



Project-Based Learning Methodology as a Promoter of Learning Math Concepts: A Scoping Review

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The scoping review represents an important step toward constructing scientific knowledge on a topic in a sustained and integrated manner. Therefore, this article contemplates a scoping review of the resource on project-based learning (PBL) in learning math concepts. This research resulted in 17 studies that were reviewed to establish connections between PBL and its potential to promote understanding of math concepts. All articles were collected in scientific journals subject to blind review available on open research online, identified as empirical studies. The research was organized around three central themes: math, PBL, and ICT technologies. Data analysis allowed the building of a model in which the empirical data on PBL in learning math concepts in terms of (i) the learning environment, (ii) the mathematic content, (iii) the process, and (iv) the student skills. The potential results suggest that PBL engages students in math learning environments. PBL must be understood as a learning strategy to develop hard and soft skills related to mathematics. There is also evidence that PBL improves the integration of math concepts in a natural context, promotes differentiated teaching and enhances the student-centered logic in math education. Moreover, the retained partial results in the analysis showed the feasibility of this scoping review, thus providing a basis for developing a scoping review. The presented review can work as a guide for other scoping reviews and a model for reflecting on future action on the covered topics.

Keywords: project-based learning, scoping review, math concepts, technology-enhanced learning (TEL), math learning

INTRODUCTION

In a society with a constant process of change, the use of technology and the internet have taken on an increasingly important role in teachers' daily routines (Cruz, 2019). This reality leads teachers to resort to artifacts that not always integrate into their teaching strategies, such as online communication platforms. Many of these artifacts reversed the asymmetries previously present in the classroom. The centrality of the teacher's authority in processing content gives students a more comfortable position, which has to do with their greater adaptability to technological evolution. Do not forget that today's students belong to a generation that was born in a digital, connected, mobile environment and have never seen the world without the internet (Prensky, 2009). Students are used to connecting to the internet to communicate, share information and socialize through

mobile devices, which they use daily. Students live spontaneously in a network and use a language based on emojis to communicate (Ribeiro et al., 2016; Lopes, 2020).

Teaching with technology allows new modalities of work practices, focusing the teaching process on learning, allowing students to have greater control of the time and pace of study, and allowing them to create individualized learning adjusted to their needs (Cruz, 2019). It enhances pedagogical innovation and the renewal of teaching and learning spaces, so analyzing these learning spaces is essential (Baeta and Pedro, 2018). In terms of acquiring knowledge in mathematics, digital technologies, and active methods such as learning through projects, the inverted classroom, among others, can make an essential contribution to transforming the way they are teaching the subjects and, at the same time, enabling an improvement in learning (Cruz, 2019).

The scoping review (SR) is one method amongst many that might be used to review literature. A technique to “map” relevant literature in the field of interest (Arksey and O’Malley, 2005). The scoping review allows information about selected bibliographic references based on a given subject. A systematic method allows for obtaining empirical transparent and structured data (Gough et al., 2012). Furthermore, it will enable systematic filtering of documents, namely empirical studies, and a quality assessment to obtain answers to the premises of an investigation (Gough et al., 2012).

A SR can aim to quickly map the main concepts that underpin an area of research and the main sources and types of evidence available (Mays et al., 2001). The SR is a method of the publication and dissemination of research findings in a particular field of enquiry, is part of an ongoing process of reviewing, the ultimate aim of which is to produce a full systematic review (Arksey and O’Malley, 2005). This way, the SR aim to map the key concepts underpinning a research area and the main sources and types of evidence available (Mays et al., 2001). Thus, unpublished information, coincident or contradictory data and important conclusions for future investigations may emerge.

This article begins with an overview of the method for scoping review, including a description of the options for inclusion/exclusion of documents for analysis. Next, we include the results of the review stages carried out so far, presenting some theoretical results, inferences about the work carried out and recommendations for future research. This article is part of an ongoing investigation. It presents a SR that aims to evaluate, synthesize and present empirical data on project-based learning (PBL) in learning math concepts. Due to its cognitive nature, research is assumed as an objective, and adjustable process that allows to understand a situation (Coutinho, 2014). In this line of thought, the SR allows transmitting information about bibliographic references selected based on a specific subject. In a SR, the researcher develops a regulated research and literature analysis practice accompanied by reflection in a permanent training and updating perspective. The studies in a SR guide the development of research projects. The direct research synthesizes information from studies relevant to that topic or an issue under investigation (Rocha et al., 2010). It is thus assumed as a method of assigning answers to the premises of a study where there is the possibility of filtering documents, namely empirical studies and

making a quality assessment (Gough et al., 2012). As we intend to contribute to the creation in the reader of an overview of the topics covered, SR legitimizes the need to identify relationships, looking for forms of causal interpretation appropriate to the contextual situation. Thus, we designed this literature review to delimit the topics to be addressed and increase the degree of understanding of the investigations carried out on these themes, placing these themes in a historical and relational perspective.

This article is structured in five sections: in section “Methods,” we introduce an overview of the SR method used, including a description of the options for inclusion/exclusion of documents for analysis, the data organization, the constitution of the documentary corpus and the quality assessment. Section “Results” presents our main results, then section “Discussion” presents our lessons about the work developed and reflections. Finally, we conclude in section “Conclusion” with a synthesis and proposals for future work.

METHODS

The choice for the theoretical framework was the scoping review proposed by Arksey and O’Malley (2005): the scientific rigor of the document, being current, using only the results that are significant for the investigation, ensuring accountability in document reviews, in the editorial processes, and methodological systems described. We used a SR process divided into four stages in which we eliminated some documents according to the following specific criteria:

- i. Identify keyword sequences in the databases.
- ii. Exclude repeated articles and articles that do not have an abstract or keyword.
- iii. Exclude articles by analyzing the titles.
- iv. Exclude articles through analysis of abstracts.

