

Systematic Review

Phases and Activities of Technology-Integrated Project-Based Learning in K-12: Findings from a Systematic Literature Review

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Abstract

Despite the growing adoption of technology-integrated project-based learning (PjBL) in K-12 education, little research has systematically examined its implementation. To address this gap, we conducted a systematic literature review, guided by PRISMA standards, of 24 studies describing successful PjBL interventions using digital technologies. Our findings reveal that while most interventions include the initial phases of PjBL, fewer than half incorporate a closing phase, often neglecting revision and reflection. Additionally, the activities within each phase are partial, omitting key elements necessary to fully leverage this methodology, which poses challenges to the comparability and transferability of PjBL. Moreover, the use of digital technologies is often partial and limited. To improve implementation, we analyze the full range of activities and technology use and propose an empirical model for designing future PjBL interventions and enhancing teacher training and professional development. Furthermore, we emphasize the need to formally integrate project management skill development into PjBL practices.

Keywords: project-based learning (PBL PjBL); primary education; secondary education; digital technologies; PjBL phases; systematic literature review



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1. Introduction

Project-based learning (PjBL) has become established as an effective educational methodology that facilitates the development of skills in students. Interventions using PjBL have been reported to improve student learning outcomes and foster skills such as critical thinking, collaboration, and creativity (Almulla, 2020; Chen & Yang, 2019; J. Krajcik et al., 2022; L. Zhang & Ma, 2023). Furthermore, evidence shows that PjBL also promotes autonomous learning, collaborative work, and the development of personal skills in students, such as self-confidence and emotional management (J. S. Krajcik & Shin, 2022), making it a comprehensive teaching methodology (Ruiz Hidalgo & Ortega-Sánchez, 2022).

PjBL is frequently integrated with digital technologies, as these tools foster motivation and enhance product creation, collaboration between students, and access to learning resources (Chen & Yang, 2019; J. S. Krajcik & Shin, 2022; Markula & Aksela, 2022). Tools such as project management platforms and digital simulations have been used to support the inquiry, organization, and communication of ideas, as well as for the creation and critique of prototypes in the development of final products (Farber, 2017; J. S. Krajcik & Czerniak, 2018).

The positive results of using the PjBL methodology in the school context, especially when incorporating digital technologies during project development, show the importance

of systematizing previous experiences to enhance its use. However, based on a preliminary review of a set of articles (Alò et al., 2020; Dasgupta et al., 2019; Hwang et al., 2018; Song, 2018), we identified that the phases developed in the projects, as well as the use of digital technologies, were considerably different when comparing interventions, which could constitute a risk to the potential impact of the methodology.

Considering this risk, the purpose of this study is to identify and systematize the phases and activities developed in PjBL-based interventions in K-12 and to analyze the uses of digital technologies at each phase through a systematic literature review. This dual focus offers a more integrated understanding of how technology supports PjBL interventions, providing guidelines for assessing their implementation and potential scalability across diverse school contexts.

2. Previous Research

2.1. Project-Based Learning (PjBL)

PjBL has been described as a teaching process, a learning process, a type of curriculum, and an educational approach (Hasni et al., 2016). J. S. Krajcik and Shin (2022) define PjBL environments according to six key characteristics: (1) they start with a driving question that is meaningful to the students; (2) they focus on achieving certain learning objectives; (3) students participate in discipline-specific inquiry and problem-solving activities in which they apply their knowledge; (4) collaborative activities are developed that include different members of the educational communities; (5) students use learning technologies to develop challenging activities; and (6) they create tangible products that answer the driving question and are shared beyond the classroom. These characteristics are defined similarly in other sources and reviews on the subject (Farber, 2017; Hasni et al., 2016; Kokotsaki et al., 2016; Markula & Aksela, 2022; Santhosh et al., 2023).

In terms of implementing PjBL in the classroom, Larmer et al. (2015) describe a “Project Path”, which is consistent with the characteristics described (Figure 1).

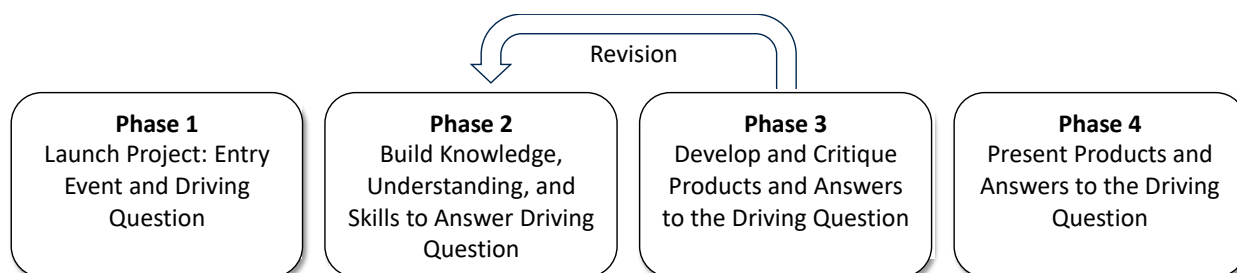


Figure 1. Project Path. Source: Adapted from Larmer et al. (2015, p. 104).

In Phase 1, students participate in an entry event that seeks to motivate them, co-define a driving question, and plan the following phases, including the formation of groups and the definition of products. In Phase 2, they acquire the knowledge and skills necessary to develop the project through independent research activities, resources, and lessons delivered by teachers. During Phase 3, students apply what has been learned, and develop drafts and prototypes, which are subjected to criticism by third parties, before adjusting them and developing the product. Finally, in Phase 4, students present their products, reflect on the process, and are evaluated.

Although suggestions for implementing the PjBL methodology exist, there is little research that systematically reviews the empirical evidence of the phases involved in PjBL implementation in K-12. In this regard, in their multiple-case study, Markula and Aksela (2022) used the inquiry-based learning framework proposed by Pedaste et al. (2015) to

examine the extent to which “scientific practices” were present in the implementation of PjBL. The results highlight that, although scientific practices are present, elements such as the formulation of questions and goals by students are scarce. Based on their findings, they suggest that additional support is needed to foster the research-based implementation of PjBL and that there is a need to study the key characteristics from the perspective of flexible PjBL implementation.

In other education levels, such as engineering education, [Sukacké et al. \(2022\)](#) found that papers describing PjBL do “not always follow the same phases, nor do the papers provide detailed information on the implementation on the same level of informativeness” (p. 13). They summarize the PjBL implementation phases as Question (the process starts with a question to solve), Plan (generate possible solutions and agree on a plan to develop the end product), Research (review of the literature, but also learning from other similar experiences, and, if stakeholders are involved, getting to know their context), Produce (the first step is prototyping the product and validating its use; the second step is the creation of the end-product or solution to the initial answer), Improve (improvement after testing the possible solution(s) or product(s) created), and Present (the solution is presented to the teachers, peers, and stakeholders).

From a different perspective, since PjBL is a methodology focused on project development, studies on the teaching of project management ([Delle-Vergini et al., 2024](#); [Ebm et al., 2024](#); [Fernandes et al., 2024](#)) recognize four main phases. These phases may vary in their nomenclature, but the activities considered in each are similar. They correspond to:

- **Initiation:** consists of defining the problem or purpose of the project, establishing objectives, scope, and resources, and exploring ideas. Management artifacts include resource lists, mind maps, project definition documents, and team-working agreements. Initial meetings and alignment workshops are also held to organize the team’s objectives, skills, and practices.
- **Planning:** Focuses on planning activities and tasks, identifying resources, and defining roles and responsibilities. Detailed plans are developed for project scope, schedules, budgets, and responsibility assignment matrices. Communication and resource acquisition are planned.
- **Execution:** The production and presentation of the project results and the fulfillment of the objectives are carried out. Final products include scale models, prototypes, solutions, services, and designs. The presentation of these products can be performed through exhibitions, contests, and portfolios, among others. Students usually act as project managers, ensuring that the objectives are met.
- **Closing:** Focuses on reviewing and reflecting on the project. It involves stakeholder feedback, the celebration of success, recognition, and self-reflection. Project success or failure, performance, and lessons learned are documented. Artifacts include project management evaluation rubrics. Performance is analyzed, lessons learned are refined, process standardization is assessed, and results are presented to all stakeholders.

