1.5 years on developing a mature plan and duration, from planning activities to analyzing the results following STEM project activities. Therefore, it is anticipated that choosing a topic and developing a mature strategy will be essential at the start of the learning period (Aydin, 2020). The findings of a study (Winagun & Kurniawan, 2019) found that funding restrictions, unsupportive school systems and facilities, poor time management, low collaboration, lack of support, unstable preparation, and ignorance of STEM learning are barriers to implementing STEM in schools support this..

PBL also allows students to be creative and active in their learning. The actual quality of PjBL is its primary attribute. Learners' opinions of their STEM skills and the value of STEM are influenced by authentic experiences and PjBL, which strengthen their enthusiasm for careers in STEM disciplines. Students that have gotten familiar with STEM during their Education have more varied job alternatives (Beier et al., 2018). Student centers and genuine learning opportunities allow learners to see an overview of the field of work and what tasks are in the field of natural knowledge and engineering. Students are involved in addressing actual issues. However, in practice, STEM and PjBL learning may not always yield anticipated results. The trial-and-error approach can be used as an alternative to finding a solution when technology reacts unexpectedly. Although studying with the project demands students to accept responsibility for their actions, it is intended that after engaging in a STEM technology project, kids would desire to understand the topic of technology in depth. The study's findings (Wilson, 2020) reveal a rise in cognitive domains in learning, thinking, discussing, exploring, solving issues, generating ideas, designing, asking questions, and comprehending mathematics, science, and technology. STEM equips students with academic and 21st-century abilities and impacts their social behavior and attitudes toward health, the environment, and Sustainable Development Goals (SDGs) (Chan & Nagatomo, 2021). Personal (interest, curiosity, inventiveness, usefulness, and self-efficacy) and social (teamwork, cooperation, parent and family participation), as well as an attitude toward technology, are examples of the emotional domain (innovation, instrumentation, life needs, and future aspirations). Students are instructed orally to grasp things slowly, but they understand things rapidly if they study and practice. STEM learning outcomes also improve critical thinking, creativity, and long-term learning.

5. CONCLUSIONS

Review analysis reveals that STEM-PjBL studies are still often conducted at the elementary, high school, college, and teacher education levels in one decade (2012-2022). Mixed research methodologies are frequently used in studies, including quantitative ways to demonstrate the development of literary elements and qualitative methods to investigate the efficacy of learning on altering the attitudes of students who have used STEM PjBL. High school education is the most frequently discussed level, emphasizing the need to improve high school students' interest in careers in STEM disciplines. Another common topic is the investigation of instructors' mastery and skill in implementing and developing PjBL STEM. The successful integration of STEM PjBL in academic units is significantly influenced by preparation, professional assistance, and extracurricular activities. The analysis's findings demonstrate that STEM PjBL has successfully fostered active learning, student-centered learning, and the 21st-century abilities of creativity, collaboration, problem-solving, innovation, use of technology, and higher-level thinking. The most commonly researched idea in Education is STEM Subject, which is the incorporation of STEM PjBL into activities. The country with the most PjBL STEM learning implementations was the United States. To raise students' interest in STEM PjBL, where mastery of technology and engineering sectors has the potential to enhance the nation's economy, more STEM PjBL will hopefully be produced.

Conflict of Interest

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