In the research strategy, keywords were defined and a search was carried out in digital databases. In selecting sources, it was defined that the articles would be available on the web in one of the chosen databases. We decided to use search engines through keyword sequences to guarantee unique results for the same set of keywords. We use the following databases: ACM Digital library, SCOPUS, Web of Science and Science Direct. This search in electronic databases is an essential strategy in implementing a SR as it maximizes the possibility of finding relevant articles in a reduced time (Sampaio and Mancini, 2007).

In our work, we relied on Boland (2013) approach, which consists of a nine-step SR process, but we implement some adaptations according to these studies. With this SR, we intend to establish connections between PBL and its potential to promote understanding of math concepts. So, in the research, we used the following keywords that we considered relevant: learning mathematics, PBL and math concepts. The systematic search sequence was built from the combinations made with these keywords. The keywords were combined using the Boolean operator “and,” which implies that an article obtained in this search must include the two terms involved in the sequences.

We selected documents with full text and freely available in scientific journals. In the refinement of the search, we filtered all documents whose language was English, whose words were in the title, abstract or keywords, and we only searched for publications in journals between 2016 and 2022. The end of the various stages of our SR of the literature resulted in 17 documents that were analyzed and constituted our documentary corpus.

We structured our SR according to the following steps: (i) formulate a research question, (ii) produce a research protocol, (iii) define inclusion and exclusion criteria, (iv) develop a strategy of research, (v) select documents, (vi) evaluate the quality of studies through the Critical Appraisal Skills Program (2018) checklist, (vii) extract the data, (viii) synthesis of the data and assessment of the quality of the evidence and (ix) dissemination of results through the writing of this article.

Research Question

The general concern of this research regards the relationship of PBL (Ralph, 2016) with math learning environments. With this research work, we intend to establish connections between PBL and its potential to promote understanding of math concepts. So, the question that guided this work of scoping review was: Can the PBL pedagogical strategy engage students in mathematics learning environments? From this question, the study's objectives were outlined to obtain results.

Following Gough et al. (2012) guidelines, based on our research question, we defined a research protocol. The research protocol contains a description of how studies are reached, the relevant studies' judgment regarding their usefulness in addressing the research question, and how the results will be aligned throughout the SR (Monteiro et al., 2016).

Inclusion and Exclusion Criteria

The selected articles followed the principles presented below regarding the inclusion and exclusion criteria (Boland et al., 2017). We admitted in the review articles that presented empirical data on math, PBL, and ICT technologies in research published between 2016 and 2022. There has been some epistemological discussion regarding what is usually called the focus of a qualitative and quantitative approach in an investigation (Coutinho, 2014). Educational investigations are disciplined research using both quantitative and qualitative methods (McMillan and Schumacher, 1997), so in our analysis, we chose to include articles with both quantitative and qualitative approaches.

We considered the following inclusion criteria: articles available on the web at the ACM Digital library, at SCOPUS, and at the Web of Science and Science Direct. With search engines using keywords, the keywords are introduced in English, are included in scientific journals with free access to the full content and are available in PDF format.

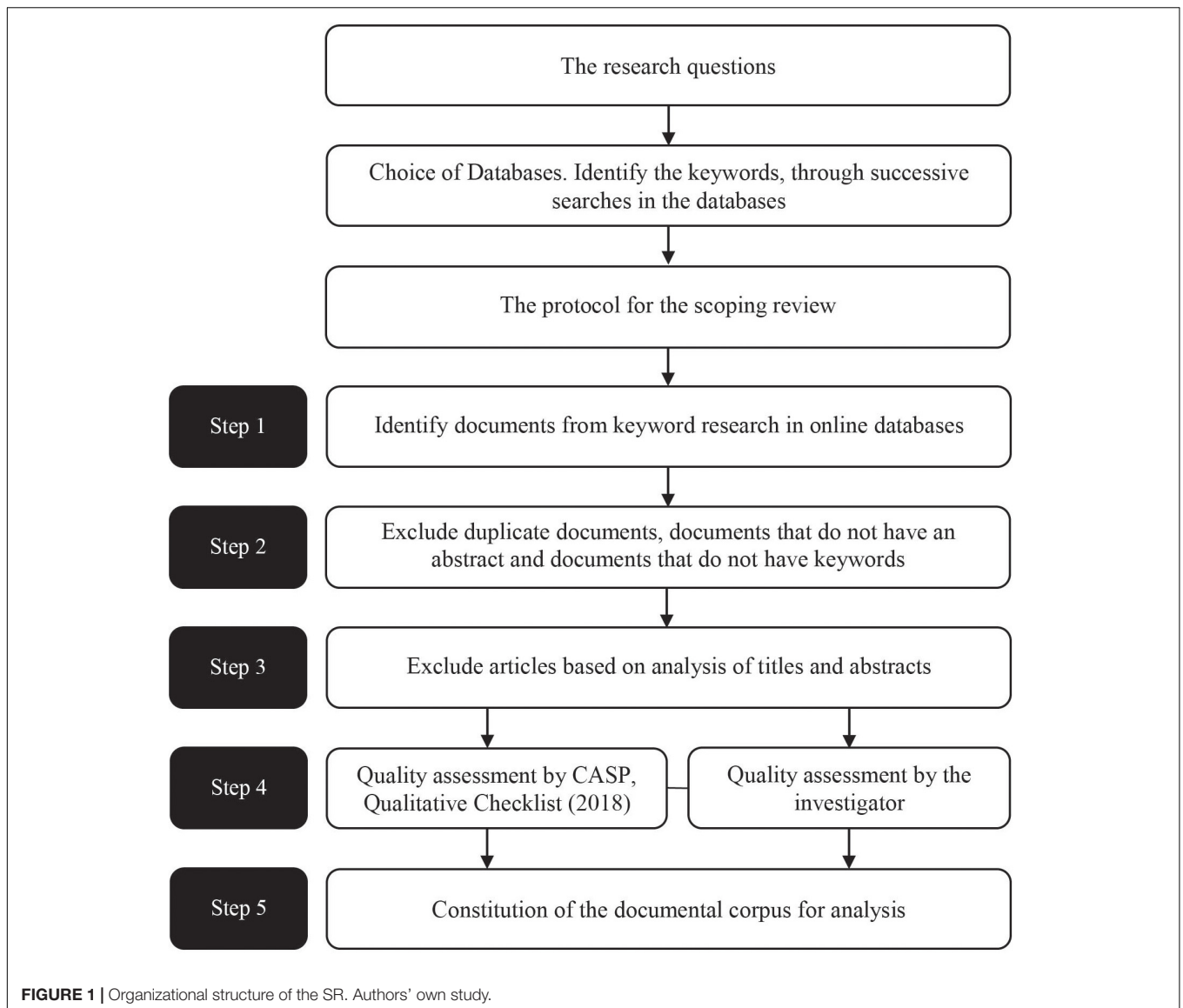
We considered exclusion criteria: being an abstract of articles, undefined articles, being an article still under analysis, being documents of an editorial type, being in a format other than PDF or not having the full text of the paper available. It was mandatory that selected articles had been submitted to peer review procedures. All studies that make up the synthesis of

