SemeAd 2025
XXVIII Seminários em Administração

10, 11, 12, 13 e 14 de novembro de 2025
ISSN 2177-3866

PROJECT-BASED LEARNING IN PROGRAMMING EDUCATION FOR CHILDREN: A SYSTEMATIC LITERATURE REVIEW

FERNANDO SANTOS
INSTITUTO DE TECNOLOGIA E LIDERANÇA

MARCELO LUIZ DO AMARAL GONCALVES
UNIVERSIDADE NOVE DE JULHO (UNINOVE)

RENATO PENHA
UNIVERSIDADE NOVE DE JULHO (UNINOVE)

GABRIEL FRANCISCO PISTILLO FERNANDES
UNIVERSIDADE NOVE DE JULHO (UNINOVE)

Agradecimento à orgão de fomento:
Ao Instituto de Tecnologia e Liderança.

PROJECT-BASED LEARNING IN PROGRAMMING EDUCATION FOR CHILDREN: A SYSTEMATIC LITERATURE REVIEW

1. INTRODUCTION

Learning is understood as a process of interpreting reality that occurs through the interaction between the actions of a subject and the objects of knowledge (Freire, 2014). From this perspective, the methodological process assumes a central role by enabling a coherent and meaningful interaction between the learner and the content to be learned (Bruner, 1960). This approach contributes to fostering the social transformation of the individual through acquired knowledge (Vygotsky, 1978).

Project-based learning (PBL) consists of an active teaching technique based on problems and challenges. It involves a series of methods already used by traditional approaches, with the addition of new dynamics that foresee the integration of the student as a protagonist, such as maintaining objectives, constructive investigations, and reflections based on real agendas (Kokotsaki et al., 2016). In practice, PBL allows the student to access classes that present the necessary theoretical frameworks, as in common curricula (Thomas, 2000), and simultaneously, they could carry out a project in which this developed knowledge can be applied, contextualizing the task to be developed through their knowledge and prior experience (Jawaid et al., 2020).

The practical application of theory promotes a deeper and lasting understanding, simplifying knowledge transfer to different contexts (Hmelo-Silver, 2004). Thus, the effectiveness of PBL manifests itself in an active learning environment that integrates practical and theoretical skills, which fosters not only student autonomy but also creativity and critical thinking (Bell, 2010). Additionally, PBL is particularly efficient in developing collaborative competencies and stimulating self-regulation, both necessary for facing complex problems in dynamic and unpredictable scenarios (Boud & Feletti, 2013).

In the current scenario, the growing relevance of digital technologies enables collaborative learning that facilitates group learning, and the sharing of knowledge connected to 21st-century demands through methodologies such as PBL (Fullan, 2016). The integration of technologies in education requires the development of pedagogical-technological knowledge, which enhances the effectiveness of active methodologies in digital environments (Mishra & Koehler, 2006).

The application of PBL in elementary and middle schools reflects a global movement to adapt curricula to competencies focused on technological literacy (Warschauer, 2004). In this regard, UNESCO guidelines for the integration of STEM (Science, Technology, Engineering, and Mathematics) in schools highlight the importance of preparing students for an increasingly technology-driven world (Tseng et al., 2013). Authors such as Bybee (2013) reinforce that the focus on STEM, integrated with active methodologies such as PBL, is crucial for developing problem-solving skills and critical thinking.

The relevance of PBL is not only for children and teenagers, as it is common dynamic in universities (Prince & Felder, 2006). Thus, PBL is seen to prepare students for their entry into the job market, training professionals capable of dealing with everyday problems (Wurdinger & Qureshi, 2015). This occurs through the development of projects verifiable with reality, in which knowledge is applied directly, favoring content retention and the end of abstraction in the face of a previously purely theoretical problem (Fernandes, 2014).

Therefore, PBL proves to be especially effective in preparing students to face real challenges, bringing learning closer to the demands of the job market. The methodology not only connects learning to practice but also promotes students' ability to transfer knowledge to different contexts (Savin-Baden, 2007). In Brazil, where structural and pedagogical challenges still permeate basic education, PBL emerges as a relevant alternative for overcoming these barriers (Grotta & Prado, 2019).

The introduction of practices such as PBL in Brazilian context complements basic education by promoting digital inclusion and access to computational tools, contributing to the reduction of educational inequalities (von Wangenheim et al., 2014). The recent redirection of the job market towards Information Technology indicates the need to prepare students for an environment largely focused on automation and innovation (Frey & Osborne, 2015; Wright et al., 2010), making programming education and other technical skills an element of student development (Tseng et al., 2013).

The present article aims to analyze the different nuances of teaching application, and answer the following research question: How can project-based learning (PBL) be used as a programming teaching methodology for children? To this end, the objective is to verify the different practices that can stimulate, within this learning pattern, the development of technological knowledge among children.

To achieve this objective, a systematic literature review (SLR) was conducted to ascertain the particularities that permeate the stimulus of PBL in the practice of oriented computational teaching. In addition, counterpoints in the application of this dynamic in relation to traditional learning measures were raised, enabling a comparative analysis. A SLR is understood as a dynamic that aims to gather evidence to answer a predetermined question, involving the identification of sources, critical judgment, and a synthesis of what is available on the subject, thus being able to form a new integrated concept (Pollock & Berge, 2018).

The article is organized into sections covering this introduction, moving through the methodological procedures and results analysis, up to the detailed discussion of applications, benefits, challenges, and complementary methodologies. The text concludes with an integrative synthesis, final considerations, limitations, and future studies.

2. METHODOLOGICAL PROCEDURES

This article seeks to understand the relationship between PBL, Computing, and the Education of children (representatives of Brazilian Basic Education) through a SLR that addresses these themes.

According to Christou et al. (2025), a SLR consists of conducting high-level research from a broad question, including a systematic search within a specific field of knowledge, and raising evidence that answers the proposed question. Through this approach, this study uses a qualitative method to explore patterns and similarities between the themes (Tranfield et al., 2003).

The research follows the pattern described by Pollock & Berge (2018) for the construction of a SLR, minimizing biases and allowing for rigorous verification and assimilation of knowledge. The steps highlighted by the authors for this article are as follows: (1) Definition of the central research question, eligibility criteria, and objectives; (2) Search for relevant information, definition of search strategies, and study selection process; (3) Information collection, including data extraction method and listing of variables that influence the different references; (4) Quality assurance of studies, with measures to avoid biases; (5) Synthesis of collected evidence, describing a statistical analysis plan and modes of results presentation; and (6) Interpretation of information, summarizing it and highlighting the importance of evidence quality.

In the phase of selecting relevant research, Pollock & Berge (2018) propose a protocol that allows for the systematic identification of studies through the stages of: (1) Identification; (2) Screening; (3) Eligibility; and (4) Inclusion, as illustrated in Figure 1.

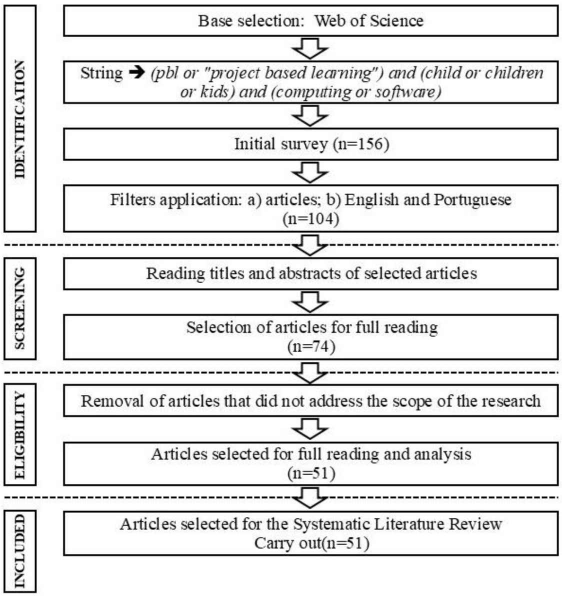

Figure 1 - Procedures used for article selection.

