THE INTERDISCIPLINARY JOURNAL OF PROBLEM-BASED LEARNING

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The Interdisciplinary Journal of Problem-based Learning

2023 SPECIAL ISSUE

Scoping review methodology and its use to review online project-based learning in higher education, 2020-2023

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ABSTRACT

A scoping review (also called a scoping study) is an increasingly popular type of literature review in diverse fields. Aiming to promote this research methodology among those researching project-based learning (PBL), the article provides a thorough overview of scoping review methodology by reviewing its history and development, elaborating on the procedure it requires, and specifying the indications when the methodology is suitable. The second half of the article illustrates how a scoping review can be conducted; the methodology is applied to review the research on the implementation of online project-based learning in the context of higher education that was published between 2020 and 2023. More specifically, the review is conducted to answer the following question: What approaches and strategies are used to ensure online project-based learning implementation across diverse subjects? This particular period is chosen due to the rise of online learning which coincided with the start of the COVID-19 pandemic. The results show a number of useful approaches and strategies in the aforementioned areas; it is anticipated that they will be applicable both to projects in face-to-face environments and especially beneficial for educators who implement PBL online.

Keywords: Scoping review (scoping study), project-based learning (PBL), online project-based learning, online, higher education

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Given the exponential growth of scientific evidence, literature reviews are an increasingly popular form of research activity among researchers, regardless of their discipline (Bradbury-Jones et al., 2022; Munn et al., 2022; Snyder, 2019; Sutton et al., 2019). Different types of literature reviews fulfill a number of functions: they are useful for overviewing some research issues, problems, or areas and mapping the existing research activity (Snyder, 2019; Sutton et al., 2019); they are especially relevant for researchers who are new to a research topic and seek a comprehensive understanding of what the current state of it is (Donthu et al., 2021); they can perform an instrumental function in decision making based on evidence (Sutton et al., 2019); literature reviews may also be applied when analyzing the development of a specific research area over time (Snyder, 2019).

Literature reviews have been classified into a number of types, each of them with its own process and purpose. For example, aiming to clarify the terminology of literature reviews, Grant and Booth (2009) distinguished 14 types: critical review, literature review, mapping review/systematic map, meta-analysis, mixed studies review/mixed methods review, overview, qualitative systematic review/qualitative evidence synthesis, rapid review, scoping review, state-of-the-art review, systematic review, systematic search and review, systematized review, and umbrella review. Similarly, seeking to increase researchers' awareness of other review methods beyond traditional systematic reviews, Sutton et al. (2019) made a summary of various typologies in the field of literature reviews that resulted in 48 types, assigned into seven broad review families: traditional reviews, systematic reviews, review of reviews, rapid reviews, qualitative reviews, mixed method reviews, and purpose specific reviews. An overview of valuable resources that help to distinguish among and conduct different types of reviews is provided in Appendix A.

Among different types of literature reviews, the scoping review (also commonly called the scoping study) is one of the most prominent and popular types of literature reviews (Bradbury-Jones et al., 2022; Peters, Marnie, et al., 2020). In comparison to the systematic review, which has enjoyed decade-long popularity, the scoping review is a relatively new method (Khalil et al., 2021). Having originated within the field of health research, the scoping review has become widespread across diverse fields, including education. For example, in the Web of Science database, the search string "PBL", "project-based learning" and "problem-based learning" in combination with "scoping study" and "scoping review" generated 22 studies (within the period between 2013 and March 17, 2023). Given the amount of research in the fields indicated in the search string and the numbers of scoping studies in all fields (more than 20,000 studies for researching diverse areas in the Web of Science database in 2022, see Figure 1), its popularity among those researching project-based learning and problem-based learning is relatively low.

Starting from the foundational paper providing a methodological guide on how to conduct a scoping study by Arksey and O'Malley (2005; initially, the authors called the method "scoping study"; we refer to it as "scoping review" for reasons that we provide later in the article) and their call to enhance it, a number of other researchers have attempted to provide additional recommendations. However, despite a vast body of literature on the method, misconceptions among editors, authors and reviewers as to when and how to apply a scoping review are still common (Campbell et al., 2023; Khalil et al., 2021). More often than not, published studies lack methodological clarity and are of poor quality, which may negatively influence the application of the method (Buus et al., 2022; Khalil et al., 2021). Therefore, the first aim of the current article is:

1) to provide a comprehensive overview of scoping review (scoping study) as a research method by reviewing its history and development, elaborating on the procedure it requires and specifying the indications when the methodology is suitable.

In the current article, we also present the application of the method in the field of project-based learning. PBL is used as an umbrella term to refer to "a wide spectrum of instructional models and variations" (Hung, 2015, p. 241). Among them, project-based learning (most commonly abbreviated as PBL or PjBL; we use the term "PBL" for the remaining part of the article) is one of the well-known methods. As defined by the Buck Institute for Education, it is "a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem or challenge" (Buck Institute for Education, n.d.). Typically, students learn in the context of projects by completing tasks longer in duration in comparison to individual ones. The method is appreciated for its potential not only to ensure meaningful learning and thus equip learners with deep content knowledge, but also for helping them to grow holistically by allowing to develop a set of 21st century success skills (Beckett & Slater, 2019; Boss & Larmer, 2018; Thomas & Yamazaki, 2021).

For higher education, PBL is especially relevant given the current prioritization of development of skills and capabilities over the amount of disciplinary knowledge that students need to acquire during their university studies (Guo et al., 2020). The method is more suitable for students to get ready for the 21st century workplace. Importantly, it prepares them for increasingly popular project work (Boss & Larmer, 2018). Moreover, students themselves usually find PBL a more enjoyable and engaging learning environment than traditional lectures (Guo et al., 2020), including its implementation online (Beyer et al., 2021; Jaleniauskiene & Lisaite, 2021). Despite the fact that project-based learning is not a new method, its use has recently attracted increasing interest among educators (Beckett & Slater, 2019; Boss & Larmer, 2018; Thomas & Yamazaki, 2021).