this work were located through a solid search of databases considered in the study. All articles that did not have keywords were excluded, all repeated articles, because they were sometimes found by searching for different word sequences. Such a stage guaranteed the elimination of duplicates.

From the analysis of the articles' titles, we included and excluded documents with relevance to the themes of this SR. From the analysis of the abstracts of the papers, we excluded articles whose focus is not on math, PBL, and ICT technologies. There was at first an initial search. Later the articles were submitted to the defined inclusion and exclusion criteria. Then, we also proceed to the screening by evaluating the quality of the materials with the application of the Critical Appraisal Competency Program Qualitative Checklist (CASP) (2018). **Figure 1** presents the various steps performed in the SR process.

Data Organization

Through a search in the databases, we selected three keywords: learning mathematics, PBL, and math concepts. In the first stage with the keywords, we create sequences of words and search all the sequences of terms established in the databases used. The relevant citations were organized using EndNote and then exported to EXCEL. The created EXCEL file registered the date, the title, the authors, and the journal of publication. Also, we noted the summary of the written articles, and filters were added to facilitate the analysis of these points. After organizing the records, in the second stage, we marked all articles that did not present keywords, all those that did not present an abstract and all those that did not present an abstract and keywords. At this stage, we exclude all repeated articles and similar documents found in the search with different word sequences, leaving only the first record found for our analysis in the next stage. In the EXCEL file, we created a column space called "stage of exclusion," and each of the articles excluded in this step was marked as "second stage." Based on the information contained in EXCEL, in the third stage, we excluded articles by analyzing their titles and abstracts. All articles whose titles or abstracts did not seem to be related to the subject of our literature review were excluded and marked as "third stage" in the EXCEL file. In step 4, the documents not excluded in the two previous stages were subject to a quality assessment through the Critical Appraisal Skills Program (CASP) Qualitative Checklist (2018). In this step, we create a new sheet in the EXCEL file used in the previous actions and list the CASP (2018) parameters per line and the articles not excluded so far per column to allow the analysis. Articles not excluded in the fourth stage of the SR process were kept. With the support of the Taguette software, we categorized the information from each of the articles chosen according to our objectives for this research. A comprehensive reading of each piece was then performed, leading to a final selection of eleven documents. The relevant information of each paper was exported to EXCEL and later analyzed in the discussion topic. To implement the quality assessment stage, we adapted the Critical Appraisal Competency Program Qualitative Checklist (CASP) (2018). For this stage, we built an Excel spreadsheet with all parameters listed in CASP (2018) generated, including a column for each article and the material examined.



Constitution of the Documentary Corpus

In the first stage, through the search of word sequences, we obtained citations (4,679), organized in EndNote and then in an EXCEL file where we collected and recorded the publication date, title for each document, authors, journal of publication and abstract. Through filters created in the EXCEL file, in the second stage, we excluded repeated articles and articles that did not have keywords or abstracts (773). With filters created in the EXCEL file, in the second stage, repeated articles and articles that did not have keywords or abstracts were excluded. Then, in the third stage, we excluded articles whose titles or abstracts did not seem to be related to our study's subject, whose focus was not learning mathematics, PBL, and math concepts (152). In the fourth stage, we analyze the quality of all documents not excluded in the previous steps.

The documents were evaluated through the CASP checklist (2018), a tool used in the methodological quality assessment of

scoping reviews. It consists of a list with ten questions divided into three sections: (i) are the results of the review valid, (ii) what are the results and (iii) will the results help me locally.

We tried to assess the accuracy, credibility, and relevance of the chosen documents for our study by applying these criteria. At the end of stage 4, we obtained 17 papers. The articles obtained at the end of the fourth stage contributed to our scoping review's documentary corpus in step 5 from our SR.