Source: prepared by the authors based on Pollock & Berge (2018).

In the Identification phase, which corresponds to the second stage described in the general protocol for SLRs and the first in the related study search structure, the Web of Science database was used. The search string included studies that present a learning context focused on teaching computing to children (and teenagers) through PBL. The search string was composed of the following terms: (PBL OR "PROJECT BASED LEARNING") AND (CHILD OR CHILDREN OR KIDS) AND (COMPUTING OR SOFTWARE). Each string was adjusted to the specificities of the search platform, ensuring the retrieval of relevant articles according to the recommendations of (Tranfield et al., 2003).

From this definition, an initial search was conducted that resulted in a wide range of articles, many of which were not directly related to the topic or its subtopics. The research was conducted in English and Portuguese, adjusting to the format of the platform, and was carried out in May 2025. The initial search resulted in 156 articles. Then filters to Portuguese and

English texts, and articles only were applied to identify works with scientific relevance, offering a view on PBL, Technological Education, and the Teaching of children and young people.

The screening process for the components of this review followed steps described by the Pollock & Berge (2018) protocol, which are initial identification, abstract screening, full-text reading, and final article selection. This evaluation was performed by a single independent reviewer, who analyzed the studies using, a priori, the traditional reading model and, subsequently, the use of Artificial Intelligence digital tools with the aim of reducing the possibility of bias in inclusion and facilitating the exclusion of readings not effectively contributing to the context of the scientific work. Discrepancies between the reviewer and the tool were resolved by a second reviewer. The use of this dynamic ensures greater rigor in the selection process.

Additionally, to ensure a high-quality selection, the articles were subjected to a methodological quality assessment using the GRADE method (Bezerra et al., 2022). With this instrument, it was possible to classify the studies regarding the robustness of the evidence, relevance of the results, and risk of bias, ensuring that only the most consistent ones were included in the final corpus. The GRADE system (Grading of Recommendations, Assessment, Development, and Evaluation) provides a systematic framework for classifying the quality of evidence and the strength of recommendations in systematic reviews. It seeks to evaluate aspects such as the consistency of results, the impact, and the precision of evidence, allowing for a robust and standardized critical analysis (Brasil, 2014). According to the manual prepared by the Ministry of Health (Brasil, 2014), GRADE organizes evidence into different levels, allowing researchers to justify their decisions based on clear and reproducible criteria.

After applying qualitative GRADE based criteria, 74 relevant works were found. As an exclusion criterion, documents that were not academic articles, papers, case studies, or published in scientific journals were discarded. Subsequently, the remaining articles underwent an eligibility assessment, reading titles and abstracts. Duplicate articles or those outside the scope of the study were once again removed, resulting in a final corpus of 51 selected articles.

Next, the qualitative analysis of the evidence began. The results were qualitatively synthesized and then grouped into thematic categories related to the impact of PBL on programming education, socio-emotional skills, and implementation challenges. This perception aims to understand similarities that aid in the correlation between the 51 selected articles, such as repetition of keywords, common authors, and thematic similarities.

3. RESULTS ANALYSIS AND DATA PROCESSING

The formation of the analysis corpus occurred after the screening procedure of academic works without temporal restrictions. The first work in the context of this study dates from 2004. The analyzed material covers 51 works published from 2004 to 2024.

Once the database compilation was completed, the data were organized and categorized using Microsoft Excel spreadsheets. This step enabled the preparation of a significant descriptive characterization of the investigation conducted, as well as an in-depth analysis that allowed for indicating the category of each article.

3.1. Analysis Methodology

It is essential to mention that the content analysis method employed follows the guidelines established by (Bardin, 2011). All chosen works were examined in full. The objective was to identify categories that would contribute to the understanding of the theme investigated. The classification parameters were consensually approved by the research team and incorporated into the electronic spreadsheet. The resulting file included both the bibliographic data of the publications and the information regarding the established classification. After the complete evaluation of the works, the team identified points of convergence through a classification procedure in the five categories described in Table 1.

3.2. Temporal Evolution of Publications

The observation of the temporal distribution of works reveals a progressive interest in the theme, with the year 2022 recording the most significant volume of publications (as illustrated in Figure 2).

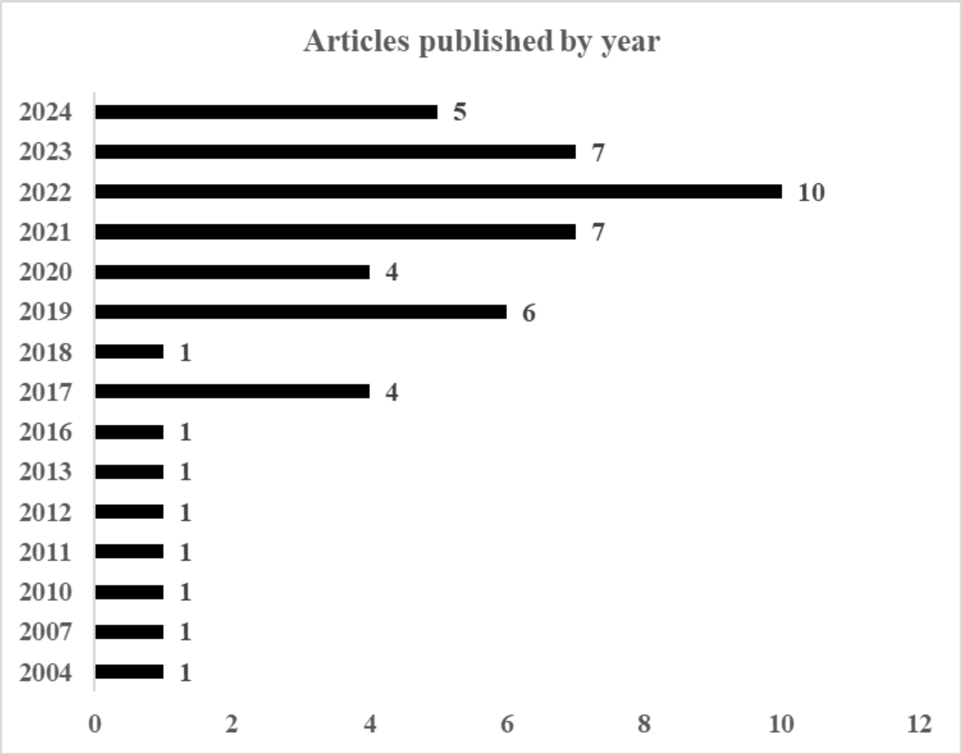

Figure 2 - Articles published per year.

Source: Prepared by the authors (2025).

3.3. Trend Analysis

Through the systematic survey of works and the meticulous analysis of each publication, it became possible to establish the interrelationships between the topics addressed and their respective authors. This process resulted in the identification of 5 main categories: 1. Conceptualization and Characteristics of PBL; 2. Applications of PBL in Programming Education and Computational Thinking for Children and Adolescents; 3. Multidimensional Effects in the Use of PBL; 4. Critical Factors and Limitations in the Application of PBL; and 5. Methodologies and Approaches Complementary to PBL. It is important to note that these categories emerged through the analytical process and the classification of works, as shown in Table 1.

3.4. Categorization Process

The classification procedure is the conceptual synthesis of the elements identified in the set of analyzed publications. Each established category synthesizes a grouping of concepts that symbolize fundamental aspects to be examined during the exposure and debate stage.

3.5. Classification Methodology

The integral analysis of the works resulted in the identification of five main categories. The classification process was systematized in an electronic matrix, employing an integrated analysis methodology that examined multiple components of each publication: denomination, synthesis, knowledge areas contemplated, purposes, methodology adopted, conclusions obtained, identified restrictions, and suggestions for future investigations. This multidimensional approach enabled the recognition of essential elements for the distribution of works into the five established categories.