Over the last three years, the landscape of higher education has changed dramatically, mainly due to the COVID-19 pandemic. As a result, new learning scenarios were introduced and the existing ones were reshaped, including project-based learning whose implementation online was rare during the pre-pandemic period. We believe that while some new solutions were merely the outcomes of emergency remote learning, the remaining ones could significantly contribute to the

advancement of the method both online and in face-to-face or mixed contexts. Having this goal in mind, in the second part of the article, we:

2) review the research published between 2020 and 2023 on the implementation of online project-based learning in the context of higher education.

Specifically, we aim to answer the following research question:

RQ: What approaches and strategies are used to ensure online project-based learning implementation across diverse subjects?

We hope that the current article will both encourage a more frequent use of a scoping review as a research method among the researchers of PBL and enhance the understanding of PBL implementation in an online environment.

Overview of Scoping Review Methodology

Brief History and Development

Arksey and O'Malley (2005) published the first paper providing the methodological guide for conducting a scoping study and explaining the six key stages framework. To this day, this article is the most frequent point of reference used by different authors of scoping reviews (Buus et al., 2022). However, the suggested original methodological guidance on how to follow each of the stages has been criticized for being insufficient (Khalil et al., 2021). For example, Davis et al. (2009) concluded that the framework lacked details about the data analysis process, which might hinder the understanding of how study findings were obtained. Therefore, a number of researchers (e.g., Buus et al., 2022; Daudt et al., 2013; Levac et al., 2010; Peters et al., 2015; Peters et al., 2017; Peters, Godfrey, et al., 2020; Tricco et al., 2016; Westphaln et al., 2021) have attempted to further refine the scoping study methodology. All the attempts to advance the methodology built on the initial framework proposed by Arksey and O'Malley's (2005); in addition, the majority of them were conducted within the field of health research.

The most prominent and influential paper aiming to advance the scoping review methodology was published by Levac and colleagues in 2010. A team of researchers conducted separate scoping studies in different fields of rehabilitation by applying Arksey and O'Malley's (2005) framework. Next, they collated their experiences by listing challenges and offering additional recommendations for each of the six stages initially proposed by Arksey and O'Malley (2005). Using the same framework, Daudt et al. (2013) followed a similar procedure, except for the fact that an inter-professional team of researchers collated their experiences after implementing separate scoping studies on the same research question. As concluded by Daudt et al. (2013), the recommendations for each stage mirrored closely the ones drawn by Levac et al. (2010); importantly, they were formulated without knowing what was concluded by Levac et al. (2010).

In 2013, seeing a further need to suggest a comprehensive step-by-step methodological guidance for its conduct, Joanna Briggs Institute (hereafter JBI; an international evidence-based healthcare research organization) initiated a methodological group of multidisciplinary researchers who have started a number of initiatives towards the enhancement of the method (e.g., workshops, conferences, consultations, meeting of professionals). A formal guide for undertaking scoping reviews developed by this group was published in 2015 (Khalil et al., 2021). The latest version of their guidance was released in 2020 (see Chapter 11: Scoping reviews by Peters, Godfrey, et al. (2020) from JBI Manual for Evidence of Synthesis (Aromataris & Munn, 2020), available at https://doi.org/10.46658/JBIMES-20-12). Indubitably, the significant contribution towards advancing the scoping review methodology and ongoing initiatives towards this goal on the part of JBI and JBI Collaboration have led to the increasing number of published scoping reviews (Khalil et al., 2021). According to this group of researchers, a scoping review is a better term for the method than a scoping study as initially used by Arksey and O'Malley (2005); this decision was based on their acknowledgment that this type of knowledge synthesis should be conducted as rigorously as other types of literature reviews and also on the fact that "review" is more commonly used to refer to such types of research activities (Peters, Godfrey, et al., 2020). As a result, currently, a number of researchers also commonly refer to this method as a scoping review, especially those that inform about using the JBI methodological guidelines explicitly.

The extensive research done by JBI professionals has enabled them to draw conclusions about the main issues within the field of scoping reviews as well as suggest potential solutions to address them (Khalil et al., 2021; Peters, Godfrey, et al., 2020). Importantly, the JBI team admitted that in comparison to an older and more advanced systematic review approach, scoping reviews are an emerging methodology and the number of scholars trained to conduct them was insufficient (Khalil et al., 2021). They also noticed that poor-quality scoping studies are still common (Khalil et al., 2021). To address these gaps, the group refers to Scoping Reviews Network (available at https://jbi.global/scoping-review-network) that offers a number of resources for conducting JBI scoping reviews, including a template for a paper utilizing this method. The journal JBI Evidence Synthesis represents the field of healthcare and is a useful reference for well-conducted literature reviews, including scoping reviews. Moreover, Khalil et al. (2021) highlight that

editors and reviewers sometimes fail to understand the scoping review methodology and tend to confuse them with systematic reviews. As such, they expect to see elements that are typical for systematic reviews but not recommended (e.g., specific recommendations for policy or practice based on the results) or optional (e.g., risk of bias appraisal) in scoping reviews.

There has also been a range of more recent yet less significant attempts to advance the methodology. For example, Buus et al. (2022) analyzed the practice of using the stage of consultation exercise in scoping studies; after the analysis of this stage in 66 studies, they concluded that very often there were no reports about its effects or they were general and brief. Westphaln et al. (2021) developed additional recommendations for team-based and mixed approach scoping reviews. Bradbury-Jones et al. (2022) suggested a structured approach for the analysis and reporting of scoping reviews: the PAGER framework (which stands for Patterns, Advances, Gaps, Evidence for practice and Research recommendations). Importantly, the debate about how to conduct scoping reviews rigorously and make the method trustworthy remains ongoing.