It is clear that the phases and activities described by [Sukacké et al. \(2022\)](#) differ from those proposed by [Larmer et al. \(2015\)](#), as well as from those used to teach project management ([Delle-Vergini et al., 2024](#); [Ebm et al., 2024](#); [Fernandes et al., 2024](#)). This confirms the need to systematically review PjBL implementation in K-12 research-based interventions. Based on these results, the first research question asks what phases and activities are implemented in K-12 PjBL-based interventions.

2.2. Use of Digital Technologies in PjBL

The use of technologies in PjBL is a fundamental characteristic to transform the classroom into a dynamic and participatory environment where students can build their

learning (Hasni et al., 2016; J. S. Krajcik & Czerniak, 2018; J. S. Krajcik & Shin, 2022; Markula & Aksela, 2022). Technological tools allow students to access information in real time and develop practical activities, as well as actively engage in problem solving. In addition, they act as a support for collaborative learning and provide opportunities to move beyond traditional teaching models, thus improving student motivation and performance (Chen & Yang, 2019; Pellegrino & Hilton, 2012).

Hasni et al. (2016) reviewed trends in K-12 science and technology. PjBL research identified that 15 of the 48 articles reviewed mentioned possibilities for students to use information and communication technologies (ICTs), consisting of accessing information, actively participating in the learning process, and, in particular, in inquiry, as well as finding and communicating solutions and creating products. In addition, they highlight the possibility of manipulating dynamic representations of the phenomena explored and of working autonomously. Regarding the tools used, they mention portable technology, computers, digital cameras, probes, dynamic simulations, electronic resources, and computer-based modeling tools.

Furthermore, Markula and Aksela (2022) suggest that the use of digital technologies in projects developed by K-12 students can be divided into two categories. The first is defined as “information and communication technologies” (ICT), which includes all those technologies that are commonly available in schools and student homes, such as text and video editing tools and programs to perform calculations. The second category, called “scientific technology”, relates to more specialized technologies used to make scientific observations and measurements, such as microscopes, voltmeters, nitrogen indicators, and pH probes. Additionally, Farber (2017) proposes uses of digital technologies focused on reflection, understood as the connection between the goals that students have established and the learning objectives. This reflection can be encouraged through exit tickets, logs, videos, artwork, blogs, or other technological means such as Wordle (word clouds), ThingLink (to make interactive images by creating tags), Padlet (for brainstorming or organizing information), or making mind maps with Google or Prezi.

As can be seen, although different researchers have described the use of digital technologies during the implementation of PjBL, these descriptions do not allow us to understand what the specific use of the technologies is, nor at what phase they can be incorporated. This is important, since by identifying the contribution of these technologies at each phase of PjBL implementation, it is possible, on the one hand, to facilitate the adoption of these technologies within the framework of this teaching strategy and, on the other, to identify opportunities to incorporate the use of new technologies at the different phases of the process.

Within this framework, it is important to systematically investigate the use of digital tools in the implementation of PjBL-based interventions. Therefore, the second research question asks what roles are played by digital technologies in the implementation of PjBL.

3. Methods

To prepare this systematic review, we followed the steps of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which indicates the essential elements that must be followed to carry out systematic reviews and meta-analyses (Page et al., 2021).

To search for articles, we used the Core Collection of the Web of Science (WoS) database, using terms related to project-based learning (“project based learning”, “project-based learning”, “PBL”, “PjBL”) crossed with terms for technology (“technology”, “web”, “online”, “blended”, “seamless”, “digital”, “ICT”, “mobile”, “VR”, “virtual reality”, “AR”, “augmented reality”, “technology-assisted”, “BYOD”, “bring your own device”, “gamification”).

At the same time, we excluded terms for educational levels and participants other than K-12 (“universit*”, “colleg*”, “higher education”, “graduate*”, “pre-service”, “undergraduate*”).

We used Topic (title, abstract, or keywords) as the search field, with the following filters: the search period was between 2014 and 2024; the language of the articles was English; and the document type was articles or early access. In choosing the WoS indexes, the Emerging Sources Citation Index (EDN = (“WOS.SCI” OR “WOS.SSCI” OR “WOS.AHCI” OR “WOS.ISTP”)) was excluded; the Citation Topics Meso (TASCA = (“METEOROLOGY ATMOSPHERIC SCIENCES”)) was discarded; and the Citation Topics Micros that were not in technology fields (such as health sciences) (TMIC = (. . .)) were also excluded.

The inclusion criteria for selecting the publications were as follows: (a) participants were required to be K-12 students; (b) publications had to describe educational interventions based on experimental or quasi-experimental research designs; (c) they had to apply some project-based learning model; (d) they had to explicitly use some kind of digital technology; (e) the modalities considered were face-to-face, virtual, or mixed; and (f) the research results had to present some degree of positive impact on the learning or learning process of the students of a conceptual, procedural, and/or attitudinal nature.

With regard to the exclusion criteria, we excluded publications with participants who did not belong to K-12 levels and in which the PBL or PjBL keywords referred to the problem-based learning methodology.

Taking the above into account, we found 401 results, from which two duplicates were discounted. Once the inclusion and exclusion criteria were applied, 48 publications were selected for the review. Two researchers reviewed and discussed the eligibility of the articles. In cases where there was no consensus, two additional researchers allowed the review to be triangulated and a decision to be reached. The results are shown in Figure 2.

To define the phases of PjBL implementation, we considered those commonly used to describe the project management cycle (PMI, 2021; Westland, 2006), which correspond to: initiation; planning; execution; and closing. The activities to be considered at each phase were defined based on those described in the literature associated with the teaching of project management (Delle-Vergini et al., 2024; Ebm et al., 2024; Fernandes et al., 2024), adapting them to the educational context (for example, references to economic resources or budget were not considered).

Based on the above, the initiation phase activities include reviewing the background to the problem, reviewing theoretical concepts associated with the problem, defining the problem to be resolved, and/or establishing the challenge, objectives, or research questions. Activities to define and develop the skills required by the students to carry out the project are also included in this phase. The activities of the planning phase correspond to the planning of activities and tasks, the definition of work teams, and the assignment of roles and responsibilities. The execution phase includes activities such as designing the product, defining the requirements and materials that will be needed, and developing the product, which, in many cases, involves an analysis of the intermediate results and design improvements. End products include scale models, solutions, services, and end-product designs. This phase also includes presentation of the finished products. The final stage of the project is the closing phase, which takes place after the presentation of the finished product. It includes an evaluation of the product and a reflection on learning, both in terms of the process and the final product.