Quality Assessment

All included articles were evaluated using a checklist (CASP, 2018) based on ten questions that help diagnose the studies' quality. These checklists were designed to be used as educational pedagogic tools, and assessment of study results validity; an evaluation of the continuity of the study; an assessment of methodological quality and presentation of results; an assessment of results of the investigation. One reviewer assessed each article

independently, and two more researchers reviewed the results. To maintain reliability, any differences in the score were settled through discussion.

RESULTS

The bibliographic review that formed the basis of this article began with a survey of all articles obtained by searching the word sequences learning Mathematics, PBL and math concepts in the digital databases Science Direct, SCOPUS, Web of Science, and ACM Digital library. In the first phase, based on the word sequences, we identified the journal articles available in open access in the databases, the year of publication, the article's title, journal where it was published, abstract, and keywords mentioned in the document. Then, these data were organized in an EXCEL file to allow further analysis. This phase resulted in 4,679 papers. In the second phase, all duplicate documents, all documents that do not have an abstract and documents that do not have keywords were excluded clearly and objectively, thus proceeding to the next phase 773 articles. In the third phase, we analyze all the titles and summaries of the documents gathered in the previous phase to assess their relevance to the topics covered in our SR. All titles unrelated to learning mathematics, PBL, or teaching and learning math concepts were excluded. All the articles' titles that raised doubts about their framing in the topics covered in our SR were included in the next phase of the analysis. From the third phase, 152 articles continued to the next phase. In the fourth phase, the quality of the articles was analyzed. From the third phase, 152 articles continued to the next step. In the fourth phase, the quality of the articles was analyzed. At the end of the exclusion phases, we obtained 17 articles that constituted our documentary corpus. In **Table 1**, we present the distribution of the documents collected by the various stages of exclusion and inclusion:

One of the interesting results of this SR is the amount of work developed in Indonesia, which looks pretty enthusiastic about the PBL methodological approach applied to mathematics concepts. Most of the studies support their research on empirical data, with many quantitative studies and practical training on the subject.

The method used in an investigation describes the way in which all the methodological procedures of the investigation were conducted (Thomas and Harden, 2008). Analyzing the articles and grouping them according to the methodological research strategies adopted: exploratory, descriptive and experimental.

The years 2021–2022 had more evidence of the number of publications of quantitative studies (**Graph 1**).

Table 2 organizes the descriptive data of the articles analyzed, providing information about the title and study's objective. The results presented corroborate the notion that the pedagogical methodology of project learning promotes learning in different domains, particularly in mathematics and at the most varied ages. Learning by the project is a topic already addressed in most continents (**Graph 2**). The highest incidence of publications is found in America—United States, Mexico, Costa Rica and Canada between 2018 and 2019. There is also a significant incidence in Oceania—Indonesia between 2020 and 2021.

DISCUSSION

The analysis of different approaches in empirical studies constitutes an understanding of the existing theoretical construction and its development (Cruz et al., 2014). The results of the study show that some studies have revealed a particular interest in the processes in the PBL environment (Hsu and Shiue, 2017; Bosica et al., 2021), the mathematic content (Siswono et al., 2018; He et al., 2021; Johar, 2021; Kholid et al., 2022), the process (Giaffredo et al., 2017; Choi et al., 2019) and the student skills, in particular interdisciplinary skills (Bakermans and Plotke, 2018; Sarwi et al., 2021). Several of these studies report that using active learning methods jointly with technology can be beneficial to add engagement to the teaching and learning processes. The PBL instructional practice is not only an outcome of teacher self-efficacy, as generally perceived, but can also cause changes in teacher self-efficacy (Choi et al., 2019).

The integration of PBL with science learning needs to be explored for students to develop higher-order thinking skills (Widiyawati et al., 2020). PBL structured teaching environment accentuates one's ownership of learning, provides a purposeful collaborative structure to learning together, uses authentic problems of practice, enhances the engagement in and acquisition of learning goals and improves cognitive and affective outcomes (Bosica et al., 2021). In addition, PBL led to more positive educational experiences among students, which led to increases in teacher self-efficacy (Choi et al., 2019). Nylén and Isomöttönen (2017) promoted the teaching intervention based on Flanagan's Critical Incident Technique (CIT) during a project-based software development course. With this intervention, the authors aimed to increase student's awareness of their learning and encourage reflective practice throughout the project. The results indicate that the project approach creates a learning environment that promotes reflection on education and positively affects students' awareness of their professional knowledge. Lara and Quesada (2019), in his study, carried out a learning experience based on PBL, a project that enables student motivation, and sustained inquiry. In this learning experience, students face authentic and motivating problems requiring them to answer complex questions and develop success skills. The results of these authors show that students were highly motivated and capable of identifying which skills they needed improvement.

TABLE 1 | Number of articles analyzed in each stage.

Database	1st stage	2nd stage	3rd stage	4th stage
Science direct	208	95	28	4
SCOPUS	4,163	479	65	4
Web of science	46	17	14	4
ACM digital library	262	182	45	5
Total	4,679	773	152	17

Authors' own study (2022).

TABLE 2 | Descriptive data.