Table 1
Categories of analysis of the research corpus

Category	**Description**	**Authors**
1. Characteristics of PBL	Student-centered; Methodological Structure - 3-Phase Process: Pre-discussion; Self-study; Report; Pillars of the methodology: Investigative question, student decisions with teacher support, collaborative work, and real-problem solving; Student autonomy in theme selection, curricular contextualization, and flexibility for diverse educational contexts; Development of skills such as critical thinking, creativity, communication, student initiative, and increased motivation.	(Alves et al., 2019; Bascopé & Reiss, 2021; da Silva & Pátaro, 2019; Hovington et al., 2020; Jawaid et al., 2020; Kokotsaki et al., 2016; Lombardi et al., 2022; Lu et al., 2022; Mishra & Koehler, 2006; Purnomo et al., 2022; von Wangenheim et al., 2014)
2. Applications of PBL in computing for Children and Teenagers	Areas of Application in computing - robotics and AI robotics, engineering and computing, game development; Tools and Resources - Visual languages (Scratch) for children, open-source hardware/software, educational platforms like Micro:bit; Integrated STEAM Program combining design and programming covering electrical circuits and optics to perform programming and creative problem solving; For robotics courses, the pedagogical structure involves five levels: Introduction, basic robotics, advanced robotics, competition, and exhibition; Benefits in Skill development: Computational thinking, creativity, problem-solving, self-efficacy, and STEM competencies; Technical gaps and limited vision: Risk of students not mastering technical details and developing immature perspectives on industries.	(Cherniak et al., 2019; Chiazzese et al., 2019, 2019; Hämeen-Anttila et al., 2010; Jawaid et al., 2020; LeTendre & Gray, 2024; Lien et al., 2023; Purnomo et al., 2022; Smith & Hung, 2017)
3. Multidimensional Effects in the use of PBL	PBL raises student motivation through stimulating debates and engaging projects, promoting genuine interest; Strengthens interpersonal, cognitive, affective, and problem-solving competencies through collaborative work; Strengthens self-confidence and motivation, making students more active and participatory; Improves conceptual mastery and retention, especially in complex concepts; Promotes holistic and social development, transforming passive students into active knowledge seekers and future teacher preparation; Connects school, community, and family, applying knowledge in real contexts as a "living laboratory"; Shows significant effects on students' oral and written comprehension.	(Albar & Southcott, 2021; Alghamdi et al., 2022; Alimisis, 2019; Alò et al., 2020; Alvarez, 2023; Amin et al., 2022; Cherniak et al., 2019; Fruett et al., 2024; Hämeen-Anttila et al., 2010; Jdidou et al., 2023; L. Hartman & Littell, 2020; Lara et al., 2021; Lombardi et al., 2022; Malik & Sime, 2022; Polman, 2004; Purnomo et al., 2022; Rodrigo Segura, 2022; Tang et al., 2024; Veraksa et al., 2024; Videnovik et al., 2021)

Category	Description	Authors
4. Limitations and challenges in the Application of PBL	Pedagogical: Limited teacher knowledge about PBL, insufficient resources, and technological disparities between public/private schools; Time Management: Need for more time for teachers to guide, supervise, and organize activities; Engagement and Attitude: Student difficulties in starting projects, lack of family/community motivation, and low political priority; Quality of Proposed Solutions: Superficial solutions that do not address root causes or depend on third parties, limiting deep understanding; Design Complexity: Activity complexity can prevent students from following all steps linearly and sequentially; Educational equity, working with special needs children.	(Bascopé & Reiss, 2021; Chiazzese et al., 2019; da Silva & Pátaro, 2019; Fruett et al., 2024; Hämeen-Anttila et al., 2010; Hurtado-Martín et al., 2023; Inna et al., 2021; LeTendre & Gray, 2024; Lien et al., 2023; Parwoto et al., 2024; Polman, 2004; Purnomo et al., 2022, 2022; Videnovik et al., 2021)
5. Complementary Approaches to PBL	Collaborative Learning (CL): Students in teams develop project strategies with equal rewards, demonstrating success with PBL; Activity-Based Learning (ABL): Influences PBL design, increases student involvement and attention to technical details; Hands-on Activities: Engages students in physical principles, especially robotics, integrating hardware/software effectively; Open-Source Tools: Use of platforms like Arduino and Micro:bit is common in hardware/software-based PBL for robotics; Game-Based Learning: Complementary approach to PBL in programming education, using playful tools for computational thinking; Teacher's Role: Evolves from an authority figure to a facilitator or mentor in the PBL environment; Theory of Multiple Intelligences (Gardner): Optimizes multimedia PBL, differentiates tasks by skills and correlates intelligences with ICT; Design Thinking Process: Introduced in STEM projects to guide students in problem-solving and solution prototyping; Visual Programming Languages (VPL): like Scratch, are highlighted for their suitability for beginners; Contextual and Interdisciplinary Learning: A pillar of PBL, connecting content with students' real lives, integrates different disciplines.	(Alò et al., 2020; Chiazzese et al., 2019; Fruett et al., 2024; Ghosheh Wahbeh et al., 2021; Hämeen-Anttila et al., 2010; Hsin & Wu, 2023; Hurtado-Martín et al., 2023; Inna et al., 2021; Kaldi & Zafeiri, 2023; Lara et al., 2021; Purnomo et al., 2022; Rodrigo Segura, 2022; Tang et al., 2024; Videnovik et al., 2021)

Source: Prepared by the authors (2025).

The next section is dedicated to a detailed discussion of the identified categories, presenting the findings of this investigation and exploring their interconnections and implications for the field of study.

4. DISCUSSION OF RESULTS

This section discusses the categories found and the relationships between them, considering the benefits and barriers encountered in the process of using and implementing PBL.

4.1. Characteristics of PBL

Project-Based Learning (PBL) configures itself as an active methodology that fundamentally reorganizes the educational dynamic, positioning the student as the protagonist of their learning journey (Barak & Asad, 2012; da Silva & Pátaro, 2019). In the specific context of programming education for children and adolescents, this approach acquires contours that deserve in-depth analysis (Chiazzese et al., 2019). The literature shows that PBL transcends the mere application of pedagogical techniques, constituting an educational philosophy that integrates multiple dimensions of human development (da Silva & Pátaro, 2019; Veraksa et al., 2024).

The characterization of PBL in programming education reveals its multifaceted nature, where knowledge construction occurs through the active investigation of authentic problems (Barak & Asad, 2012). This authenticity manifests when young programmers are challenged to create technological solutions for real-world issues in their communities, establishing significant connections between the code they write and the social impact they can generate (Chiazzese et al., 2019; da Silva & Pátaro, 2019; Jdidou et al., 2023; Kim et al., 2019). Interdisciplinarity emerges naturally in this process, as programming projects frequently demand knowledge of mathematics, design, communication, and even ethical and social aspects of technology (da Silva & Pátaro, 2019).

The investigative process inherent in PBL in programming education is characterized by iterative cycles of planning, implementation, testing, and refinement – mirroring professional practices in the software industry (Gestwicki & McNely, 2016; Hojeij et al., 2021; Mettas & Constantinou, 2007; Videnovik et al., 2021). This approximation to the real world of software development not only technically prepares students (Barak & Asad, 2012; Gestwicki & McNely, 2016) but also introduces them to the culture and values of the programming community, including open-source collaboration (Fruett et al., 2024; Gestwicki & McNely, 2016; Videnovik et al., 2021), code documentation (Gestwicki & McNely, 2016). The production of tangible artifacts – be they games, applications, or websites – provides concrete evidence of learning (Alò et al., 2020, 2020; Gestwicki & McNely, 2016; Hojeij et al., 2021; Romo-Mayor & Pellicer-Ortín, 2022) and serves as a source of intrinsic motivation (Barak & Asad, 2012; Videnovik et al., 2021), especially relevant for the age group in question (Chiazzese et al., 2019; Videnovik et al., 2021).