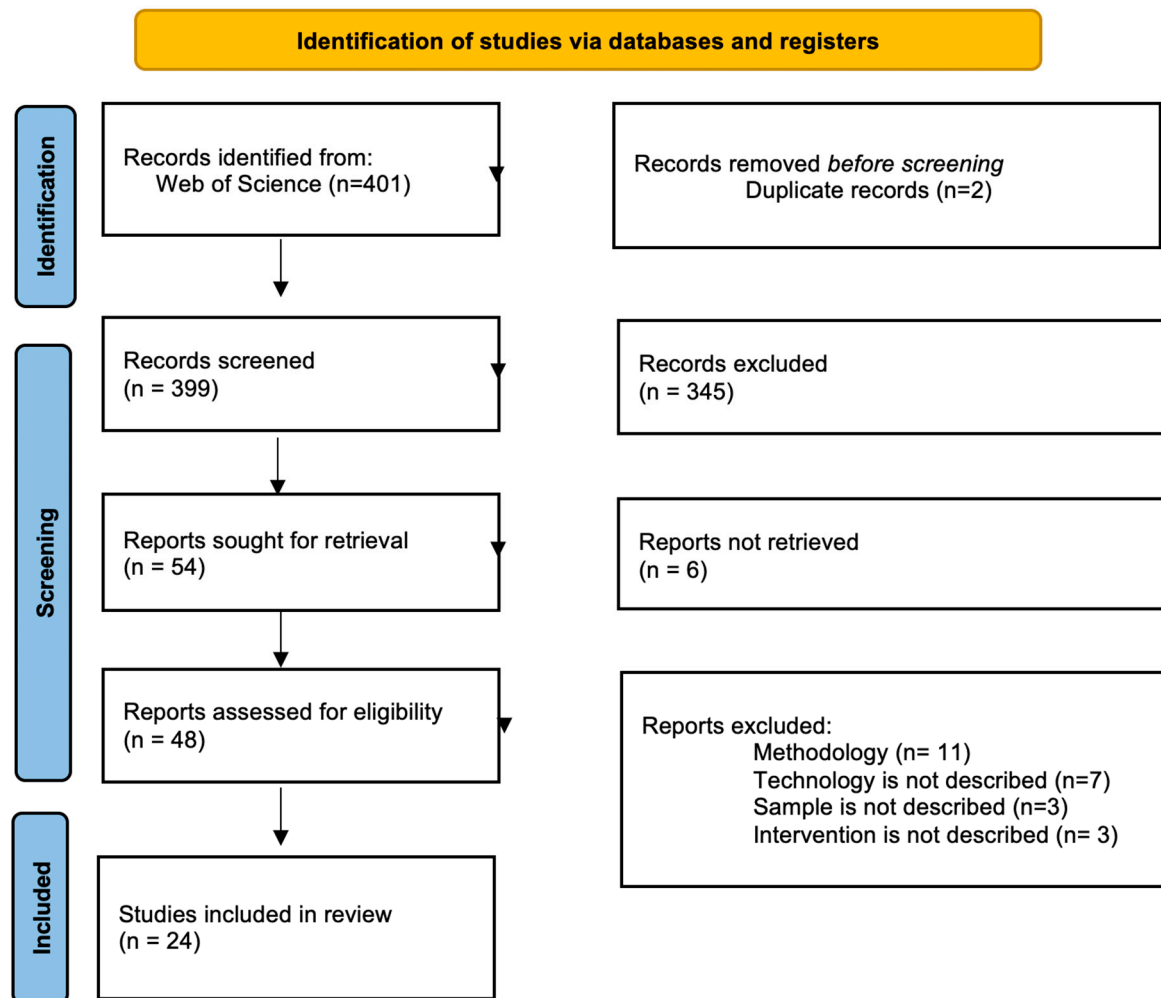


Figure 2. Investigation method following the PRISMA guidelines. Source: Authors' own, created using the website of [Haddaway et al. \(2022\)](#).

The above allowed us to structure a framework from which a directed content analysis was carried out ([Hsieh & Shannon, 2005](#)), identifying and classifying the activities described in the selected articles. When activities other than those described in the defined framework were mentioned, the purpose of said activity was discussed and incorporated into one of the four main phases, expanding its definition if necessary.

Additionally, to define the roles of digital technologies, we analyzed the activities that involved the use of digital technologies at each phase in order to determine their characteristics and define general categories through a conventional content analysis ([Hsieh & Shannon, 2005](#)) using an inductive approach ([Skjott Linneberg & Korsgaard, 2019](#)).

4. Results

4.1. Phases of Project-Based Learning

We present the activities described in the reviewed articles below, grouping them into the four phases of PjBL implementation in the K-12 educational context defined for this analysis. Additionally, Table 1 presents a summary of the activities identified in each article.

Table 1. Summary of phases and activities of PjBL interventions.

Phase	Activity	Focus	Alò et al. (2020)	Applebaum et al. (2017)	Awad (2023)	C. C. Chang and Chen (2022)	C. Y. Chang et al. (2023)	Cheng and Yang (2023)	Dasgupta et al. (2019)	Hsiao et al. (2022)	Hu et al. (2023)	Hwang et al. (2018)	Li et al. (2022)	Lou et al. (2017)	Lu et al. (2022)	Owens and Hite (2020)	Queiruga-Dios et al. (2021)	Song (2018)	Vallera and Bodzin (2020)	Valls Pou et al. (2022)	Videnovik et al. (2021)	Wang (2020)	Winarni et al. (2024)	Xie and Zhang (2023)	Zha et al. (2021)	D. Zhang and Hwang (2023)	Total Focus	Total Activity	Total Phase	
Initiation	Background review			1	1		1	1	1					1		1		1			1			1			10	10	24	
	Theoretical concepts review	Teachers	1	1		1	1		1	1	1		1	1	1			1		1	1		1	1		1	1	16		24
		Students			1				1				1	1			1	1		1		1		1	1		10			
	Definition of objectives, challenge, or research question	Teachers		1					1	1		1				1	1			1					1			8		12
		Students				1	1												1					1				4		
	Development of competencies	Tools		1	1	1	1	1	1		1		1			1		1			1	1	1	1	1	1	1	1		17
		Project management				1												1										2		17
		Others														1					1					1		3		
Planning	Plan activities and tasks			1			1		1	1	1		1	1	1		1	1	1	1			1			1	14	14	21	
	Define the work teams	Groups	1	1	1	1				1				1		1	1	1		1	1		1	1	1	1	1	15		18
		Mixed												1		1				1								3		
	Define roles and responsibilities													1			1					1					3	3		

Table 1. Cont.

Phase	Activity	Focus	Alò et al. (2020)	Applebaum et al. (2017)	Awad (2023)	C. C. Chang and Chen (2022)	C. Y. Chang et al. (2023)	Cheng and Yang (2023)	Dasgupta et al. (2019)	Hsiao et al. (2022)	Hu et al. (2023)	Hwang et al. (2018)	Li et al. (2022)	Lou et al. (2017)	Lu et al. (2022)	Owens and Hite (2020)	Queiruga-Dios et al. (2021)	Song (2018)	Vallera and Bodzin (2020)	Valls Pou et al. (2022)	Videnovik et al. (2021)	Wang (2020)	Winarni et al. (2024)	Xie and Zhang (2023)	Zha et al. (2021)	D. Zhang and Hwang (2023)	Total Focus	Total Activity	Total Phase		
Execution	Design the product	Design the product		1			1		1	1		1	1		1	1	1			1			1	1		1	13	13	24		
	Define requirements and materials	Collect data					1	1					1					1							1			5		17	
		Requirements	1	1						1						1		1				1		1		1		8			
		Materials				1					1				1					1			1					5			
	Product development	Models or prototypes					1										1							1	1			4		24	
		Iterative		1					1	1	1		1	1	1	1				1	1	1					1	12			
		Components	1		1	1						1						1	1	1						1		8			
	Product presentation	Institution				1			1		1							1		1		1					1			8	15
		External	1		1		1												1		1					1				6	
		Support material																		1				1						2	
Trial														1														1			
Closing	Product evaluation	Teachers						1		1														1				3	9	11	
		Peers		1									1								1					1		5			
		Mixed																1									1				
		External													1												1				
	Reflection on the process or product	Reflections		1					1					1	1				1			1			1		7	7			

4.1.1. Initiation

A **background review of the problem** was presented in 42% of the articles, where the problem was contextualized to introduce the project topic and connect it to previous knowledge. In other cases, real-world situations were presented that illustrated the problem to be solved, such as “the teacher starts the lesson with a picture of bird habitat destruction in the real world. Then teacher asks the class: What can be the possible consequences of the destruction?” (Xie & Zhang, 2023, p. 9). This was also performed through observation or exploration of the situation in order to better understand the problem (C. Y. Chang et al., 2023; Song, 2018), such as “they joined a field trip to a school farm to gain some understanding of plants and their living environments” (Song, 2018, p. 8), or using simulators, “students explore a virtual model of a balloon-powered, self-propelled vehicle, whose features can be manipulated” (Applebaum et al., 2017, p. 183).