Short citation	Title	Purpose
Han et al. (2016)	How science, technology, engineering, and mathematics project based	To investigate how STEM project-based learning affected high-need students in the United States in terms of their academic.
Nylén and Isomöttönen (2017)	Exploring the critical incident technique to encourage reflection during PBL	Explores a teaching intervention based on Flanagan's Critical Incident Technique during a project-based software development course.
Hsu and Shiue (2017)	Exploring the Influence of Using Collaborative Tools on the Community of Inquiry in an Interdisciplinary project-based learning context	Explore the relationships among three presences, namely cognitive presence, social presence and teaching presence in a community of inquiry framework in the context of interdisciplinary project-based learning through technology.
Giaffredo et al. (2017)	From the project-based learning method toward the competence-based approach to education	To find active ways to support the adoption of the competence-based approach in the Italian secondary schools.
Bakermans and Plotke (2018)	Assessing information literacy instruction in interdisciplinary first year project-based courses with STEM students	To Assess the changes in student perceptions of their competency in information literacy after continuous efforts in course curriculum.
Siswono et al. (2018)	Effectiveness of project-based learning in Statistics for Lower Secondary Schools	Investigating the effectiveness of implementing project- based learning on the topic of statistics at a lower secondary school.
Lara and Quesada (2019)	A project-based learning experience in a Compilers Course.	Describes a project-based learning experience in a compilers course.
Chan and Holbert (2019)	Exploring modalities of reflection using social online portfolios for maker-oriented project-based learning.	Finding out how students present their reflections to do with learning concepts or about their personal emoticons in their portfolio tool.
Choi et al. (2019)	How does learner-centered education affect teacher self-efficacy? The case of project-based learning in Korea.	To assess how project-based learning is associated with teacher self-efficacy.
Guzman (2019)	Blending Gamification and project-based learning with Rapid Prototyping Technologies in Enhancing Students' Learning of Design	To measure how the performance of the students is affected by the implementation of different techniques on educational innovation and rapid prototyping technologies
Widiyawati et al. (2020)	STEM-Project based learning Integration on Bioacoustics Worksheet to Enhance Critical Thinking Skills	To develop bioacoustics student worksheet based on STEM-project to enhance critical thinking skills.
Bosica et al. (2021)	Incorporating problem-based learning in a secondary school mathematics preservice teacher education course.	Mathematics education instructors using a mixed instruction.
He et al. (2021)	The Impact of STEM Education on Mathematical Development in Children Aged 5–6 Years	Explores the relationship between STEM education and development of children's mathematics ability, as manifested in spatial ability
Sarwi et al. (2021)	Implementation of project-based learning Based on STEM Approach to Improve Students' Problems Solving Abilities	To analyze the improvement of the problems solving abilities by implementing project-based learning with a STEM approach using a distance learning strategy
Mializar and Johar (2021)	Examining Students' Intention to Use Augmented Reality in a project-based geometry Learning Environment	To examine factors that affect secondary students' behavioral intention to use GeoGebra Augmented Reality to support a project-based geometry learning environment.
Kholid et al. (2022)	GeoGebra in project-based learning (Geo-PJBL): A dynamic tool for analytical geometry course	Differences in the influence of the Geo-PJBL and PJBL models on the learning achievement of analytic geometry courses for prospective mathematics teachers.
Saputri et al. (2022)	Analysis of momentum and impulse on students' creative thinking skill through project-based learning integrated STEM	To analyze students' creative thinking skills on momentum and impulse material through project-based learning integrated STEM.