4.2. Applications of PBL in computing for Children and Teenagers

The operationalization of PBL in programming education for children and adolescents demands specific pedagogical strategies that consider both the developmental characteristics of learners and the peculiarities of computational knowledge (Chiazzese et al., 2019; Videnovik et al., 2021). The analyzed literature reveals that the successful implementation of this methodology requires a delicate balance between structure and freedom, guidance and autonomy, challenge and support (Barak & Asad, 2012; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Stojanović et al., 2023).

Gamification emerges as a predominant strategy, not as a trivialization of content, but as a recognition that play constitutes a natural language for young learners (Veraksa et al., 2024; Videnovik et al., 2021). Projects involving game creation not only engage students but also introduce complex programming concepts in a contextualized way: loops through repetitive mechanics, conditionals through game rules, variables through scoring systems (Chiazzese et al., 2019; Videnovik et al., 2021). This approach demonstrates pedagogical sophistication by aligning form with content, using games to teach about programming (Chiazzese et al., 2019).

4.3. Multidimensional Effects in the use of PBL

The analysis of PBL's benefits in programming education reveals impacts that transcend the technical domain, encompassing cognitive, socio-emotional, and metacognitive dimensions of youth development (Ghosheh Wahbeh et al., 2021; Jdidou et al., 2023; Purnomo et al., 2022; Veraksa et al., 2024). This multiplicity of benefits positions PBL as a holistic approach particularly suited to train not only competent programmers but critical and creative digital citizens (Jdidou et al., 2023; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022). In the domain of technical competencies, accelerated development of computational thinking is observed, manifesting in an improved ability to decompose complex problems, recognize patterns, abstract, and design algorithms (Chiazzese et al., 2019; Jdidou et al., 2023). These cognitive gains are not limited to the programming context, transferring to other areas of knowledge and everyday problem-solving situations (Barak & Asad, 2012; Chiazzese et al., 2019). Contextualized learning of programming languages through meaningful projects demonstrates greater retention and deeper understanding compared to traditional approaches based on decontextualized exercises (Barak & Asad, 2012; Ghosheh Wahbeh et al., 2021; Jdidou et al., 2023; Purnomo et al., 2022).

The development of digital creativity emerges as a distinctive benefit of PBL, where students not only apply technical knowledge but explore expressive possibilities of programming (Hojeij et al., 2021; Jdidou et al., 2023; Lu et al., 2022; Mettas & Constantinou, 2007). This creative dimension manifests in experimenting with different solutions for the same problem, aesthetic customization of interfaces, and innovation in game mechanics or application functionalities (Barak & Asad, 2012; Gestwicki & McNely, 2016; Purnomo et al., 2022). PBL cultivates a "programming as art" mindset, where code becomes a means of personal and collective expression (Barak & Asad, 2012; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Hojeij et al., 2021; Jdidou et al., 2023; Lu et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022).

The socio-emotional competencies developed through PBL are equally significant (Hämeen-Anttila et al., 2010; Hojeij et al., 2021; Purnomo et al., 2022; Veraksa et al., 2024).

The intensive collaboration demanded by complex projects develops communication, negotiation, and conflict management skills (da Silva & Pátaro, 2019; Gestwicki & McNely, 2016; Hämeen-Anttila et al., 2010; Hojeij et al., 2021; Jdidou et al., 2023; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Veraksa et al., 2024). The need to present projects to real audiences - whether peers, teachers, or the community - develops oral and visual communication skills, essential in the contemporary professional world (da Silva & Pátaro, 2019; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Hojeij et al., 2021; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Veraksa et al., 2024). The autonomy cultivated through managing one's own projects transfers to other spheres of student life, promoting self-regulation and responsibility for one's own learning (Gestwicki & McNely, 2016; Hojeij et al., 2021; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022).

The resilience developed through the inevitable challenges and frustrations of the programming process constitutes a particularly valuable benefit (Hämeen-Anttila et al., 2010; Purnomo et al., 2022; Veraksa et al., 2024). In PBL, errors and bugs are recontextualized as learning opportunities, developing tolerance to frustration and persistence – essential qualities for both programmers and lifelong learners (Gestwicki & McNely, 2016; Hämeen-Anttila et al., 2010; Jdidou et al., 2023; Purnomo et al., 2022). Critical thinking is constantly exercised through evaluating different approaches, analyzing trade-offs between solutions, and reflecting on the ethical and social implications of created technologies (Barak & Asad, 2012; da Silva & Pátaro, 2019; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Hojeij et al., 2021; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Veraksa et al., 2024).

4.4. Limitations and challenges in the Application of PBL

The implementation of Project-Based Learning (PBL) in programming education faces multidimensional challenges that demand careful attention and mitigation strategies (Barak & Asad, 2012; Bhogal et al., 2011). These obstacles, far from invalidating the methodology, point to the need for systemic and contextualized approaches in its adoption (Barak & Asad, 2012).

Structural challenges related to technological resources represent significant barriers, especially in contexts of socio-economic vulnerability (Purnomo, 2022). The need for adequate computers, stable internet connection, and appropriate software creates access disparities that can amplify existing educational inequalities (Alò et al., 2020; Purnomo et al., 2022). Mitigation strategies include the use of mobile devices, unplugged programming for fundamental concepts, and partnerships with organizations that provide technological resources (Bhogal et al., 2011). Pedagogical creativity becomes essential to adapt PBL to contexts with limited resources without compromising its fundamental principles (Barak & Asad, 2012; Bhogal et al., 2011).

The temporal issue emerges as a persistent challenge, given that authentic projects demand substantially more time than traditional expository classes (Hämeen-Anttila et al., 2010; Hojeij et al., 2021). The rigidity of curricula and the pressure for programmatic content coverage create tensions with the exploratory and iterative nature of PBL (Gestwicki & McNely, 2016; Polman, 2004). This challenge requires not only logistical adjustments but a paradigm shift about what constitutes meaningful learning in programming (Hojeij et al., 2021). The quality and depth of understanding developed through a well-executed project can outweigh the quantity of topics superficially covered in traditional approaches (Gestwicki & McNely, 2016; Hämeen-Anttila et al., 2010; Kaldi & Zafeiri, 2023; Wijnen et al., 2017).

The evaluative complexity in PBL represents a significant conceptual and practical challenge (Chiazzese et al., 2019; Mettas & Constantinou, 2007; Peeples et al., 2017). How to evaluate multidimensional learning that includes not only technical mastery but also creativity, collaboration, and critical thinking (Hämeen-Anttila et al., 2010; Hojeij et al., 2021; Veraksa et al., 2024)? Traditional evaluative instruments prove inadequate to capture the richness of the learning developed (Barak & Asad, 2012; Gestwicki & McNely, 2016; Polman, 2004). Promising approaches include digital portfolios, peer evaluation, holistic rubrics, and reflective documentation of the development process (Barak & Asad, 2012; da Silva & Pátaro, 2019; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Kaldi & Zafeiri, 2023; Mettas & Constantinou, 2007; Romo-Mayor & Pellicer-Ortín, 2022). Continuous formative assessment, integrated into the project development process, emerges as a more aligned alternative to PBL principles (Barak & Asad, 2012; Gestwicki & McNely, 2016; Romo-Mayor & Pellicer-Ortín, 2022; Schneider et al., 2022; Wijnen et al., 2017).

Pedagogical challenges primarily center on teachers whose traditional paradigms often lack both technical knowledge in programming and experience with active methodologies (Barak & Asad, 2012; Brown & Jain, 2022; da Silva & Pátaro, 2019; Hojeij et al., 2021; Neto et al., 2019). The transition from the role of knowledge transmitter to learning facilitator demands substantial and continuous professional development (da Silva & Pátaro, 2019; Hojeij et al., 2021; Neto et al., 2019). Teacher training programs that integrate not only technical training but also practical experience with PBL prove essential for successful implementation (Brown & Jain, 2022; Gestwicki & McNely, 2016; Hojeij et al., 2021; Kaldi & Zafeiri, 2023).