In 100% of the articles reviewed, theoretical concepts related to the problem were addressed; from these, in 16 articles the review was guided by the teachers, and in ten articles it was addressed through exploration by the students. In the first case, teachers taught basic concepts related to the project theme, as well as more complex concepts that included the application of advanced theories, the integration of multiple disciplines, critical analysis of information, and problem solving that required deeper and more strategic thinking. In the second case, students searched for information in both digital and physical media (e.g., books), explored the concepts through the use of simulators, and/or discussed the content. In these cases, the teachers played the role of consultants with whom the students could discuss any doubts they had about the content. For example, in the article by Li et al. (2022), they mention that the students completed an introductory unit of the contents and then discovered the information through experimentation with simulators.

The **definition of an objective, challenge, or research question** was included in 50% of the articles. In eight articles, it was performed by the teacher. In other articles (Awad, 2023; C. C. Chang & Chen, 2022; Song, 2018), the students defined the problem that would be addressed in the project based on the lessons and reflections drawn from the background review. In some cases, the choice was restricted to the specific object within the framework of the defined problem: “They also reflected on what they learned in the field trip [...] and deciding what plants they wanted to study in their project-based learning as group common goals” (Song, 2018, p. 8). In others, the choice was more open within a general theme: “Throughout the study [...], the students were asked to choose a challenge SWCS topic that interested them, and they would like to study independently” (Awad, 2023, p. 13).

The **development of competencies** required for the implementation of the project could be identified in 71% of the articles. These correspond to technical skills, which include learning to use specific tools and technologies necessary for the execution of the project, skills associated with project management, and other transversal skills such as creativity and communication.

In all these articles, students were taught how to use the tools that would be employed, including, for example, basic programming concepts and the use of sensors.

Only two articles mention the development of project management skills. In Awad (2023) article, instructions were given regarding how to work: “The teachers gave the students short explanations about general issues that are common to all projects such as how to address a subject, how to use media or find references” (Awad, 2023, p. 14). Along the same lines, Queiruga-Dios et al. (2021) define a student management team, where the development of their functions requires the development of leadership and management skills.

Finally, three articles illustrate the development of transversal skills. The article by Lu et al. (2022) describes a specific activity aimed at developing creativity: “brainstorming

helped students to develop divergent thinking skills, as well as to enhance fluency and openness in the cognitive facet of creativity” (p. 2568). Furthermore, [Valls Pou et al. \(2022\)](#) mention the incorporation of activities aimed at developing communication, collaboration, and creativity. [D. Zhang and Hwang \(2023\)](#) also show that the development of collaboration through peer assessments was encouraged.

4.1.2. Planning

With regard to the **planning of activities and tasks**, 58% of the articles mention activities aimed at product planning. For example, “Groups worked out plans for growing the plants they chose, such as what plant to grow, how many samples they would like to prepare and what living conditions for each sample; how to observe and document their growth, and carried out their plans raising them” ([Song, 2018](#), p. 8).

The **definition of work teams** is mentioned in 75% of the articles, where the participating students were organized into groups. In most cases, no criterion for group formation was specified, and in others, they were organized in a random manner. For example, “Students were assigned into 16 groups at random, and there were three students in each group” ([C. C. Chang & Chen, 2022](#), p. 3). Additionally, three articles ([Li et al., 2022](#); [Lu et al., 2022](#); [Vallera & Bodzin, 2020](#)) mention that some project activities were carried out individually and others in a group.

Only 13% of the articles mention explicit instructions regarding the **assignment of roles and responsibilities**. One article indicates that responsibilities within the groups were defined: “The teacher grouped the students and instructed them to divide the group’s tasks among all group members and to specify responsibilities, such as collecting and sorting out network information, collecting materials and producing design drawings to nurture the flexibility of their thinking” ([Lou et al., 2017](#), p. 2394). In another article a group of students acted as a “management team” to coordinate the course project: “While the multimedia production was in development, a management team was created in the reference classroom, made up of five student volunteers who adopted the role of project manager and spokespersons” ([Queiruga-Dios et al., 2021](#), p. 7).

4.1.3. Execution

The **design of the product** is described in 54% of the articles. This activity involves generating ideas regarding the features of the product to be developed using sketches or scripts. In another article, models were created collaboratively using a virtual platform (Canvas) to share ideas ([Owens & Hite, 2020](#), p. 7). Additionally, [Dasgupta et al. \(2019\)](#) incorporate a “design journal” in the design stage, where students are asked to record ideas about their prior knowledge and learning.

In 71% of the articles the **definition of requirements and materials** for the product is mentioned. In seven of these articles, the requirements were given as part of the teacher’s instructions, and in the article by [Xie and Zhang \(2023\)](#), the requirements were inferred by the students themselves: “Derived from the comprehension of birds’ adaptive characteristics, each student group is required to select a particular bird species and determine the functional requirements for that kind of bird’s feeder” (p. 9). In five of these articles, the students defined the materials to be used for the development of the product. Five other articles describe activities to collect data needed for product development. In [Song \(2018\)](#) article, students observed and documented plant growth under different conditions (for example, light intensity and water amount) to better understand the factors that contributed to growth. In [Li et al. \(2022\)](#), students collected data on the internal temperature of their desalination units during testing and uploaded this data along with images of their designs to the WISE platform. In [Xie and Zhang \(2023\)](#) and [C. Y. Chang et al. \(2023\)](#), students

made observations about the phenomenon of interest, in the former to identify the adaptive characteristics of birds and their habitats, and in the latter to identify the needs of their peers in order to make a chair.

The **production of products** is mentioned in all the articles and was carried out in various ways, including the production of models or prototypes, iterative processes, and following a sequence of steps and stages.

Three articles describe the development of models, where initial design proposals were drawn up and presented to the teacher or colleagues and tested to identify possible improvements for the development of the final product. In one article, small-scale prototypes of the product were developed and discussed to identify improvements: “In the final week of this phase, students used 3-D printing to make the prototype of their self-designed device” (C. Y. Chang et al., 2023, p. 4).

Twelve articles mention that development was iterative, where the elaboration of products was subject to constant evaluation, and development cycles were carried out to overcome design problems. For example, “they have been focused on analyzing the given task, finding a current sequence of instructions, producing a code, testing, finding, and correcting code errors” (Videnovik et al., 2021, p. 6).

In eight articles, students developed parts of the product that were then integrated to build the final product. For example, in the article by Hu et al. (2023), three consecutive stages are mentioned in which students build product components and then integrate those components in a final stage (i.e., constructing a 3-D paper house, making an IoT control module, writing and editing robot scripts for storytelling, and demonstrating an integrated system component). This approach is similar to that described by Alò et al. (2020), where, in four workshops, students progressed in stages towards the construction of an environmental micro-station with Arduino. Meanwhile, in the article by Song (2018), product development was carried out in a multi-stage process, where the elements that make up the final product were prepared: “In this process, they needed to prepare the containers for the plants at home, collect data by taking records of the plants’ growth with thermo-hygrometers and light meters, take photos daily to document the plants’ growth, make AR artifacts whenever they considered necessary, and upload the files to Google Classroom daily. They also needed to analyze the data and present the results” (Song, 2018, p. 8).

In 63% of the articles, an activity to **present the product was included**. Eight articles mentioned presentation activities conducted within the school to members of the institution. In six other articles the presentations were made to external stakeholders.

In addition to presenting the products, in two articles, support materials for the presentation of the products were developed, such as booklets. Meanwhile, in the article by Lou et al. (2017), the opportunity is given to rehearse the presentation beforehand.

4.1.4. Closing Stage

Evaluation of the final product is mentioned in 38% of the articles. In three articles, the evaluation was carried out by the teacher; in five articles, a co-evaluation was carried out between peers; in one it was mixed (teacher and peers); and in another, expert guests in the area were invited.