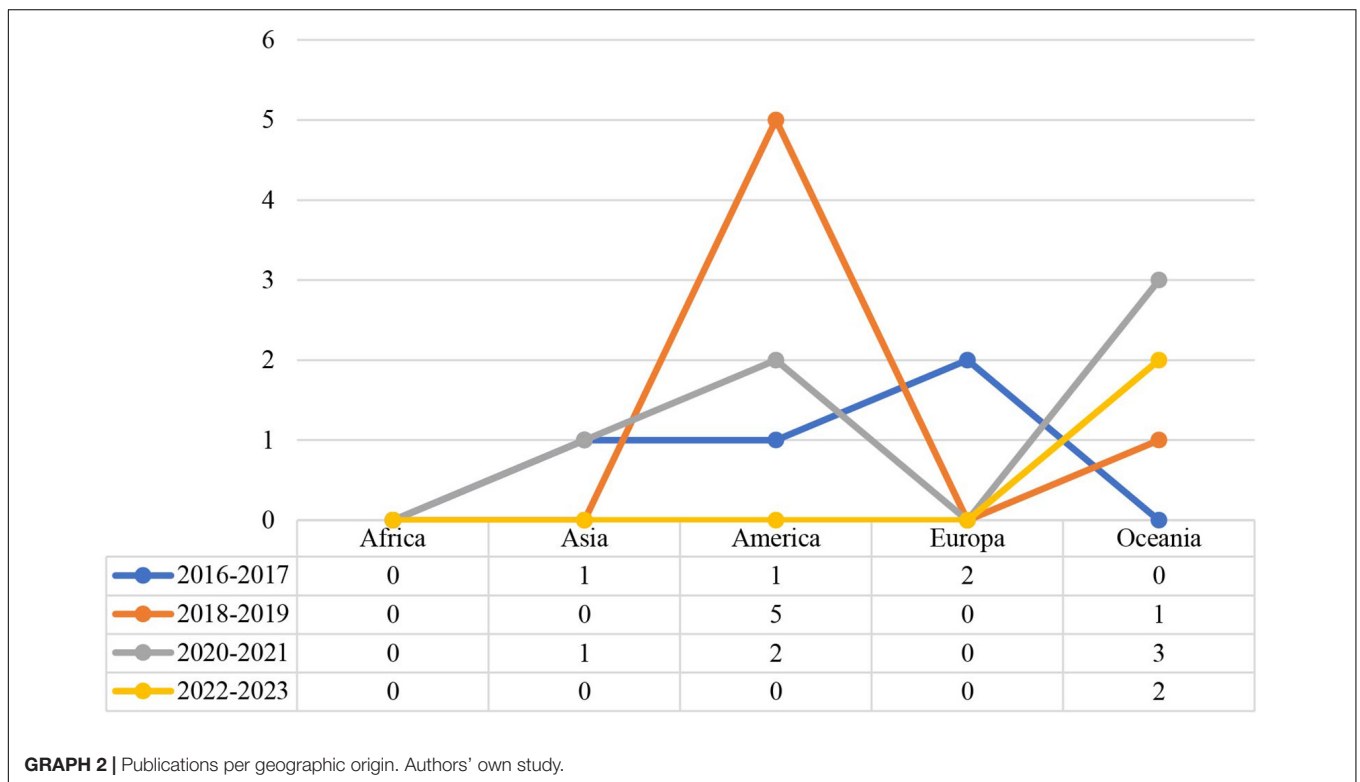
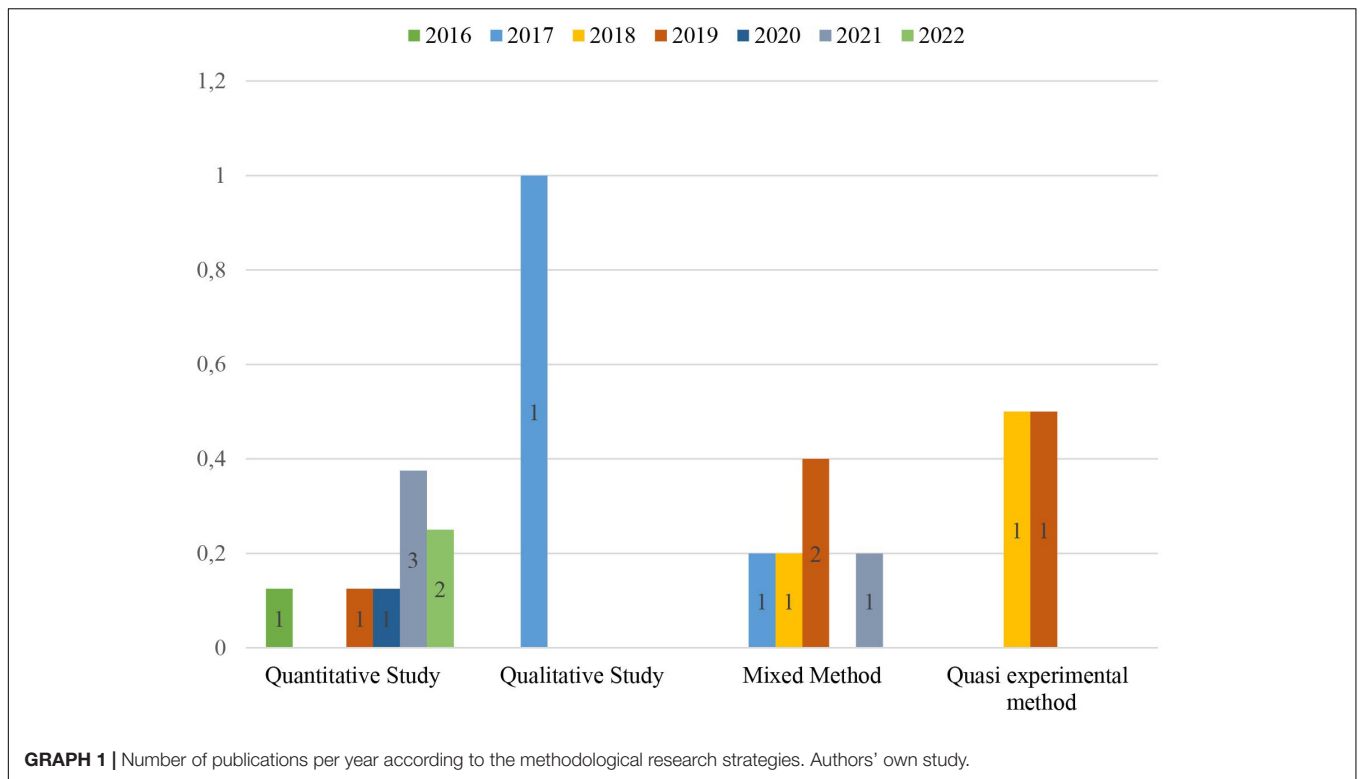
Authors' own study (2022).

In PBL, students play an active goal in learning, and professors act like facilitators of knowledge (Lara and Quesada, 2019). The PBL teaches students how to apply their knowledge in real situations and inspires them to use their creativity to solve problems (Guzman, 2019). Choi et al. (2019) implemented quasi-experimental methods to assess how PBL is associated with teacher self-efficacy. These results show that teacher self-efficacy can be positively affected by increased use of PBL and is positively associated with student engagement and instruction. Johar (2021) implemented a study with which they intended to examine factors that affect secondary students' behavioral intention to use GeoGebra Augmented Reality to support a project-based geometry learning environment. Their students attended six lessons of project-based geometry learning assisted with GeoGebra augmented reality. This study suggested

that the secondary school students well accepted GeoGebra augmented reality.

On the other hand, the student's attitude toward using Augmented Reality has no direct effect on behavior intention. Therefore, Kholid et al. (2022) conducted investigations regarding geometry courses at this level and determined the average scores of some geometry courses in the last 5 years. The results obtained by these researchers show the potential of the PBL model and GeoGebra by analytical geometry courses. These models help prospective mathematics teachers gain an understanding of analytical geometry.