Resistance to change manifests at multiple levels – from teachers insecure about the perceived loss of control, to parents concerned about non-traditional methods, and educational systems structured around standardized metrics (Brown & Jain, 2022; Hämeen-Anttila et al., 2010; Neto et al., 2019; Polman, 2004). This resistance reflects broader tensions between educational paradigms and requires communication strategies and demonstration of results to build institutional and community support (Barak & Asad, 2012; Brown & Jain, 2022; da Silva & Pátaro, 2019; Gestwicki & McNely, 2016; Hojeij et al., 2021; Neto et al., 2019).

4.5. Complementary Approaches to PBL

The integration of complementary methodologies to Project-Based Learning (PBL) in programming education proves to be a significant enhancing factor, creating pedagogical synergies that amplify the benefits of project-based learning (Jawaid et al., 2020). Different research has sought to combine PBL with other emerging tools, including active learning, pedagogical skills development, collaborative learning (CL), and cognitive development (Jawaid et al., 2020).

PBL is recognized for promoting critical thinking, problem-solving, creativity, and communication, which are essential 21st-century skills, being an effective alternative to traditional teaching methods (Bell, 2010; Inna et al., 2021; Thomas, 2000). Educational robotics, often combined with PBL, is an effective tool for acquiring knowledge in STEM disciplines (Science, Technology, Engineering, and Mathematics) and for developing computational thinking in K-12 students (Jawaid et al., 2020).

Participation in hands-on activities is important for engaging students in the physical principles of science and engineering, especially in educational robotics (Jawaid et al., 2020). This methodological convergence does not represent superficial eclecticism, but a recognition that the complexity of teaching programming to young people demands multifaceted and adaptive approaches (Barak & Asad, 2012). Contextual and interdisciplinary integration, which connects content with students' real lives and integrates different disciplines, is fundamental to making learning more meaningful (Barak & Asad, 2012).

Research suggests that teaching a new subject will require the teacher to present basic theory, making it unlikely that complex courses will be taught using only PBL or problem-based approaches without conventional teacher-guided classes (Barak & Asad, 2012). The implementation of the Theory of Multiple Intelligences, for example, can optimize PBL, allowing for the differentiation of tasks to adapt to students' diverse abilities (Inna et al., 2021).

Problem-Based Learning, often confused with PBL, offers valuable complementarity by focusing on specific and well-defined problems within the larger context of projects (Hojeij et al., 2021; Mettas & Constantinou, 2007; Peeples et al., 2017; Wijnen et al., 2017). This approach allows for the development of essential debugging and troubleshooting skills in programming, where students learn to isolate, diagnose, and systematically solve technical problems (Brown & Jain, 2022; Jdidou et al., 2023). The alternation between a macro view of the project and a micro focus on specific problems develops the cognitive flexibility characteristic of experienced programmers (Barak & Asad, 2012; Gestwicki & McNely, 2016; Lu et al., 2022; Mettas & Constantinou, 2007).

Design Thinking emerges as a particularly synergistic framework with PBL in the context of programming, introducing structured processes of empathy, ideation, and prototyping (Plattner et al., 2017). This methodology humanizes software development, reminding young programmers that technology exists to serve people (Barak & Asad, 2012; da Silva & Pátaro, 2019; Jdidou et al., 2023). The empathy and problem definition phases in Design Thinking enrich the initial phase of PBL projects, ensuring that technical solutions respond to real needs identified through user research (Barak & Asad, 2012; da Silva & Pátaro, 2019; Mettas & Constantinou, 2007). The culture of rapid prototyping and iteration, central to Design Thinking, aligns perfectly with agile software development practices (Gestwicki & McNely, 2016).

Gamification, when consciously integrated into PBL, transcends the superficiality of points and badges to create intrinsic motivational systems (Jawaid et al., 2020). Game design elements such as engaging narratives, visible progression, and immediate feedback can be incorporated not only into the products created by students but into the very structure of learning projects (Lu et al., 2022). This meta-gamification, where the process of learning programming becomes a "game" with progressive challenges and significant achievements, demonstrates pedagogical sophistication by aligning form and content (Videnovik et al., 2021).

STEAM (Science, Technology, Engineering, Arts, and Mathematics) offers an interdisciplinary framework that enriches programming projects with artistic and scientific dimensions (Chiazzese et al., 2019; Fruett et al., 2024; Lu et al., 2022; McCullough et al., 2018).

This integration is particularly valuable in developing games and interactive applications, where programming meets visual design, narrative, music, and even concepts from physics and mathematics (Gestwicki & McNely, 2016; Lu et al., 2022). STEAM projects demonstrate that programming does not exist in a disciplinary vacuum, but as a powerful tool for creative expression and scientific investigation (Barak & Asad, 2012; Fruett et al., 2024; Gestwicki & McNely, 2016; Lu et al., 2022).

The integration of these complementary methodologies does not occur in a simple additive way, but through creative syntheses that respect the fundamental principles of each approach while creating something new (Lu et al., 2022; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022). For example, a project might start with a Design Thinking process to identify the needs of the school community, develop through a PBL framework with gamification elements, incorporate STEAM investigations in creating scientific data visualizations, and use PBL to solve specific technical challenges that arise during development (Barak & Asad, 2012; Kim et al., 2019; Lu et al., 2022; Mettas & Constantinou, 2007).

This methodological orchestration demands considerable pedagogical sophistication from educators, who must not only master each approach individually but understand their synergies and know when and how to mobilize each one (Gestwicki & McNely, 2016; Kaldi & Zafeiri, 2023; Neto et al., 2019; Romo-Mayor & Pellicer-Ortín, 2022). Teacher training for this methodological integration represents an essential investment, but the observed results – in terms of student engagement, depth of learning, and development of multiple competencies – justify the effort required (Barak & Asad, 2012; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Lu et al., 2022; Neto et al., 2019; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Veraksa et al., 2024; Wijnen et al., 2017).

4.6. Integrative Synthesis of Categories

The integrated analysis of the five categories reveals that Project-Based Learning can be used as a programming teaching methodology for children and teenagers through a systemic approach that recognizes and articulates multiple pedagogical dimensions (Chiazzese et al., 2019; Lu et al., 2022; Purnomo et al., 2022; Stojanović et al., 2023; Veraksa et al., 2024). The answer to the research question is not limited to technical prescriptions but involves a deep understanding of how constructivist principles can be materialized into transformative educational practices (Barak & Asad, 2012; Purnomo et al., 2022).

The successful implementation of PBL in programming education requires alignment between theoretical foundations and pedagogical practices, where the robust conceptualization of the methodology informs decisions about project design, facilitation strategies, and evaluation systems (Barak & Asad, 2012; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Kaldi & Zafeiri, 2023; Lu et al., 2022; Neto et al., 2019; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Stojanović et al., 2023). The identified benefits, from the development of computational thinking to socio-emotional competencies, validate the investment needed to overcome the structural and pedagogical challenges inherent in the methodology (Barak & Asad, 2012; Bell, 2010; Brown & Jain, 2022; Chiazzese et al., 2019; da Silva & Pátaro, 2019, 2019; Gestwicki & McNely, 2016; Ghosheh Wahbeh et al., 2021; Kaldi

& Zafeiri, 2023; Lara et al., 2021; Lu et al., 2022; Neto et al., 2019; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022; Stojanović et al., 2023; Veraksa et al., 2024).

Integration with complementary methodologies emerges not as a pedagogical luxury, but as a necessity to address the complexity of contemporary programming education (Jdidou et al., 2023). This methodological convergence, when well-orchestrated, creates rich and adaptive learning environments that prepare young people not only as technically competent programmers but as critical thinkers, creative problem solvers, and conscious digital citizens (Brown & Jain, 2022; da Silva & Pátaro, 2019; Jdidou et al., 2023; Purnomo et al., 2022; Romo-Mayor & Pellicer-Ortín, 2022).