Definition and Nature of Scoping Reviews

Up until now, no single definition for the terms scoping study/scoping review has been agreed upon. In their seminal paper, Arksey and O'Malley (2005) defined the term scoping study as "a technique to 'map' relevant literature in the field of interest" (p. 20) or, more generally, as a type of a literature review that aims "to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available, and can be undertaken as stand-alone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before' (Mays, Roberts, & Popay, 2001, p. 194; emphasis in the original)" (p. 21). Grant and Booth (2009, p. 95) defined the term scoping study as "preliminary assessment of potential size and scope of available research literature [that] aims to identify nature and extent of research evidence (usually including ongoing research)." A formal definition agreed by JBI researchers is as follows:

> Scoping reviews are a type of evidence synthesis that aims to systematically identify and map the breadth of evidence available on a particular topic, field, concept, or issue, often irrespective of source (i.e., primary research, reviews, non-empirical evidence) within or across particular contexts. Scoping reviews can clarify key concepts/definitions in the literature and identify key characteristics or factors related to a concept, including those related to methodological research. (Munn et al., 2022, p. 950)

In the original definition of the term scoping study provided by Arksey and O'Malley (2005), the use of "rapidly" might suggest that scoping studies do not require extensive time resources; however, as noted by Arksey and O'Malley (2005), they do not represent a quick option of a literature review. According to Pollock (2023), sometimes the amount of data might be much larger (e.g., 400 articles) than for a systematic review aiming at answering a more focused research question and thus makes the process of data extraction more time consuming.

Currently, the scoping review is an increasingly popular method among researchers. For example, we searched the Web of Science database using the following search string: "scoping study" and "scoping review"; time filter applied: 2013–2022. The search revealed a steady growth of the number of studies throughout the last decade (see Figure 1). In addition, the same search revealed that the largest number of publications employing this methodology was the health sector.

Major Components and Procedure

The original six-stage framework for conducting a scoping study was proposed by Arksey and O'Malley (2005; Figure 2). For a more comprehensive methodological guide, we suggest reading the aforementioned Chapter 11: Scoping reviews (Peters, Godfrey, et al., 2020).

We chose to visualize the framework with the use of arrows to remind researchers that, according to both Arksey and O'Malley (2005) and other researchers who have contributed significantly to advancement of the method (e.g., Campbell et al., 2023; Levac et al., 2010; Peters, Godfrey, et al., 2020), conducting a scoping review is not a linear process (which is typical to systematic reviews) but an iterative one. It requires researchers to reflect on each stage and, if necessary, move back and forth between the stages and decisions made (e.g., reformulate the research question(s), add new search terms or sources of evidence, or change the charting of the data) based on new findings and/or insights. In addition, while the foundational paper envisions the sixth stage as optional (Arksey & O'Malley, 2005), it is included in the present paper since the later contributions towards the method indicated it as an important one. Below we provide a brief explanation of each stage.

1) Identifying the Research Question

Researchers need to identify and define the research question(s), link it with the purpose of the research, envision the intended outcomes, and clarify the concepts present in the research question (Arksey & O'Malley, 2005; Daudt et al., 2013; Levac et al., 2010; Peters, Marnie, et al., 2020). In the majority of scoping reviews, one primary research question

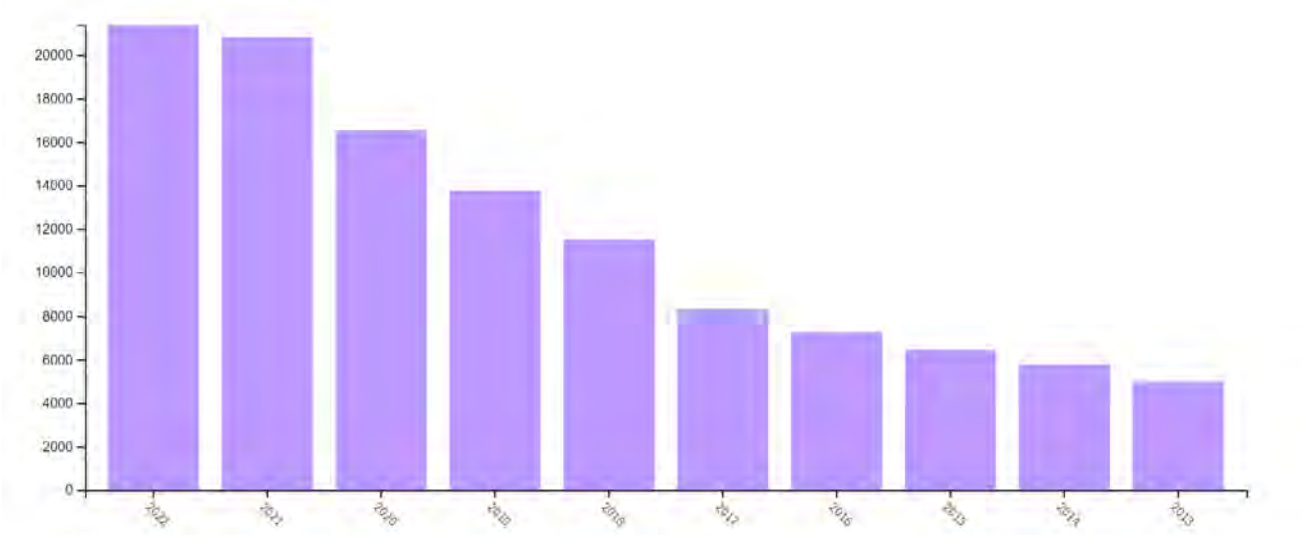

Figure 1. The Growth of Numbers of Scoping Reviews (Scoping Studies) in 2013–2022 (Web of Science Data)