Current generations of students face challenges in learning. Many students perform poorly because they are subject to standard educational systems and teaching methodologies, learning environments in which they do not feel comfortable



(Guzman, 2019). In PBL, students face authentic and motivating problems that require them to answer complex questions and develop success skills (Lara and Quesada, 2019).

Giaffredo et al. (2017) designed a study investigating whether the PBL method helps embrace the competence-based approach inductively. The results obtained by these authors showed a

weak commitment of the teachers to the competence-based approach. However, results also suggest that the PBL method can drive toward the competence-based approach, provided the projects are carefully designed, and subsequently managed. Hsu and Shiue (2017), in the study explore the relationships among three presences, namely cognitive presence, social presence, and teaching presence in a Community of Inquiry (CoI) framework in the context of interdisciplinary project-based learning (IPBL) through the collaborative technology Google Applications. These authors realized that PBL context, with the support of the Google Applications, social presence had more predictive power in explaining students' cognitive presence than the support provided by the online discussion boards. Guzman (2019) implements a study to measure how student performance is affected by implementing different educational innovation techniques and rapid prototyping technologies. To improve the learning experience, these authors obtained these results from student learning. Customizing student assessments according to each skill and using technologies such as 3D printing and 3D scanning have helped students improve their learning experience, increase their grades and develop diverse skills. Sarwi et al. (2021) implemented a study that aims to analyze the improvement of the problem-solving abilities by implementing PBL with a STEM approach. This research method used by these authors was the pre-experimental pretest-posttest one group design. This study showed that with the implementation of projects in the STEM area, students' problem-solving ability increased significantly.

Some teachers have implemented the constructionist pedagogical style to guide students in PBL in Makerspaces

(Chan and Holbert, 2019). For example, Bakermans and Plotke (2018) developed a study with which they assessed changes in student perceptions of their competence in information literacy after continuous efforts in the course curriculum. The results obtained by these authors suggest a significant increase in students' perception of their familiarity with library resources, search strategies, citation use, and ability to evaluate source quality and notice that there was no change in their perception of their ability to evaluate the variety of source and source relevance and a decrease in their perception of the ethical use of interdisciplinary information. Similarly, Saputri et al. (2022) conducted a quasi-experimental study to analyze students' creative thinking skills on momentum and impulse material through PBL integrated with STEM. The researchers' creative thinking skill test indicators were fluency, flexibility, originality, and elaboration. The results obtained by these authors suggest that the implementation of PBL integrated with STEM positively impacts improving students' creative thinking skills. Chan and Holbert (2019) also conducted research investigating how elementary school-aged students in a maker-oriented, PBL environment use a digital portfolio to present their work. The results achieved by these authors show that students primarily use either video/audio recording or text-based captions or labels to describe and explain their work. On the other hand, for the older elementary school students, video/audio recording also reflects conceptual understanding or emotional feelings related to their projects, in addition to the text-based elements.

Therefore, in a PBL context, social presence plays an essential role because it allows communication between stakeholders to

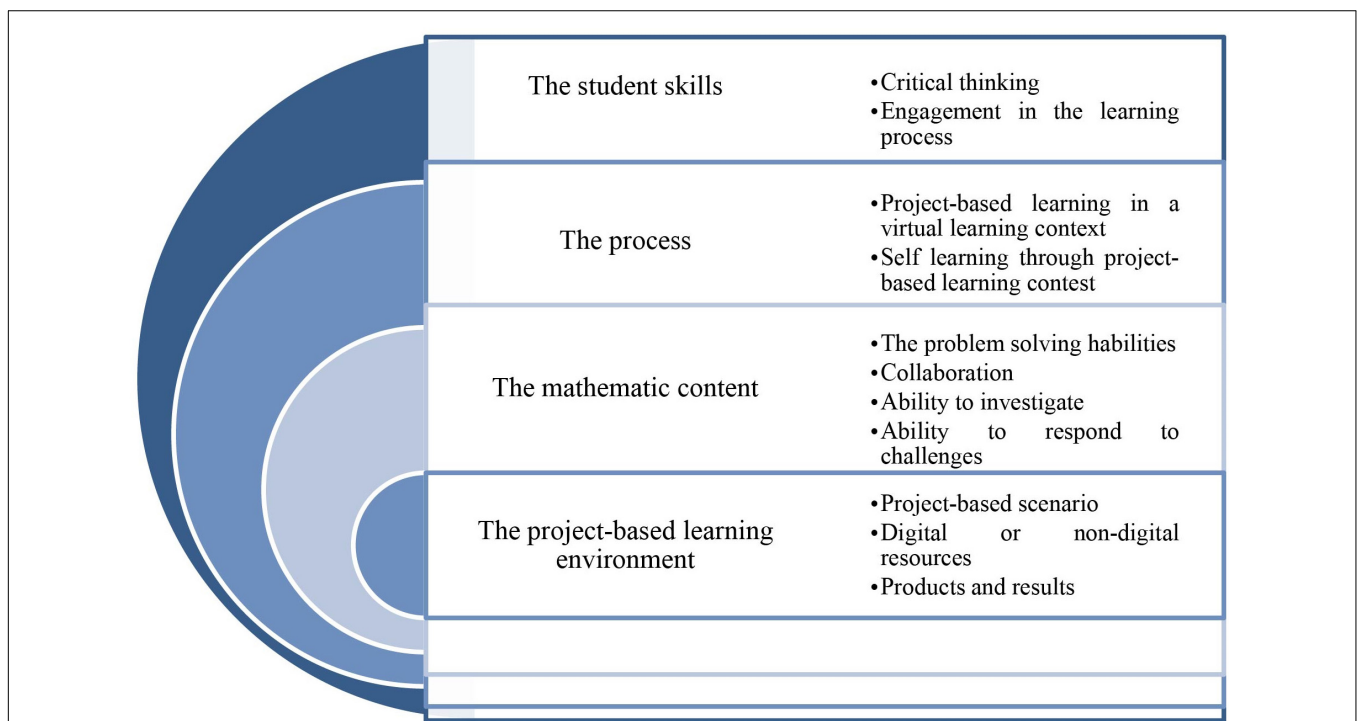


FIGURE 2 | Framework on regarding mathematical skills in teaching through a PBL. Authors' own study.