The identified barriers, far from discouraging the adoption of PBL, point to the need for contextualized approaches and systemic support (Barak & Asad, 2012). Investments in technological infrastructure, continuous teacher training, and the development of specific pedagogical resources constitute prerequisites for the democratization of this approach (Kaldi & Zafeiri, 2022). The construction of communities of practice, where educators share experiences, resources, and strategies, emerges as a critical factor for the sustainability and scalability of PBL in programming education (Lara et al., 2021).

Ultimately, PBL in programming education for children and adolescents represents more than an educational methodology – it constitutes a vision for the role of technological education in forming young people for the 21st century (Brown & Jain, 2022; Chiazzese et al., 2019; Hojeij et al., 2021; Parwoto et al., 2024). By engaging students in meaningful projects that connect code with purpose, technique with ethics, and individual learning with collective impact, PBL cultivates a generation capable not only of navigating but actively shaping the digital future (da Silva & Pátaro, 2019; Hojeij et al., 2021; Hsin & Wu, 2023; Jawaid et al., 2020; Kersten, 2017; Lu et al., 2022; Parwoto et al., 2024; Purnomo et al., 2022; Stojanović et al., 2023; Veraksa et al., 2024). This transformative perspective, grounded in evidence and enriched by innovative practices, positions PBL as an essential approach to programming education that is simultaneously rigorous, relevant, and transformative (Barak & Asad, 2012; da Silva & Pátaro, 2019; Hojeij et al., 2021; Hsin & Wu, 2023; Jawaid et al., 2020; Kaldi & Zafeiri, 2023; Purnomo et al., 2022; Veraksa et al., 2024).

5. FINAL CONSIDERATIONS

This investigation into the application of Project-Based Learning (PBL) in programming education for children reveals a promising approach, capable of offering multiple educational benefits. Due to its constructivist and student-centered nature, PBL stimulates the creation of tangible products, such as games, applications, or robots, through the resolution of authentic problems. This practical characteristic proved fundamental to making learning more engaging and to maintaining student interest in a field often perceived as abstract. Evidence corroborates that the implementation of PBL holistically develops 21st-century competencies, such as critical thinking, problem-solving, creativity, and communication skills, all directly applicable to programming. The methodology also promotes students' self-efficacy, resulting in more active, participatory, and motivated students to overcome the challenges of the learning process.

Regarding specific practical applications in programming, the results indicate that PBL finds fertile ground in domains such as educational robotics and digital game development.

Especially among elementary school students, positive impacts were observed in the acquisition of computational thinking skills. The use of visual programming languages, such as Scratch, in conjunction with accessible hardware platforms, such as Arduino and Micro:bit, proved effective in reducing entry barriers, allowing young learners to direct their cognitive efforts towards developing algorithmic logic and creative expression, rather than syntactic concerns.

However, despite these evident benefits, the investigation revealed that the implementation of PBL in programming education faces substantial challenges. Issues related to project time management, the need for specialized teacher training, and the scarcity of appropriate teaching materials represent barriers. Budgetary limitations for hardware acquisition in school contexts with restricted financial resources also stand out, amplifying inequalities. It was also found that excessively structured or overly abstract projects can compromise the effectiveness of the methodology, resulting in superficial learning or high levels of student frustration. The effective application of PBL requires a high level of teacher preparation and training, often unavailable in contexts of limited infrastructure (Fernandes, 2014), and the heterogeneity of students' knowledge levels can make the project dynamic a complex task. The lack of adequate access to technological tools can also limit the potential of the methodology (Bell, 2010).

Despite these barriers, the challenges encountered also highlight the emergence of educational opportunities. The adoption of PBL in programming education prepares students for a rapidly transforming job market, where skills such as complex problem-solving, innovation, and critical thinking are increasingly demanded, in addition to the soft skills developed during the collaborative process (Harris, 2013; Wurdinger & Qureshi, 2015). In summary, the results of this research allow concluding that Project-Based Learning represents a robust and adaptable pedagogical methodology for programming education in educational contexts aimed at children and adolescents.

By contextualizing learning through practical challenges anchored in real-world problems, PBL demonstrates the ability to encourage creation, collaboration, and critical thinking development in an integrated manner. The methodology not only facilitates the acquisition of specific technical programming competencies but also catalyzes the holistic development of cognitive and socio-emotional skills fundamental for the formation of citizens prepared for the challenges of the 21st century, aligned with the constructivist assumptions of (Freire, 2014; Vygotsky, 1978).

The research offers theoretical contributions by supporting the effectiveness of Project-Based Learning (PBL) in training children and adolescents in programming, aligning with the constructivist assumptions of Vygotsky and Freire and enriching the understanding of the integration of theory and practice. In the practical sphere, the study provides subsidies for educators by identifying effective applications of PBL in educational robotics and digital game development, highlighting the relevance of tools such as Scratch, Arduino, and Micro:bit to reduce entry barriers. Additionally, it points out implementation challenges, such as time management and the need for teacher training and technological resources, and suggests strategies to optimize PBL application, preparing students for the demands of the digital job market and promoting inclusion.

However, its effectiveness depends on institutional support, teacher training, and the availability of adequate technological resources. It is therefore recommended that future implementations of PBL in programming education be accompanied by careful planning, investment in resources, and continuous teacher training programs, essential elements for transforming learning into a meaningful experience.

6. REFERENCES

Albar, S. B., & Southcott, J. E. (2021). Problem and project-based learning through an investigation lesson: Significant gains in creative thinking behaviour within the Australian foundation (preparatory) classroom. Thinking Skills and Creativity, 41, 100853. https://doi.org/10.1016/j.tsc.2021.100853

Alghamdi, A. K. H., Al Ghamdi, K. S., & Kim, S. Y. (2022). Epidemiology in Middle School Science Curricula: A COVID-19 Pre–post Intervention. Journal of Science Education and Technology, 31(5), 583–593. https://doi.org/10.1007/s10956-022-09975-y

Alimisis, D. (2019). Teacher Training in Educational Robotics: The ROBOESL Project Paradigm. Technology, Knowledge and Learning, 24(2), 279–290. https://doi.org/10.1007/s10758-018-9357-0

Alò, D., Castillo, A., Marín Vial, P., & Samaniego, H. (2020). Low-cost emerging technologies as a tool to support informal environmental education in children from vulnerable public schools of southern Chile. International Journal of Science Education, 42(4), 635–655. https://doi.org/10.1080/09500693.2020.1723036

Alvarez, A. (2023). The Perspectives and Experiences of Families from Mexican Immigrant Backgrounds with Collaborative Project-based Learning in their Children’s Bilingual Classroom. Journal of Latinos and Education, 22(3), 1192–1207. https://doi.org/10.1080/15348431.2021.1935257

Alves, S. V. L., Alves, E., & Baia, P. B. (2019). Programação e Aprendizagem Baseada em Projetos como estratégias no ensino de Pensamento Computacional para crianças e adolescentes. Anais dos Workshops do Congresso Brasileiro de Informática na Educação, 8(1), 759. http://milanesa.ime.usp.br/rbie/index.php/wcbie/article/view/9024

Amin, M., Suarsini, E., & Lukiati, B. (2022). 1 Biology Education Program, Postgraduate Program, Universitas Negeri Malang, Malang, Indonesia 1Biology Education Program, Faculty of Natural Sciences and Mathematics, Universitas Sulawesi Barat, Majene, Indonesia. International Journal of Early Childhood Special Education, 14(03).

Barak, M., & Asad, K. (2012). Teaching image-processing concepts in junior high school: Boys’ and girls’ achievements and attitudes towards technology. Research in Science & Technological Education, 30(1), 81–105. https://doi.org/10.1080/02635143.2012.656084

Bardin, L. (2011). Análise de conteúdo 4aed. Lisboa: Edições, 70, 1977.