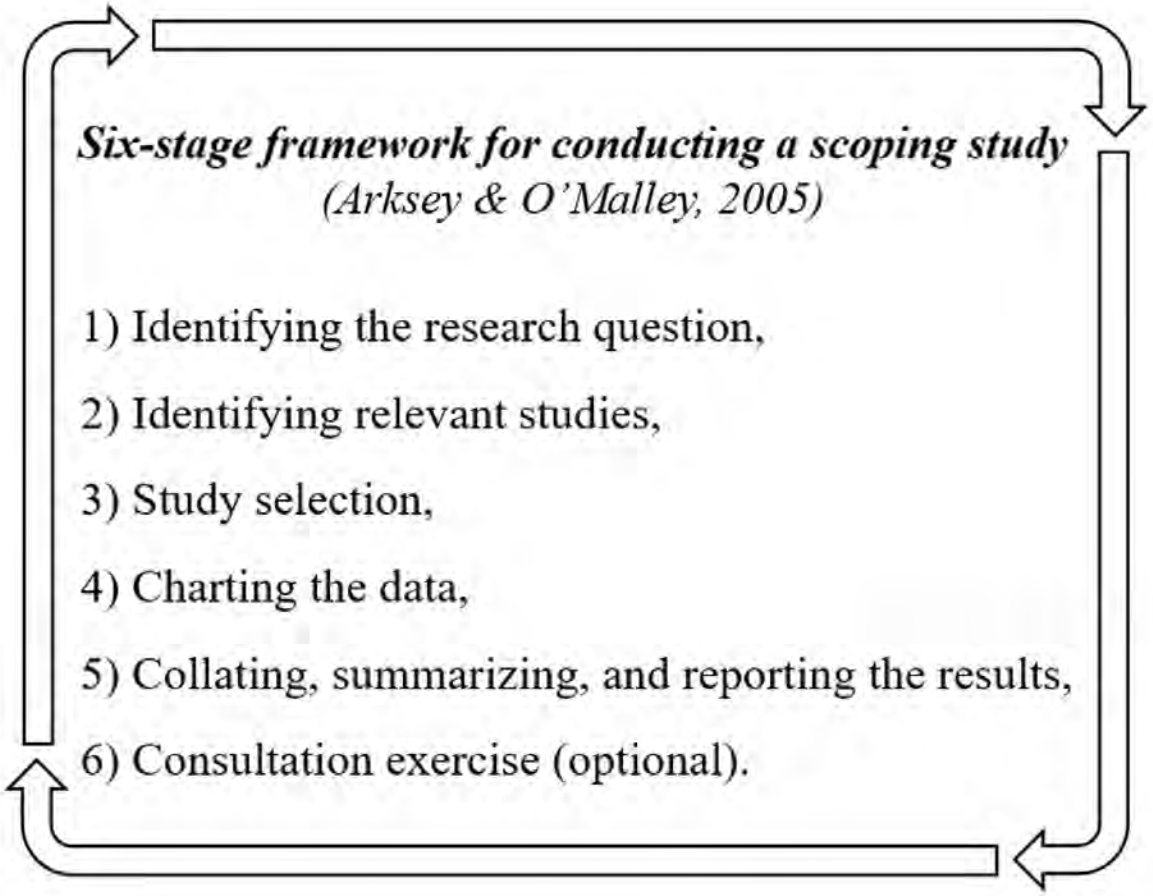

Figure 2. The Six-Stage Framework Originally Proposed by Arksey and O'Malley (2005, pp. 22–23)

is enough (Peters, Godfrey, et al., 2020). According to Khalil et al.'s (2021) recommendations, beginning a scoping review with a detailed protocol also ensures a rigorous methodological conduct and a smooth reporting phase.

2) Identifying Relevant Studies

Researchers need to search for diverse sources of evidence, make decisions about the scope of the study, revise the research question(s) and search terms (if necessary), and develop the list of inclusion criteria based on the research question(s) and purpose of the study (Arksey & O'Malley, 2005; Daudt et al., 2013; Levac et al., 2010; Peters, Godfrey, et al., 2020). Databases, reference lists, key journals, and sources provided by relevant organizations, networks, and conferences (Arksey & O'Malley, 2005) or any existing literature (e.g., research articles utilizing any research methodology, policies, websites, blogs, or other types of sources; Peters, Godfrey, et al., 2020) can be included. Sometimes scoping reviews can even solely synthesize evidence from grey literature (Pollock, 2022). Titles and research questions usually guide the selection of the inclusion criteria; most commonly, they are selected given the concepts present in them, context of the study, and sometimes study participants (Peters, Godfrey, et al., 2020). In order to identify synonymous search terms, researchers might find it useful to consult other reviews on similar topics and in similar fields.

3) Study Selection

Researchers should select studies based on predetermined inclusion/exclusion criteria (Arksey & O'Malley, 2005; Levac et al., 2010; Peters, Godfrey, et al., 2020). While initially Arksey and O'Malley (2005) indicated that doing study selection (screening of titles, abstracts, and full texts) in teams was optional, other researchers (Levac et al., 2010; Peters, Godfrey, et al., 2020) saw this measure as necessary and highlighted the fact that researchers need to work independently and then meet regularly to reach decisions. Based on the JBI guidelines, it is recommended that papers include narrative descriptions of the study selection process utilizing a flowchart of the review process from the PRISMA-ScR statement that details "the flow from the search, through source selection, duplicates, full-text retrieval, and any additions from third search, data extraction and presentation of the evidence" (Peters, Godfrey, et al., 2020, p. 419).

4) Charting the Data

Researchers need to search for evidence that aligns with the research question(s) and the purpose of the study and extract data iteratively; general information about studies (e.g., authors, years of publication, country, methods, etc.) and specific information based on the research question are two main types of data that can be extracted (Arksey & O'Malley, 2005; Levac et al., 2010; Peters, Godfrey, et al., 2020). Importantly, researchers need to be clear and explicit about how and what data they extract; they might also apply pilot testing during this stage (Peters, Godfrey, et al., 2020).