Final reflections were included in 29% of the articles, in which students reflected on the process of developing the project and producing the products. For example, “some groups also made reflections on what they had learned by making video clips which were used to create AR artifacts” (Song, 2018, p. 8).

Finally, one article includes an analysis of the possibility of scaling the product to real-world situations: “The final seventh section asked students about their final thoughts

on how a desalination unit works and how desalination on a large scale could be helpful for areas affected by drought” (Li et al., 2022, p. 36).

4.2. Roles of Digital Technologies in the Development of PjBL

With regard to the use of digital technologies, as shown in Table 2, nine roles have been characterized during different phases of the projects: (i) PjBL process guide; (ii) organize ideas and information; (iii) share ideas and information; (iv) represent the problem to be solved or product to be developed; (v) access theoretical and practical content; (vi) collect data; (vii) design the product or its components; (viii) produce the product; and (ix) present the product and share reflection. Each of these is described below.

Table 2. Summary of the roles of digital technologies in PjBL interventions.

Roles of Digital Technologies	Alò et al. (2020)	Applebaum et al. (2017)	Awad (2023)	C. C. Chang and Chen (2022)	C. Y. Chang et al. (2023)	Cheng and Yang (2023)	Dasgupta et al. (2019)	Hsiao et al. (2022)	Hu et al. (2023)	Hwang et al. (2018)	Li et al. (2022)	Lou et al. (2017)	Lu et al. (2022)	Owens and Hite (2020)	Queiruga-Dios et al. (2021)	Song (2018)	Vallera and Bodzin (2020)	Valls Pou et al. (2022)	Videnovik et al. (2021)	Wang (2020)	Winarni et al. (2024)	Xie and Zhang (2023)	Zha et al. (2021)	D. Zhang and Hwang (2023)	Total
Produce the product	1	1	1	1	1		1	1	1	1			1		1	1	1	1	1	1			1	1	18
Access theoretical and practical content			1	1		1		1	1		1	1				1	1	1		1	1				12
Design the product or its components		1			1		1	1			1		1	1				1				1		1	10
Collect data	1		1	1		1				1	1				1	1									8
Share ideas and information		1							1					1	1	1								1	6
Present the product and share reflection						1								1		1								1	4
Represent the problem to be solved or product to be developed		1	1				1															1			4
PjBL process guide		1				1					1														3
Organize ideas and information																1									1
Total	2	5	4	3	2	4	3	3	3	2	4	1	2	3	3	6	2	3	1	2	1	2	1	4	

4.2.1. Produce the Product

The most common role of digital technologies, identified in 75% of the articles reviewed, was their use in developing the project products during the execution phase. The tools used include electronic devices, digital products, and digital product development environments. In particular, five articles mention the use of electronic devices such as Micro:bit (C. Y. Chang et al., 2023; Lu et al., 2022) or Arduino (Alò et al., 2020; C. C. Chang & Chen, 2022; Hsiao et al., 2022) to create physical or digital products. In Wang (2020), an electric current science toy is made, and in Awad (2023), an electronics kit is used to build the product. In Hu et al. (2023), students used an IoT control module and incorporated it into a 3-D paper house, as well as producing a robot script edited with Google Blockly that describes their product through a story.

In the article by [Dasgupta et al. \(2019\)](#), the Energy3D Computer Aided Design (CAD) software is used to develop a 3-D model of a house that meets certain energy consumption characteristics.

With regard to digital product development environments, authors mention the use of tools to design graphic products, such as GeoGebra ([D. Zhang & Hwang, 2023](#)), or simulators ([Applebaum et al., 2017](#)). The article by [Queiruga-Dios et al. \(2021\)](#) mentions the use of Adobe Flash Professional for the creation of an animated film. This is similar to what was performed in the article by [Song \(2018\)](#), where an AR video creation platform was used (app: MKAPS). In the article by [Hwang et al. \(2018\)](#), ShineCue software was used to design an e-book that allows for the incorporation of images, videos, and hyperlinks, among other interactive resources. In [Vallera and Bodzin \(2020\)](#), the technology used was not specified, but students produced digital brochures and a scale model of a farmers' market stall.

Finally, programming tools were used in three articles. In two, Scratch was used for digital stories and games ([Valls Pou et al., 2022](#); [Zha et al., 2021](#)), and in the article by [Videnovik et al. \(2021\)](#), students were asked to experiment with four programming tools to increase their complexity, such as Scottie Go!, Scratch, Micro:bit, and Python.

4.2.2. Access Theoretical and Practical Content

In half the articles (50%), digital technologies were used to access the theoretical and practical content necessary for the development of projects during the initiation phase. [Vallera and Bodzin \(2020\)](#) used interactive iBooks that combined text, videos, and simulations to facilitate learning and incorporated challenges to motivate students through the use of tools such as ArcGIS, Google Earth, and others based on augmented reality. Similarly, the article by [Li et al. \(2022\)](#) describes the use of online simulations to show chemical reactions.

In other articles, educational robots ([Hu et al., 2023](#)), game-based environments, interactive e-books that integrate multimedia and augmented reality ([Wang, 2020](#)), Scratch ([Valls Pou et al., 2022](#)), and virtual reality ([Winarni et al., 2024](#)) are used as tools that allow students to explore STEM concepts interactively. The use of ArduBlock and Arduino to teach programming is also mentioned ([Hsiao et al., 2022](#)).

Four other articles ([Awad, 2023](#); [C. C. Chang & Chen, 2022](#); [Lou et al., 2017](#); [Song, 2018](#)) mention the use of the Internet and digital platforms to search or review information.

4.2.3. Design the Product or Its Components

In 42% of the articles, digital tools were used to design the product or some of its components. [Li et al. \(2022\)](#) and [Applebaum et al. \(2017\)](#) describe student use of the WISE platform to illustrate designs, explain the reasons behind their decisions, and fine-tune their ideas. In the article by [Hsiao et al. \(2022\)](#), they mention that students had the opportunity to make design sketches of their electric boats using ArduBlock and Arduino, which allowed them to plan and adjust their ideas before proceeding to construction. This role is complemented by the use of more advanced technologies, as described in the study by [Lu et al. \(2022\)](#), where students combined and designed light art features using a BBC Micro:bit microcomputer and other electronic components.

Furthermore, in [Dasgupta et al. \(2019\)](#) the CAD Energy3D tool was used for the design of energy-efficient homes, and in [Owens and Hite \(2020\)](#) students published images of 3-D models created to illustrate the water cycle. Additionally, in [C. Y. Chang et al. \(2023\)](#) and [Valls Pou et al. \(2022\)](#), students worked with platforms that fostered computational thinking and creativity, such as Scratch and educational robotics tools, to create prototypes and program projects. Finally, in [Xie and Zhang \(2023\)](#), virtual reality (VR) was used to design bird feeders in an immersive environment, and in [D. Zhang and Hwang \(2023\)](#),

mobile technologies and a web-based collaborative platform were used for students to design interactive e-books.

4.2.4. Collect Data

The use of digital technologies for data collection is described in 33% of the articles and is associated with the execution phase for both the design and production activities of the products. The article by [Song \(2018\)](#) describes the use of cameras integrated into mobile devices to collect photos and videos in order to document the process and create the final product, which was a booklet. Similarly, [Cheng and Yang \(2023\)](#) used mobile devices to register information after testing their product. [Li et al. \(2022\)](#) mention that students used tools to record the temperature associated with the developed products.

In the article by [Hwang et al. \(2018\)](#), the Internet is used to search for images, videos, and information that are then incorporated into the developed products (e-books). Furthermore, the article by [Queiruga-Dios et al. \(2021\)](#) mentions the use of digital tools to conduct interviews in person or through videoconferences, information from which is used as part of the project context.

With regard to the use of these tools during product development, the articles by [Alò et al. \(2020\)](#) and [C. C. Chang and Chen \(2022\)](#) mention the use of a set of sensors that were incorporated into the developed products. Finally, in [Awad \(2023\)](#), various devices (microphones, temperature sensors, etc.) are described to collect data that were used to examine various concepts associated with the final product.