Bascopé, M., & Reiss, K. (2021). Place-Based STEM Education for Sustainability: A Path towards Socioecological Resilience. Sustainability, 13(15), 8414. https://doi.org/10.3390/su13158414

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. The Clearing House. https://doi.org/10.1080/00098650903505415

Bhogal, S. K., Murray, M. A., McLeod, K. M., Bergen, A., Bath, B., Menon, A., Kho, M. E., & Stacey, D. (2011). Using Problem-Based Case Studies to Learn About Knowledge Translation Interventions: An Inside Perspective. Journal of Continuing Education in the Health Professions, 31(4), 268–275. https://doi.org/10.1002/chp.20140

Boud, D., & Feletti, G. (2013). The challenge of problem-based learning. Routledge.

Brasil, M. (2014). Diretrizes Metodológicas: Sistema GRADE—Manual de Graduação Da Qualidade Da Evidência e Força de Recomendação Para Tomada de Decisão Em Saúde. Ministério da Saúde, Secretaria de Ciência, Tecnologia e Insumos Estratégicos, Depar-tamento de Ciência e T.

Brown, A. L., & Jain, P. (2022). Doing projects with young children in a field-based early childhood education course. Educational Studies, 48(5), 692–707. https://doi.org/10.1080/03055698.2020.1798743

Bruner, J. S. (1960). On learning mathematics1. Mathematics Teacher, 53(8), 610–619.

Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities.

Cherniak, S., Lee, K., Cho, E., & Jung, S. E. (2019). Child-identified problems and their robotic solutions. Journal of Early Childhood Research, 17(4), 347–360. https://doi.org/10.1177/1476718X19860557

Chiazzese, G., Arrigo, M., Chifari, A., Lonati, V., & Tosto, C. (2019). Educational Robotics in Primary School: Measuring the Development of Computational Thinking Skills with the Bebras Tasks. Informatics, 6(4), 43. https://doi.org/10.3390/informatics6040043

Christou, E., Parmaxi, A., & Zaphiris, P. (2025). A systematic exploration of scoping and mapping literature reviews. Universal Access in the Information Society, 24(1), 941–951. https://doi.org/10.1007/s10209-024-01120-3

da Silva, B. E., & Pátaro, R. F. (2019). Convivência e resolução de conflitos na escola: Uma experiência com a Pedagogia dos projetos no Ensino Fundamental. Revista Eletrônica Pesquiseduca.

Fernandes, S. R. G. (2014). Preparing Graduates for Professional Practice: Findings from a Case Study of Project-based Learning (PBL). Procedia - Social and Behavioral Sciences, 139, 219–226. https://doi.org/10.1016/j.sbspro.2014.08.064

Freire, P. (2014). Pedagogia da esperança: Um reencontro com a pedagogia do oprimido. Editora Paz e Terra.

Frey, C. B., & Osborne, M. (2015). Technology at work: The Future of Innovation and Employment. https://www.oxfordmartin.ox.ac.uk/downloads/reports/Citi_GPS_Technology_Work.pdf

Fruett, F., Barbosa, F. P., Fraga, S. C. Z., & Guimaraes, P. I. A. (2024). Empowering STEAM Activities with Artificial Intelligence and Open Hardware: The BitDogLab.

Fullan, M. (2016). The new meaning of educational change. Teachers college press.

Gestwicki, P., & McNely, B. (2016). Interdisciplinary Projects in the Academic Studio. ACM Transactions on Computing Education, 16(2), 1–24. https://doi.org/10.1145/2732157

Ghosheh Wahbeh, D., Najjar, E. A., Sartawi, A. F., Abuzant, M., & Daher, W. (2021). The Role of Project-Based Language Learning in Developing Students' Life Skills. Sustainability, 13(12), 6518. https://doi.org/10.3390/su13126518

Grotta, A., & Prado, E. P. V. (2019). Benefits of the project-based learning to cope with computer programming education: A systematic literature review. PBL2019 Immersive Virtual International Conference, 2019b. Proceedings. 1, 10. https://www.researchgate.net/profile/Alexandre-Grotta/publication/380729234_BENEFITS_OF_THE_PROJECT-BASED_LEARNING_TO_COPE_WITH_COMPUTER_PROGRAMMING_EDUCATION_A_SYSTEMATIC_LITERATURE_REVIEW/links/664bfc05bc86444c72f2677c/BENEFITS-OF-THE-PROJECT-BASED-LEARNING-TO-COPE-WITH-COMPUTER-PROGRAMMING-EDUCATION-A-SYSTEMATIC-LITERATURE-REVIEW.pdf

Hämeen-Anttila, K., Saano, S., & Vainio, K. (2010). Professional Competencies Learned Through Working on a Medication Education Project. American Journal of Pharmaceutical Education, 74(6), 110. https://doi.org/10.5688/aj7406110

Harris, K. (2013). Teacher, I had a dream: A glimpse of the spiritual domain of children using project-based learning. International Journal of Children's Spirituality, 18(3), 281–293. https://doi.org/10.1080/1364436X.2013.858665

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? Educational Psychology Review, 16(3), 235–266. https://doi.org/10.1023/b:edpr.0000034022.16470.f3

Hojeij, Z., Tamim, R., Kaviani, A., & Papagianni, C. (2021). E-books and digital storytelling for Emirati school children: Project-based learning for pre-service teachers.

Hovington, S., Blanchet-Cohen, N., & Mann-Feder, V. R. (2020). INNOVATION IN A CAPSTONE COURSE IN YOUTH WORK. International Journal of Child, Youth and Family Studies, 11(3), 146–166. https://doi.org/10.18357/ijcyfs113202019713

Hsin, C.-T., & Wu, H.-K. (2023). Implementing a Project-Based Learning Module in Urban and Indigenous Areas to Promote Young Children's Scientific Practices. Research in Science Education, 53(1), 37–57. https://doi.org/10.1007/s11165-022-10043-z

Hurtado-Martín, M., López-Torres, L., Santín, D., Sicilia, G., & Simancas, R. (2023). El impacto del COVID-19 en el aprendizaje durante el confinamiento. Educación XX1, 26(1), 185–205. https://doi.org/10.5944/educxx1.33047

Inna, K., Liudmyla, T., Iryna, V., & Natalia, M. (2021). IMPLEMENTING THE THEORY OF MULTIPLE INTELLIGENCES INTO PROJECT-BASED MULTIMEDIA LEARNING AT PRIMARY SCHOOL. Information Technologies and Learning Tools, 82(2), 18–31. https://doi.org/10.33407/itlt.v82i2.4326

Jawaid, I., Javed, M. Y., Jaffery, M. H., Akram, A., Safder, U., & Hassan, S. (2020). Robotic system education for young children by collaborative-project-based learning. Computer Applications in Engineering Education, 28(1), 178–192. https://doi.org/10.1002/cae.22184

Jdidou, A., Aammou, S., & Er-Radi, H. (2023). ENHANCING PROBLEM-SOLVING AND PROGRAMMING ABILITIES IN CHILDREN THROUGH PROJECT-BASED LEARNING. Conhecimento & Diversidade, 15(39), 11–21. https://doi.org/10.18316/rcd.v15i39.11155

Kaldi, S., & Zafeiri, S. (2023). Identifying reflective modes in pre-service teachers' written reflections on the implementation of project-based learning during the school practicum. Frontiers in Education, 7, 1072090. https://doi.org/10.3389/feduc.2022.1072090

Kersten, S. (2017). Becoming Nonfiction Authors: Engaging in Science Inquiry. The Reading Teacher, 71(1), 33–41. https://doi.org/10.1002/trtr.1577

Kim, D., Cho, E., Couch, S., & Barnett, M. (2019). Culturally Relevant Science: Incorporating Visualizations and Home Culture in An Invention-oriented Middle School Science Curriculum. Technology & Innovation, 20(3), 251–266. https://doi.org/10.21300/20.3.2019.251

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. Improving Schools, 19(3), 267–277. https://doi.org/10.1177/1365480216659733

L. Hartman, S., & Littell, W. N. (2020). Crossing colleges: The impact of an engineering design collaboration on early childhood teacher candidate development. Journal of Early Childhood Teacher Education, 41(4), 384–402. https://doi.org/10.1080/10901027.2019.1704950