5) Collating, Summarizing, and Reporting the Results

Researchers need to select and analyze the evidence, combine and summarize it, as well as report the results in a way that aligns with the research question(s) and the overall purpose of the study; they also need to provide implications for practice, policy, or future research (Arksey & O'Malley, 2005; Levac et al., 2010; Peters, Godfrey, et al., 2020). The term "mapping" is common for the analysis process in scoping reviews (Khalil et al., 2021, p. 158). For example, it can result in collating data on the aspects such as the methodologies applied, groups of participants, or geographical locations of the reviewed studies (Levac et al., 2010).

For reporting the results, according to Arksey and O'Malley (2005), general information about studies can be provided via a descriptive numerical summary (e.g., frequency count of general information aspects) and specific information via thematic analysis. Peters, Godfrey, et al. (2020) concluded that in scoping reviews, "simple frequency counts of concepts, populations, characteristics or other fields of data will be all that is required" (p. 421). However, the volume of published studies confirms the fact that authors also choose more in-depth types of analysis (e.g., descriptive qualitative content analysis), which include the process of coding and then providing summaries of data in categories (Peters, Godfrey, et al., 2020). Peters, Godfrey, et al. (2020) observed that "qualitative content analysis in scoping reviews is generally descriptive in nature and reviewers should not undertake thematic analysis/synthesis … as this would be beyond the scope of a scoping review and would more appropriately fit within the objectives of a systematic review of qualitative evidence" (p. 421). Researchers might also make use of a framework synthesis and choose to sort and chart data "against a priori identified framework" (Peters, Godfrey, et al., 2020, p. 421). Campbell et al. (2023) highlighted the fact that scoping reviews can be either inductive or deductive and not necessarily utilize an a priori set of codes for data description. As explained by Pollock (2022), the framework/theory might be developed via inductive extraction and analysis of data. Conversely, researchers might also decide on the framework before data extraction and analysis and thus organize results based on the established framework (Pollock, 2022).

For the presentation of results, creating tables (they may be separate ones for each variable) and using various visualization forms and tools (e.g., evidence gap maps, infographics, or bubble plots) are recommended (Khalil et al.,

2021). Given the current range of modern data visualization options and tools (e.g., Canva, BioRender), including the quickly emerging range of AI-powered tools (e.g., certain tools can extract textual data and provide it in the form of a table), the process might be greatly facilitated. For example, in their scoping study, Jaleniauskiene and Kasperiuniene (2023) illustrated the use of both tables and infographics in the presentation of results.

For reporting and thus improving the quality of scoping reviews, it is recommended that a 20-item (plus 2 optional items) checklist is used, such as the PRISMA extension for scoping reviews (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews or PRISMA-ScR; Tricco et al., 2018; available at http://www.prisma-statement.org/Extensions/ScopingReviews). The checklist was prepared by a group of experts on this method (Tricco et al., 2018). In addition, the provided website offers a fillable checklist for scoping reviews either in a PDF or MS Word format. Journals editors may also consider asking authors for PRISMA-ScR checklists (cf. PRISMA checklists are required from authors of systematic reviews; Khalil et al., 2021).

6) Consultation Exercise

Researchers might seek additional insights and sources of information from experts or stakeholders in the field of research, as well as ask for their feedback on the data collected (Arksey & O'Malley, 2005; Levac et al., 2010). Despite the fact that Arksey and O'Malley (2005) saw this stage as optional, other authors (e.g., Buus et al., 2022; Levac et al., 2010) considered it as one that can facilitate the process of data collection and analysis, increase the quality and reliability of findings, and even support their dissemination.

During the consultation stage, researchers may share their preliminary findings (e.g., in the lists, frameworks, or themes) with stakeholders or experts (e.g., via interviews or focus groups) so that they could provide additional or different perspectives (Levac et al., 2010). Based on the feedback collected, researchers can consider how to incorporate it into the outcomes of their studies (Levac et al., 2010). Buus et al. (2022) concluded that authors should include comprehensive accounts of not only the outcomes of consultations, but also the process of how they were organized (for more specific advice on how to conduct the consultation stage, see Buus et al., 2022).

Finally, researchers might also consider using reference management tools (e.g., EndNote) or tools that are specifically designed for conducting literature reviews (e.g., Rayyon, EPPI-Reviewer). Such tools might greatly facilitate the processes of searching, screening, data extraction, provision of results, preparing the list of references, or collaborating with other researchers on the same study.

Indications for a Scoping Review

There are various indications when scoping reviews are suitable; researchers may choose to conduct them because of one or several reasons. While initially Arksey and O'Malley (2005) offered four main purposes for doing a scoping study (see pp. 21–22 in Arksey and O'Malley's 2005 paper), Munn et al. (2018) expanded this list as follows based on additional discussions on this method:

- To identify the types of available evidence in a given field
- To clarify key concepts/definitions in the literature
- To examine how research is conducted on a certain topic or field
- To identify key characteristics or factors related to a concept
- As a precursor to a systematic review
- To identify and analyze knowledge gaps (p. 2)

Having analyzed a range of definitions of a scoping study, Levac et al. (2010) concluded that the most common purpose reflected in them was to "map', which is "a process of summarizing a range of evidence in order to convey the breadth and depth of a field" (p. 1), or the identification of available evidence in some field of research. Peters, Marnie, et al. (2020) highlighted the fact that scoping reviews are suitable to identify gaps in some research fields that can be later researched by using systematic reviews. While conducting scoping studies for this purpose, researchers might identify a narrower research question and also identify the inclusion criteria for the selection of studies (Anderson et al., 2008). Khalil et al. (2021) noted that scoping reviews are especially useful for researching emerging topics where they might help to map a body of literature on this particular topic and identify areas for further research. The method is also useful when researchers need to analyze diverse types of evidence, including grey literature or non-research sources (e.g., policies) to provide a comprehensive overview of a given topic (Peters, Marnie, et al., 2020). Scoping reviews belong to the "Big Picture" review family (Campbell et al., 2023) and are most commonly conducted to understand background information on a particular issue, topic, or field that might drive further research or help to reveal what types of evidence are available (Pollock, 2023).