4.2.5. Share Ideas and Information

Tools for sharing ideas and information were identified in 25% of the articles, especially during the execution phase. In particular, [Queiruga-Dios et al. \(2021\)](#) mention the use of blogs to showcase and give visibility to projects. Likewise, [Song \(2018\)](#) describes the Google Classroom tool, used to share progress, receive feedback, and collaborate on the production of products. [D. Zhang and Hwang \(2023\)](#) describe the use of Zuvio, an interactive response system, to foster peer interaction during product design and knowledge sharing in class. Additionally, the WISE platform was used to provide feedback on student design decisions ([Applebaum et al., 2017](#)).

[Owens and Hite \(2020\)](#) used digital platforms such as Canvas and ePals to facilitate work between teachers and interaction between classes so that students could develop a global collaborative project where they shared photographs and videos and held video conferences with students from other locations. Finally, [Hu et al. \(2023\)](#) describe the use of a robot programming platform that allows users to share the generated code and work collectively.

4.2.6. Present the Product and Share Reflection

In 17% of the articles, the use of digital tools to present the product and facilitate reflection during the execution and closing phases is mentioned. In the article by [Owens and Hite \(2020\)](#), virtual collaboration platforms (Canvas) were used to present students' projects to peers from different locations. In [Song \(2018\)](#), mobile applications such as Google Classroom and MAKPS were used for students to share their products, as well as to make closing reflections through videos. Furthermore, in the article by [D. Zhang and Hwang \(2023\)](#), students submitted their products online using GeoGebra, which were then assessed by peers using Zuvio, and in [Cheng and Yang \(2023\)](#) students share their presentation via an interactive whiteboard.

4.2.7. Represent the Problem to Be Solved or Product to Be Developed

The use of digital technologies to represent the phenomenon of interest or problem to be solved is described in 17% of the articles, mainly during the initiation phase. In the article by [Applebaum et al. \(2017\)](#), virtual models were used to represent a type of vehicle that allowed students to visualize and manipulate variables to facilitate the understanding of scientific phenomena. In [Awad \(2023\)](#), sound, waves, and communication systems (microphones and speakers, websites, and sound conversion software) were used to carry out practical activities with simulations on sound systems and the use of Audacity for sound editing. Furthermore, [Dasgupta et al. \(2019\)](#) mention the use of CAD systems for 3-D visualization and modeling of physical phenomena. Finally, one article ([Xie & Zhang, 2023](#)) describes the use of virtual reality (VR) devices for students to observe different types of birds and bird feeders.

4.2.8. PjBL Process Guide

In 13% of the articles, the use of a platform to structure the project development process is mentioned, incorporating questions and audiovisual guides at each PjBL phase. In particular, the Web-based Inquiry Science Environment (WISE) platform used in [Applebaum et al. \(2017\)](#) and [Li et al. \(2022\)](#) guided students through the project phases by structuring the inquiry process and providing adaptive feedback. Also, [Cheng and Yang \(2023\)](#) used a learning management system where students had access through their mobile devices. The platform facilitates autonomous learning as the project progresses through interactive resources that can be used at different stages.

4.2.9. Organize Ideas and Information

The least frequent use of digital technologies was for organizing ideas, which was included in only one article. The article describes FreeMind ([Song, 2018](#)), which allowed students to create conceptual maps of their prior knowledge on the topic of interest and what they wanted to explore in the project. This concept mapping tool supported students in structuring ideas and connecting concepts related to plant growth and living conditions, as well as organizing teamwork to maintain a shared understanding of the problem and their research objectives during the initiation phase.

5. Discussion

The aim of this systematic review has been to identify and analyze the phases and activities incorporated in project-based learning (PjBL) interventions in the context of K-12 education, as well as to examine the roles played by digital technologies in the implementation of such interventions. To this end, we reviewed 24 empirical studies that reported the use of PjBL with technology in educational environments to provide a comprehensive overview of the structure and development of the PjBL process and its relationship with the use of technological tools throughout the different phases of the project.

5.1. PjBL Implementation Phases

Regarding the first research question referring to PjBL phases, the results show that all the articles incorporated activities associated with the initiation and execution phases, 88% (21) of the articles mentioned the planning phase, and only 46% (11) of the articles reported activities associated with the closing phase. This first finding accounts for the diversity in which educational interventions with PjBL are carried out, where despite the existence of clearly defined phases and activities in the literature reviewed, its implementation seems to take place without being closely aligned to a formal framework. This is reflected in the

variability of how these phases are developed and documented throughout the reviewed articles, which is consistent with the conclusions of the review by [Sukackè et al. \(2022\)](#) on PjBL methodology in higher education contexts.

We will examine each of the phases below, highlighting the particular characteristics of their implementation and the challenges observed.

As shown in Figure 3, in the **initiation** phase, all articles mention a review of the theoretical concepts associated with the project; however, only ten articles (42%) carry out a **review of the background to the problem**. The review of the concepts is guided mainly by teachers (16 articles—67%), while in only ten articles (42%) students autonomously explore the contents. Furthermore, only 12 (50%) articles mention the definition of objectives or questions to be answered. These findings show that many interventions do not consider one of the main purposes of PjBL, which is associated with developing students' autonomous learning ([Kokotsaki et al., 2016](#)). They also do not take advantage of the opportunity for students to address real-world problems, which is one of the main characteristics of the methodology ([Almulla, 2020](#); [Bell, 2010](#)). Additionally, since PjBL is a teaching method that begins with a driving question ([Banchi & Bell, 2008](#); [J. S. Krajcik & Shin, 2022](#)), it is striking that in 12 articles (33%) the activity of defining objectives or questions is not considered. This is consistent with what has previously been reported by [Markula and Aksela \(2022\)](#) regarding teachers' implementation of PjBL methodology in K-12.

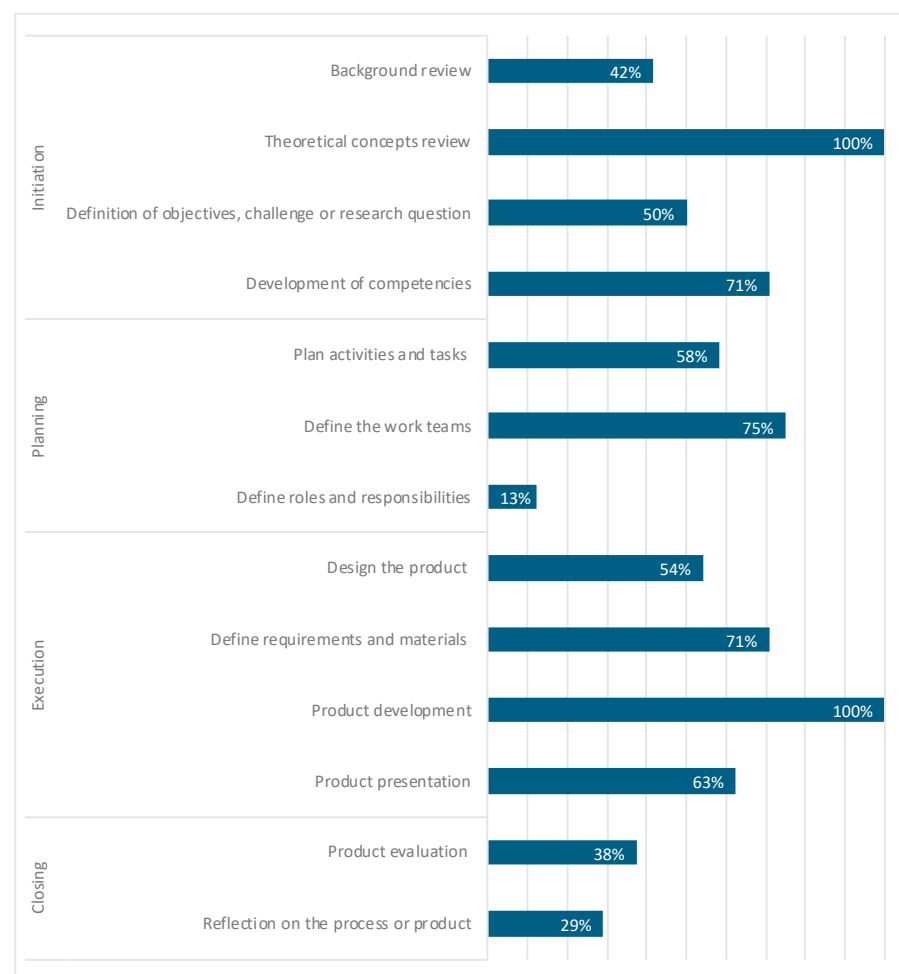


Figure 3. Frequency of articles mentioning each activity of each phase.