Lara, S., González-Torres, M. C., Ibarrola-García, S., & Zúñiga, A. (2021). Fostering Communicative Competence and Motivation through ComunicARTE Program. Sustainability, 13(5), 2600. https://doi.org/10.3390/su13052600

LeTendre, G. K., & Gray, R. (2024). Social robots in a project-based learning environment: Adolescent understanding of robot–human interactions. Journal of Computer Assisted Learning, 40(1), 192–204. https://doi.org/10.1111/jcal.12872

Lien, K.-M., Kuo, C.-C., & Pan, H.-L. (2023). Improving Concentration and Academic Performance of a Mathematically Talented Student with ASD/ADHD: An Enrichment Program. Education Sciences, 13(6), Artigo 6. https://doi.org/10.3390/educsci13060588

Lombardi, L., Mednick, F. J., De Backer, F., Lombaerts, K., & Prof. Dr., Vrije Universiteit Brussel, Department of Educational Sciences, Belgium, koen.lombaerts@vub.be. (2022). Teachers' Perceptions of Critical Thinking in Primary Education. International Journal of Instruction, 15(4), 1–16. https://doi.org/10.29333/iji.2022.1541a

Lu, S.-Y., Lo, C.-C., & Syu, J.-Y. (2022). Project-based learning oriented STEAM: The case of micro–bit paper-cutting lamp. International Journal of Technology and Design Education, 32(5), 2553–2575. https://doi.org/10.1007/s10798-021-09714-1

Malik, M., & Sime, J.-A. (2022). Orchestrating Learning Together and Development of Team-Trust in Neuro-Typical and Neuro- Atypical Students: A Multi-Case Study.

McCullough, M. B., Martin, M. D., & Sajady, M. A. (2018). Implementing Green Walls in Schools. Frontiers in Psychology, 9, 619. https://doi.org/10.3389/fpsyg.2018.00619

Mettas, A. C., & Constantinou, C. C. (2007). The Technology Fair: A project-based learning approach for enhancing problem solving skills and interest in design and technology education. International Journal of Technology and Design Education, 18(1), 79–100. https://doi.org/10.1007/s10798-006-9011-3

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Teachers College Record: The Voice of Scholarship in Education, 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Neto, O. M., Lima, R. M., & Mesquita, D. (2019). Changing an Engineering curriculum through a co-construction process: A case study in a Brazilian Higher Education School.

Parwoto, P., Ilyas, S. N., Bachtiar, M. Y., & Marzuki, K. (2024). Fostering creativity in kindergarten: The impact of collaborative project-based learning. South African Journal of Childhood Education, 14(1). https://doi.org/10.4102/sajce.v14i1.1462

Peeples, D., Guerrero, A., Bernstein, B., Hunt, J., Ong, S. H., Santos, C., Sexson, S., & Skokauskas, N. (2017). Comparing and Contrasting the Use of Problem-Based Learning in Child and Adolescent Psychiatry Programs. Academic Psychiatry, 41(5), 587–591. https://doi.org/10.1007/s40596-017-0719-z

Plattner, H., Meinel, C., & Leifer, L. (2017). Design thinking research: Making distinctions: Collaboration versus cooperation. Springer.

Pollock, A., & Berge, E. (2018). How to do a systematic review. International Journal of Stroke, 13(2), 138–156.

Polman, J. L. (2004). Dialogic Activity Structures for Project-Based Learning Environments.

Prince, M. J., & Felder, R. M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. Journal of Engineering Education, 95(2), 123–138. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x

Purnomo, H., Karim, A., Mansir, F., & Valero-Matas, J. A. (2022). Covid-19 Pandemic: Project-Based Learning as Interprofessional Learning Model to Improve Student With The Special Needs' Self Efficacy. Sociología y Tecnociencia, 12(2), 284–306. https://doi.org/10.24197/st.2.2022.284-306

Rodrigo Segura, F. (2022). Miradas sobre la guerra y el exilio desde la LIJ / Perspectives on war and exile from Children's and Youth Literature. TEJUELO. Didáctica de la Lengua y la Literatura. Educación, 36, 281–314. https://doi.org/10.17398/1988-8430.36.281

Romo-Mayor, P., & Pellicer-Ortín, S. (2022). Revitalising the Role of Literature in the Contemporary EFL Secondary Classroom: A Small-scale Study. Didáctica. Lengua y Literatura, 34, 15–48. https://doi.org/10.5209/dill.81346

Savin-Baden, M. (2007). A practical guide to problem-based learning online. Routledge. https://www.taylorfrancis.com/books/mono/10.4324/9780203938140/practical-guide-problem-based-learning-online-maggi-savin-baden

Schneider, B., Chen, I.-C., Bradford, L., & Bartz, K. (2022). Intervention initiatives to raise young people's interest and participation in STEM. Frontiers in Psychology, 13, 960327. https://doi.org/10.3389/fpsyg.2022.960327

Smith, C. S., & Hung, L.-C. (2017). Using problem-based learning to increase computer self-efficacy in Taiwanese students. Interactive Learning Environments, 25(3), 329–342. https://doi.org/10.1080/10494820.2015.1127818

Stojanović, B. J., Ristanović, D., Živković, P., & Džaferović, M. (2023). Project-Based Learning in Early Childhood Education in Serbia: First Experiences of Preschool Teachers. International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE), 11(2), 213–220. https://doi.org/10.23947/2334-8496-2023-11-2-213-220

Tang, K.-S., McLure, F., Williams, J., & Donnelly, C. (2024). Investigating the role of self-selected STEM projects in fostering student autonomy and self-directed learning. The Australian Educational Researcher, 51(5), 2355–2379. https://doi.org/10.1007/s13384-024-00696-2

Thomas, J. W. (2000). A review of research on project-based learning. https://tecfa.unige.ch/proj/eteach-net/Thomas_researchreview_PBL.pdf

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British journal of management, 14(3), 207–222.

Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. International Journal of Technology and Design Education, 23(1), 87–102. https://doi.org/10.1007/s10798-011-9160-x

Veraksa, A. N., Plotnikova, V. A., & Ivenskaya, P. R. (2024). Development of Social Competence in Preschoolers with Different Levels of Executive Functions: Role Play and Project-Based Learning. Psychological Science and Education, 29(3), 96–112. https://doi.org/10.17759/pse.2024290306

Videnovik, M., Vlahu-Gjorgievska, E., & Trajkovik, V. (2021). To code or not to code: Introducing coding in primary schools. Computer Applications in Engineering Education, 29(5), 1132–1145. https://doi.org/10.1002/cae.22369

von Wangenheim, C. G., Nunes, V. R., & Dos Santos, G. D. (2014). Ensino de computaçao com scratch no ensino fundamental–um estudo de caso. Revista Brasileira de Informática na Educação, 22(03), 115.

Vygotsky, L. S. (1978). Socio-cultural theory. Mind in society. Cambridge, MA: Harvard University.

Warschauer, M. (2004). Technology and social inclusion: Rethinking the digital divide. MIT press.

Wijnen, M., Loyens, S. M. M., Smeets, G., Kroeze, M., & Van Der Molen, H. (2017). Comparing problem-based learning students to students in a lecture-based curriculum: Learning strategies and the relation with self-study time. European Journal of Psychology of Education, 32(3), 431–447. https://doi.org/10.1007/s10212-016-0296-7

Wright, J. T. C., Silva, A. T. B., & Spers, R. G. (2010). O mercado de trabalho no futuro: Uma discussão sobre profissões inovadoras, empreendedorismo e tendências para 2020. RAI-Revista de Administração e Inovação, 7(3), 174–197.

Wurdinger, S., & Qureshi, M. (2015). Enhancing College Students' Life Skills through Project Based Learning. Innovative Higher Education, 40(3), 279–286. https://doi.org/10.1007/s10755-014-9314-3