It is agreed that scoping reviews are suitable when researchers need to address broad research questions to identify and report characteristics or concepts in studies (Arksey & O'Malley, 2005; Daudt et al, 2013; Peters, Marnie,

et al., 2020; Pollock, 2022). The example of a research question used by Arksey and O'Malley (2005) was "What is known from the existing literature about the effectiveness and cost-effectiveness of services to support carers of people with mental health problems?" (p. 23). Khalil et al. (2021) provided the following examples of broad research questions amenable to scoping reviews: "'What has been done previously' or 'What does the literature say?'" (p. 157). Daudt et al. (2013) found that "questions portraying comparisons such as between interventions, programs, or approaches seem to be the most suitable to scoping studies" (p. 1).

However, when research questions are more focused (e.g., Does this intervention work for ...?) and thus the findings of such studies are meant to provide specific recommendations to inform practice or guide decision making, scoping reviews are not suitable. Thus, systematic reviews are a more effective choice in such cases (Khalil et al., 2021). Some scholars (e.g., Khalil et al., 2021; Pollock, 2022) conclude that scoping reviews are not suitable for checking feasibility, appropriateness, effectiveness, or meaningfulness of some phenomena, practice, or treatment. To avoid confusion, researchers are recommended to use the Right Review tool (https://rightreview.knowledgetranslation.net/) which provides a number of directing questions before suggesting the right method for knowledge synthesis (Pollock, 2022).

Looking at articles with a focus on PBL and employing the scoping study/review method, we have found the following examples of research questions: "What is the connection between problem-based learning and critical thinking?" (Cruz et al., 2022), "What is the influence of group function on individual student PBL outcomes?" (Li et al., 2022) or "What are the structure, content, and potential impact of post-residency medical education fellowships?" (Cataldi et al., 2021).

Most frequently, scoping reviews are contrasted with systematic reviews, which is an older and a better-known method. Both methods include a structured process or steps to be taken while reviewing literature (Peters, Godfrey, et al., 2020). However, they differ in a number of ways: for example, systematic reviews have more specific and narrow-scope research questions in comparison to the broader scope of scoping reviews (Arksey & O'Malley, 2005; Campbell et al., 2023; Munn et al., 2018; Sucharew & Macaluso, 2019). While systematic reviews identify a specific study design prior to conducting the actual search, scoping studies may adapt their designs if the need arises (Sucharew & Macaluso, 2019). Systematic reviews aim to have a thorough search while the search in scoping reviews is dependent on the time and availability of other resources researchers have at their disposal (Levac et al., 2010). Different from systematic reviews, scoping reviews do not need to synthesize the results or outcomes of the sources of evidence; if such results are extracted, it is enough to map these findings descriptively rather than analytically (Peters, Godfrey, et al., 2020). Furthermore, unlike systematic reviews, scoping reviews do not include critical appraisal or assessment of the quality of the literature included (Grant & Booth, 2009; Peters, Godfrey, et al., 2020). Regarding conclusions, while researchers typically provide substantial recommendations and conclusions (e.g., policy recommendations) as a result of systematic reviews, authors of scoping reviews should not overstretch this activity as they are allowed "to conclude the scope and extent to which something is being done or being used in relation to the review question" (Khalil et al., 2021, p. 159).

The remaining part of the present article illustrates a scoping review conducted on online project-based learning in the context of higher education (2020–2023).

Illustrative Scoping Study of Online Project-Based Learning in the Context of Higher Education, 2020-2023

Introduction and Theoretical Framework

While the introduction and literature reviews (which can serve as a venue for establishing a framework for inductive data extraction and its analysis) are included in scoping reviews, these sections will not be included in the present paper due to the paper length limit.

Methods

Search Strategy

The current review was conducted in accordance with the scoping review protocol PRISMA-ScR (Tricco et al., 2018). PubMed, Scopus, and Web of Science databases were searched to identify relevant literature on the basis of a selection of search terms; the search was conducted on April 7, 2023. The search terms aimed to cover the review question in a comprehensive way. The following parameters delineated our search strategy: (a) articles published between 2020 and 2023; (b) full text available, (c) English only. Specifically, see Table 1 for the full search string used. In our attempt to use a string of keywords that includes the most commonly used words to refer to the concepts covered, we listed an array of synonyms. Moreover, to expand our selection further, we have consulted search strings on similar concepts used in other research. For example, in order to cover the idea of "online", we have looked into Chipps et al.'s (2022) and Wooley et al.'s (2019) systematic reviews. Similarly, in order

to generate more synonyms for "higher education," we have identified relevant ideas in Spelt et al.'s (2009) and Wu and Shen's (2016) systematic reviews. To avoid confusion with problem-based learning, we have decided against including the abbreviated form of project-based learning, i.e., "PBL".

In our review, we aimed to overview studies that were published in English. In terms of the participants, we looked into studies conducted in higher-education settings (i.e., at university or college), but did not include studies from non-formal learning contexts or other adult education settings. All types of subjects, fields, and disciplines were eligible for consideration. We only focused on full-text journal articles and excluded dissertations, book chapters, or other types of documents. Table 1 presents the summary of the search process of the current scoping review.