be oriented toward learning objectives (Hsu and Shiue, 2017). In this way, project learning can help good students show increases in knowledge, but it can also help students who have struggled with failing skills (Bakermans and Plotke, 2018). In this way, a PBL learning environment offers an excellent opportunity to develop the capacity for professional learning attitudes and lifelong skills (Bosica et al., 2021). Furthermore, students' social presence has shown greater predictive power concerning cognitive presence than teaching, so future educators should consider using collaborative web 2.0 communication tools to promote student attention (Hsu and Shiue, 2017).

The PBL activities based on the STEM approach with distancing learning strategies could significantly improve students' problems solving abilities (Sarwi et al., 2021). In their study, He et al. (2021) explores the relationship between STEM education and the development of children's mathematics ability, as manifested in spatial ability. These authors involved kindergarten students, and their results indicate STEM education promotes significant spatial ability improvement in children aged 5–6.

They also showed that the evolution of knowledge is more significant in children with intermediate or lower preview mathematical abilities. The results indicated that STEM training mainly affects children's mathematics ability through building blocks skills. Similarly, Han et al. (2016) carried out a study with which they aimed to investigate how science, technology, engineering, and mathematics PBL affect high-need students in the United States (U.S.) in terms of their academic achievement. The results obtained by these authors show that the STEM methodology of PBL instruction positively influenced students' achievement in mathematics. Siswono et al. (2018) conducted a quasi-experimental method over 2 months involving two classes of seventh graders. These authors intended to investigate the effectiveness of implementing PBL on the topic of statistics in a lower secondary school in the city of Surabaya. The results of these authors show that students' learning outcomes in PBL are superior to those in conventional learning. These authors concluded that PBL was effective in statistical learning and suggested that teachers apply PBL to other math topics so that students can get excited about mathematics learning in the classroom. Bosica et al. (2021) investigated the professional learning model for preservice teachers, the mathematics education instructors using a mixed instruction course incorporating an initial phase of transmission and transactional teaching practices by a step of problem-based learning instruction. Their results suggest significant changes in preservice teacher beliefs and orientations. In learning environments that use PBL, the teacher becomes the facilitator of student action, choosing subjects, screening information and references who may also contribute to the foundation of knowledge. The student takes an active role in their deal training, developing mathematical skills, and soft skills.

This study uncovered four themes regarding mathematical thinking skills in teaching through a PBL context: the learning environment, the mathematic content, the process, and the student skills. The review indicates that most studies were conducted to understand skills developed with the PBL method.

This SR found a higher percentage of PBL documents around various techniques incorporating diverse mathematics abilities such as critical thinking, problem-solving, and social skills such as creative thinking, collaboration, effective communication, and interdisciplinary literacy. Based on the discussion of the study, a theme development framework for enhancing mathematical thinking abilities in students through PBL. Also, Widiyawati et al. (2020) developed research to develop the STEM project to enhance critical thinking skills. These authors used the Gall et al. (1996) model consisting of five project development steps: research and information collecting; planning; developing a form of product; expert judgment; product revision. The results obtained by these authors show that STEM-project can enhance critical thinking skills (Figure 2).

CONCLUSION

The SR reported in this article intends to establish connections between PBL and its potential to promote understanding of math concepts. We realize that the PBL must be understood as a learning strategy to develop hard and soft skills related to mathematics. Some authors also mention the advantages of using PBL to promote students' development of the ability to adapt to teamwork environments, including positive and conflict-infused situations. In the SR we sought to identify, select, and critically evaluate a set of relevant research that aims to evaluate, synthesize, and present empirical data on PBL in learning math concepts through systematic methods organized in phases. The approach described in this study provides the scientific community with an example of how to conduct a literature review. Although all phases of the SR are critical, the fourth step is decisive in adapting the information in the articles to the research question. Results align with those found by Cruz et al. (2014) in a SR on video editing. This SR shows not only a few articles about PBL in learning math concepts but also confirms several options and techniques for enhancing mathematical thinking abilities through PBL. In the analyzed documents, we found connections between PBL and its potential to promote understanding of math concepts. We realize that the PBL method in mathematics education enhanced students' team involvement and learning capacity, leading to collaborative practice, critical thinking and transversal skills. However, some difficulties were discovered in developing non-traditional skills, defining educational objectives, and monitoring through assessment processes. Nevertheless, based on the analyzed literature, we realized that PBL seems to have the potential to promote understanding of math concepts. Further research is needed to study the pedagogical relevance of this.

LIMITATIONS OF OUR SCOPING REVIEW

Scoping reviews are subject to bias in articles selection and data extraction due to our choice of inclusion and exclusion criteria and databases. Aware of these limitations, we established

a protocol for this review that allows us to respond to a specific research question.

AUTHOR CONTRIBUTIONS

SC, JL, and FV contributed to the conception and design of the study and wrote sections of the manuscript. SC organized the database and wrote the first draft of the manuscript. SC and FV performed the statistical analysis. All authors contributed to manuscript revision, read, and approved the submitted version.

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