Regarding the **planning** phase, in 18 articles (75%) students are organized into work groups; however, in most cases the criteria for the formation of the groups are not mentioned

or are defined randomly (14 articles—58%). In addition, only three articles (13%) mention the definition of the roles and responsibilities of group members. Previous studies have highlighted the importance of assigning roles in group projects, pointing out that simply grouping students together does not guarantee effective collaboration (Gillies, 2016). In a recent study, it was found that perceived efficacy towards the roles assumed by peers during project development, such as coordinator and communicator, was significantly related to the group's performance in executing the project (Hanham & Hendry, 2024).

Only 14 articles (58%) mention the planning of project activities and tasks. As another study shows (Almulla, 2020), although it is possible to assume that teachers take charge of planning teaching activities, one of the key aspects for successful project management is to have good planning (Blampied et al., 2023; Project Management Institute, 2018), a skill that in 10 cases (42%) students would not be developing. This finding once again highlights the loss of opportunities to promote the development of skills associated with project management in students (Delle-Vergini et al., 2024).

The **execution** phase is described in all articles and includes the design, production, and presentation of the products. Product design was mentioned in 13 articles (54%), where students sketched and modeled the products, defined the requirements and materials to be used, and collected data to inform the design. Design allows students to visualize the final product, anticipate the effort required to develop it, and identify potential risks or errors, encouraging discussion and reflection to support their decisions (Project Management Institute, 2018).

The production of the products is described in all the articles that were reviewed and was carried out in different ways. The most common was iterative development, which allowed students to evaluate and improve their products based on the results of tests carried out and the feedback received. As reported in previous studies, by incorporating iterative activities in project development, the evaluation and progressive adjustment of products is enhanced, guaranteeing greater adaptation to project requirements and improving the quality of the final result (Butler et al., 2020; Marnewick, 2023). This process of constant refinement makes it easier for students to not only complete the product but also acquire problem-solving and continuous improvement skills (Almulla, 2020).

Finally, product presentation was mentioned in 15 articles (63%). This is an activity in which students show the results of their effort, which contributes to extrinsic motivation and has been associated with better learning achievements (Wijnia et al., 2024). Additionally, it contributes to the development of communication and presentation skills, which are essential for success in professional contexts, as indicated by studies that underline the importance of these skills in the 21st century (Rahmawati et al., 2020).

The **closing** phase includes a review of the results and reflection on the achieved product and implementation processes. The final closing activity allows students to analyze the strategies used and the learning acquired, promoting self-assessment and continuous improvement skills, which are associated with the development of metacognitive strategies (Maor et al., 2023; Sart, 2014; Satheesan et al., 2024), as well as skills associated with project management. However, it is mentioned in only 11 articles (46%), which adds to the previous arguments regarding the wasted opportunities offered by the PjBL methodology.

5.2. Roles of Digital Technologies in PjBL

Although evidence has shown that the use of digital technologies in PjBL is associated with a greater impact on student motivation and learning (Ábalos-Aguilera et al., 2024; Ruiz Hidalgo & Ortega-Sánchez, 2022), our results show that, in practice, its use in PjBL-based interventions is partial. As Figure 4 shows, most of the interventions reviewed use digital tools that are associated with only two or three of the potential roles of these technologies.

This finding is significant, since this underutilization can limit the scope and effectiveness of project-based learning, preventing students from fully benefiting from the opportunities offered by digital technologies. In this regard, [J. S. Krajcik and Shin \(2022\)](#) argue that the possible benefits of these technologies are “(1) They allow students to use the practice of disciplines by engaging real-world problem-solving; (2) They support collaborative learning for feedback, reflection, and revisions; and (3) They provide unprecedented opportunities to move teaching away from a transmission-and-acquisition model of instruction” (p. 82).

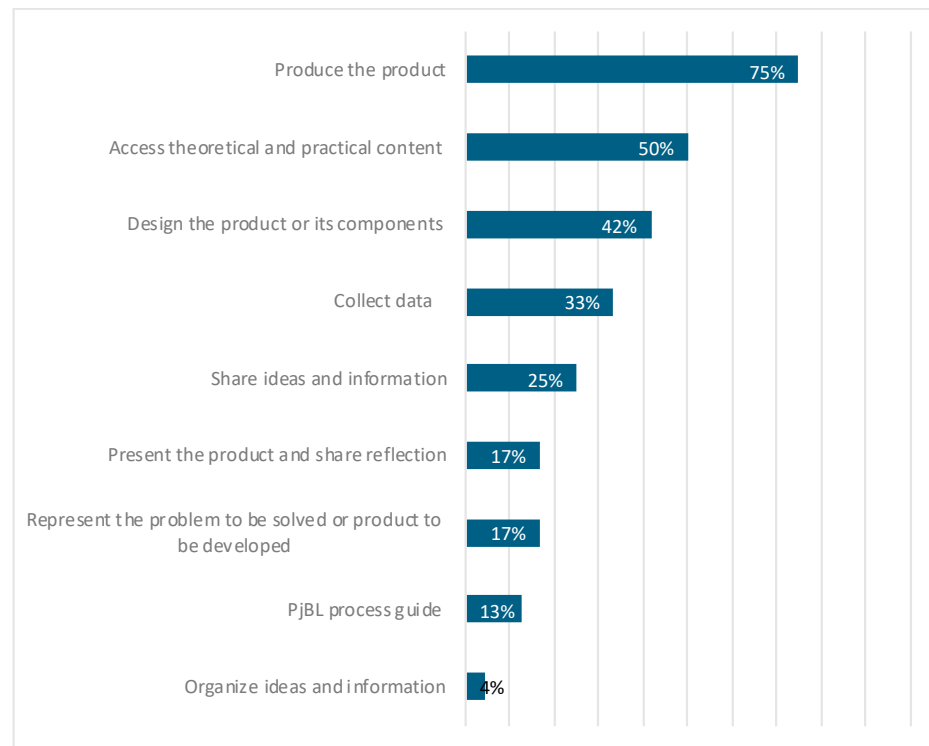


Figure 4. Frequency of articles mentioning the use of digital technologies for different purposes.

However, taken as a whole, the results reflect a variety of uses of digital technologies at each phase of PjBL implementation, allowing us to identify specific opportunities and take advantage of them. Based on this, the uses identified at each phase are reviewed below.

During the initiation phase, digital technologies are used to review background information and theoretical content through texts, videos, simulations, and other sources of information, both to understand theoretical concepts and to develop the skills necessary to implement the projects. These roles are consistent with those suggested by [Larmer et al. \(2015\)](#), who propose the use of video clips or photos from digital archives, primary source repositories, or video clips from TED Ed, YouTube, etc., as well as the use of formative assessment tools and tools for sharing ideas, such as Padlet and Bloggs. Additionally, the articles also mention the use of digital models to represent the problem and facilitate its understanding by students, which is consistent with what has been proposed by [J. S. Krajcik and Shin \(2022\)](#).

With regard to the use of digital technologies to organize ideas and information, these results confirm that their use remains limited in K-12, and few studies apply them. For example, mind mapping programs (e.g., FreeMind) were included in only one article but can serve as a powerful tool by helping students to improve their problem comprehension, coordinate group perspectives, and facilitate collaborative planning. This finding suggests that the potential of digital technologies to support active learning, one of the key principles

of PjBL (Belagra & Draoui, 2018; Kokotsaki et al., 2016), is not being fully exploited, despite the availability of digital tools.