Data Extraction, Analysis, and Presentation

Iteratively, we searched for evidence and extracted two types of data: general information about the studies focusing on the implementation of online PBL in the context of higher education during the period of 2020–2023, and specific information about the research question posed. First, we provided the frequency count for a range of descriptive characteristics, such as the year of the publication, geographical distribution, and the study field of our research synthesis (see Table 2). Next, a detailed overview of the main conceptual categories of each study conducted was provided, including the aims and main findings of the studies included, sample sizes, and intervention duration (see Table 3 in Appendix B). Table 4 in Appendix C provides an overview of the aspects related to online implementation of PBL found in the studies.

Stage	Details
Databases	PUBMED SCOPUS Web of Science
Search terms	"Project-based learning" OR "Project based learning" AND "internet-based" OR "web-based" OR "internet based" OR "web based" OR computer OR internet OR web OR electronic OR online AND "higher education" OR "university" OR "college" OR "graduate" OR "undergraduate" OR "tertiary education"
Inclusion criteria	Full text: Yes Date range: 2020 to 2023 Type: journal articles Education level: higher education, university, college Focus: online PBL in higher-education settings
Exclusion criteria	Education level: trade/professional schools Type: Dissertations, conference proceedings, book chapters Focus: non-formal learning contexts, adult education

Table 1. Scoping Review Search Process. The decisions (e.g., the inclusion and exclusion criteria, the range of years, etc.) made here should be based on the theoretical framework and research questions provided in the introduction and theoretical framework sections. of Science Data)

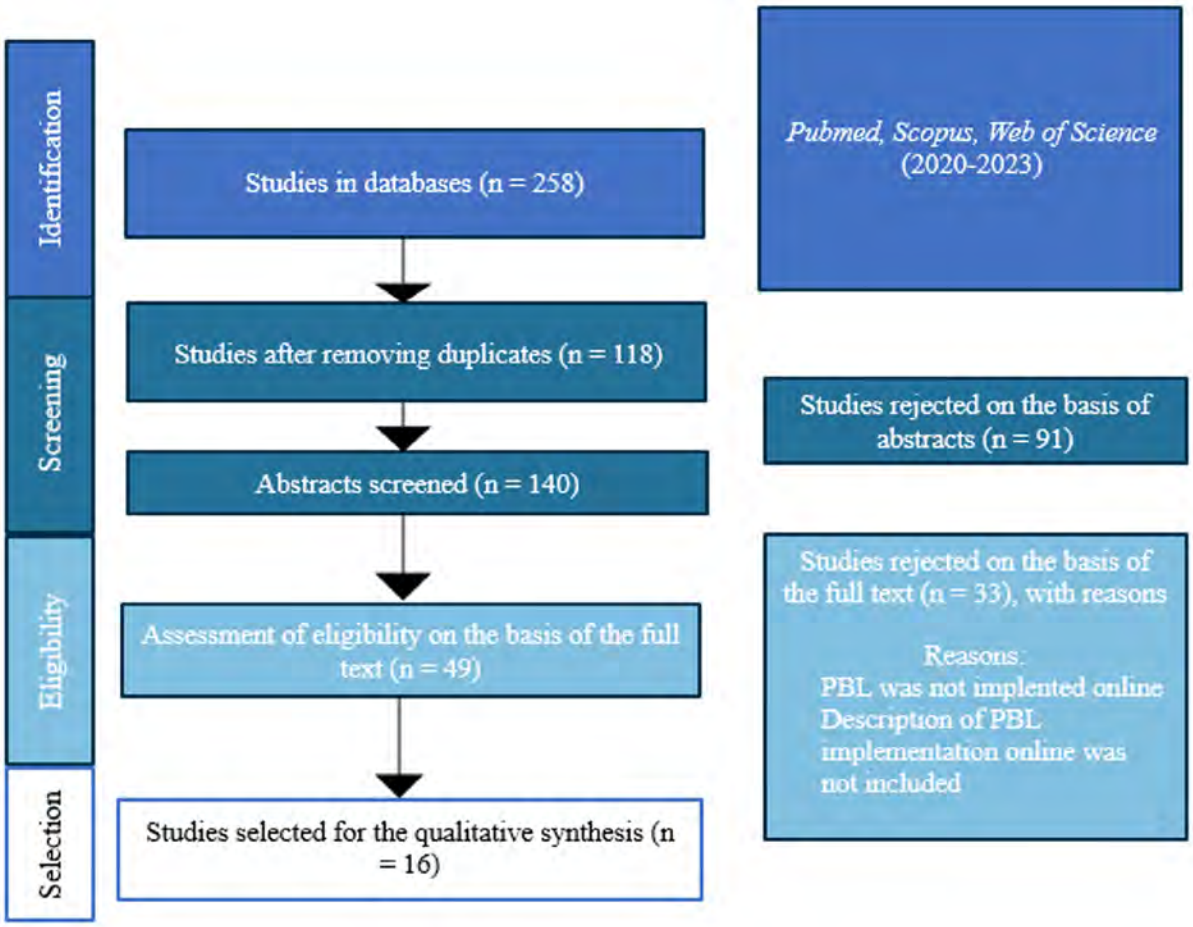

Figure 2. Flow Diagram of the Review Process (based on Tricco et al., 2018)

Results

General Information on the Studies Reviewed

Table 2 represents the descriptive characteristics of the articles included in the review.

As can be seen in Table 2, the largest number of the studies were conducted in different countries in Asia (n = 8), followed by North and South America (n = 4) and Europe (n = 2), while one study (Baudin et al., 2022) was conducted transnationally across North and South America and Europe; one more study was carried out in Africa. In terms of the range of courses which reported on including online PBL as part of their activities, Engineering (n = 3) was the most frequent one, followed by Biology (n = 2) and Computer Science (n = 2). The remaining studies encompassed a variety of fields but were only represented once in each category.