In the planning phase, technologies were used to guide the project implementation process in a transversal manner, including, for example, platforms such as WISE or learning management systems that offered students feedback, and supported autonomous learning throughout the project phases. In this regard, although the use of learning management systems has been previously reported (Rahmawati et al., 2020), the use of platforms to guide project development is less common (Meng et al., 2023), which is confirmed by these results. This could be supplemented by other project management tools, including shared calendars, task organizers, and others, as proposed by Larmer et al. (2015).

In the execution phase, greater use of digital technologies is observed, mainly in the design and development of products. However, specific uses for sharing ideas or information, collecting data and designing the product or its components, and presenting the product and sharing reflections are less common in the articles reviewed. These results point to the opportunity to generalize the potential use of these technologies, as proposed by J. Krajcik et al. (2022), which includes “(1) accessing and collecting a range of data and information; (2) providing visualization and data analysis tools; (3) allowing for collaboration and sharing of information across sites; (4) planning, building, and testing models or simulations; (5) creating artifacts that represent understanding; and (6) providing opportunities to interact, share, and critique the ideas of others” (p. 75).

Finally, in the closing phase, technologies are used to facilitate reflection on the process in just three articles. Digital platforms such as Canvas or GeoGebra allow students to share their work and reflect on their learning, promoting more interactive and collaborative assessment (Larmer et al., 2015).

Regarding the limitations of the present review, it should be considered that the search focused on empirical studies published in English, present in a specific database, which may introduce language and publication biases, and leave out other valuable experiences. Another aspect to consider is linked to the use of digital tools. The selected studies showed diversity in the presentation of results and methodologies to evaluate the impact of these technologies. This makes it difficult to compare interventions and limits the generalizability of their effectiveness in each phase of the PjBL process.

6. Conclusions

With regard to the first research question, the results show that, although the interventions mention most of the formal phases of PjBL, there is diversity in the activities developed in each phase. This leaves aside some activities that would be key to taking advantage of the potential of this methodology. Based on this, Figure 5 presents the key phases and activities resulting from the review of the articles. Aligned with previous studies that have reported inconsistency in the implementation of the PjBL methodology among K-12 teachers (Markula & Aksela, 2022), our findings reflect the need to systematize its application in research in order to evaluate its impact more rigorously and ensure comparability and transferability of the methodology.

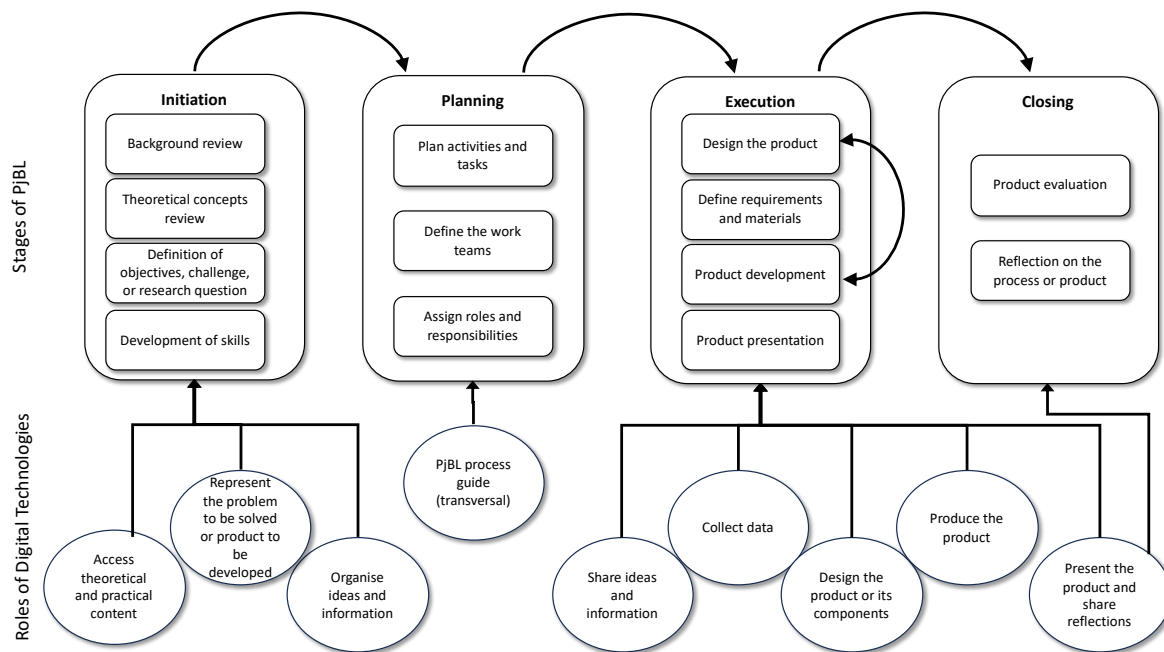


Figure 5. Empirical model of the phases of PjBL and roles of digital technologies.

It is important to mention that the planning phase is not frequently considered in proposals for implementing the PjBL methodology. However, it constitutes an opportunity to incorporate the development of project management skills, which are a critical component for successfully implementing PjBL (Meng et al., 2023). On the other hand, in several countries the development of project management skills is part of the learning objectives of the national curriculum (Delle-Vergini et al., 2024). Within this framework, we suggest that the development of these skills should be included among the objectives of the interventions.

With regard to the second research question, the results show a partial and limited use of digital technologies in each intervention. However, as Figure 5 shows, taken together, they account for a wide range of options to consider when designing new interventions to enhance the impact of PjBL on teaching-learning processes.

In this regard, the review by Hasni et al. (2016) concludes that the methodology of projects that incorporate technology requires greater structuring and formalization for it to be implemented, highlighting a lack of clarity in the conceptualization and justification of the key components. Almost 10 years later, our findings again highlight the need to establish more formal and defined frameworks for both the planning and characterization of PjBL, which could help reduce variability and define standards in implementation that would allow for the comparability of results. The findings indicate that the implementation of technology-integrated PjBL remains inconsistent and fragmented, showing slow progress toward the development of shared standards and coherent practices across educational settings.

This scenario is consistent with the growing integration of digital technologies in the educational field, where tools such as artificial intelligence (AI) and augmented reality (AR) platforms promise to revolutionize learning by facilitating more interactive and personalized experiences (Herczeg, 2024; J. S. Krajcik & Shin, 2022). Despite this, technology alone does not guarantee student autonomy, especially if its implementation minimizes their active role in the construction of knowledge.

PjBL specifically presents a context in which students should act autonomously, applying technologies to investigate and solve real problems; but, in many cases, the conceptual

review and structuring of projects are still guided by teachers, which limits the potential of technologies to empower students. While advanced learning management platforms and AI-based assistants can guide students in research and inquiry processes, it is crucial that their use is oriented towards fostering true autonomy, rather than simply facilitating tasks without promoting active learning (Kokotsaki et al., 2016).

The results of systematizing the phases of PjBL interventions in the K-12 context and the activities considered at each phase make up the empirical model for implementing PjBL that is shown in Figure 5. Unlike other proposals for implementing PjBL (i.e., J. S. Krajcik & Shin, 2022; Larmer et al., 2015), this model proposes the inclusion of objectives associated with learning the themes of the discipline as well as project management skills, which would justify the incorporation of a planning stage. Regarding the role of digital technologies, these results constitute an empirical basis for designing the use of digital tools within the PjBL framework. Although it would be possible to propose other uses and other digital technologies, considering the presented results, this proposal should constitute a baseline for the integration of digital technologies in PjBL. Furthermore, the model is useful for designing courses for the professional development of both practicing and future teachers, which in turn can facilitate the scalability of PjBL methodology across diverse school contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

PjBL Project-Based Learning

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