In terms of sample sizes used in the studies, the number of participants varied: the smallest study sample included 13 participants, while the largest one consisted of 183 students. The length of the studies indicated in the articles differed too: while some studies included online PBL as part of a semester course typically lasting 14–16 weeks, some only referred to the actual length of the implementation of online PBL (6–8 weeks). Hayashi et al. (2023) reported on several courses implemented over the academic year 2020–2021. The remaining characteristics of studies are provided in Table 4 in Appendix C.

Strategies and Approaches for Online PBL Implementation in Higher-Education Settings

Specifically, in order to answer our review question, we focused on the strategies and approaches highlighted in terms of online PBL implementation in higher-education settings. We extracted and analyzed data inductively without an established framework. As a result, the thematic analysis (Braun & Clarke, 2013) revealed two main strands of strategies and approaches used: first, the use of software to facilitate the implementation of online PBL; second, a range

Characteristic		*Count*
Year of publication	2020	2
	2021	6
	2022	6
	2023	2
Continent	Asia (China, Indonesia, Japan, Thailand, United Arab Emirates)	8
	North America (USA)	2
	South America (Brazil)	2
	Transnational (North America (USA)-South America (Brazil, Bolivia, Mexico, and Peru) - Europe (Spain))	1
	Europe (Italy, Spain)	2
	Africa (South Africa)	1
Study field	Teacher Education	3
	Biology	2
	Computer Science	2
	Engineering	2
	Chemistry	1
	Consumer Sciences	1
	Cultural Heritage and Tourism	1
	Data Sciences	1
	Innovation and Entrepreneurship	1
	Mental Health	1
	Visualization	1

Table 2. Descriptive Characteristics of the Studies Under Review

of forms employed to ensure instructor facilitation. In addition, we also analyzed the key findings relating to elements of online PBL implementation as presented by the authors of the studies included in the review and provide a synthesis of these findings below.

Software Used in the Implementation of Online PBL

The use of software was the first main theme that emerged in our analysis. In our review, we established two main categories of software that were employed while implementing online PBL. First, most of the articles referred to online platforms and/or other tools that were used to facilitate teacher-student, student-student interaction, and activities online. The authors referred to a variety of common tools used for video conferencing, such as Zoom, Microsoft Teams, Google Meet, Cisco Webex Meeting; discussion forums, WeChat groups, as well as a range of Google applications (e.g., Google Forms, Google Docs, Google Jamboard) were used for communication and data sharing among group members; WhatsApp (Paristiowati et al., 2022) and phones (Poonpon, 2021) were also referred to as communication means.

Second, some studies also referred to discipline-related specific tools, software, and applications or generic tools that were used to implement the content of the projects. Examples of this type included visualizations tools such as Java, Tableau, D3 (Beyer et al., 2021), Internet of Things (IoT) technologies (Baudin et al., 2022; Hayashi et al., 2023); Azure Notebooks (used for remote programming; Sakamaki et al., 2022), a virtual desktop infrastructure enabled by Citrix machine creation system which enables instructors to take control of students' virtual machines (Sola-Guirado et al., 2022), making use of the online virtual simulation experiment websites, employing bioinformatics tools (VSEARCH and MicrobiomeAnalyst) in order to analyze data (Sun et al., 2023), and the use of online platforms for creating multimedia videos or multimodal content (Canva and Powtoon; Poonpon, 2021).

Beyer et al.'s (2021) study illustrates that the use of tools should be well-considered and responsible: specifically, they pointed out that in their study, they chose to limit the range of tools suggested to students on purpose so as not to overwhelm them; in addition, they made sure to provide instructions on how each tool should be used.

Instructor Facilitation

Instructor facilitation emerged as the second main theme with regard to the organization of implementing PBL online because most of the studies under review provided descriptions of how instructors and/or researchers attempted to provide support to their students as they carry out their projects. It has to be underlined, however, that considerable variety could be noted in terms of completeness of these descriptions: while some of the studies provided an in-depth picture of how instructor facilitation worked in practice, others disclosed relatively few details. Below, we distinguish separate groups of strategies that were used in order to support students in online PBL.

Online Class Sessions. A number of studies (i.e., Beyer et al., 2021; Arantes do Amaral & Fregni, 2021; Guo et al., 2021; Hayashi et al., 2023; Sola-Guirado et al., 2022, Sun et al., 2023) referred to the availability of the instructor(s)/researchers(s) during online sessions with the participants, organized chiefly during synchronous class time slots, to provide some theoretical insights, discuss related texts and the activities as well as steps related to the projects, clarify instructions, answer questions, and/or provide feedback. While some of the procedures involved a clear time limit dedicated to this activity, followed by students' group work (e.g., Sola-Guirado et al., 2022, referred to dedicating 30 minutes to going over different specifications related to the projects and allowing students time afterwards to work on their projects; Beyer et al., 2021, stated that the teaching staff remained available for questions and feedback during classes; Guo et al., 2021, referred to teachers' answering questions about subject matter as well as reminding students of practical matters to be considered), other studies referred to organizing meetings whose sole purpose was to discuss and solve challenges and provide feedback (e.g., Arantes do Amaral & Fregni, 2021; Peng et al., 2022).

Formats of Feedback Provision. A few articles under review (i.e., Beyer et al., 2021; Arantes do Amaral & Fregni, 2021; Halaweh, 2021; Peng et al., 2022) explained how feedback provision was managed. For example, when explaining the provision of feedback during classes, Halaweh (2021) pointed out that the instructor navigated the sessions of different groups online effortlessly and could provide on-the-spot feedback where necessary. Conversely, Sakamaki et al. (2022) referred to difficulties that the teacher experienced trying to supervise different groups' work simultaneously and therefore a "leader was determined in each group and the leader reported progress during and at the end of the class" (p. 762). Sakamaki et al. (2022) also pointed out a nuance related to instructors' navigating the online meeting platform; that is, some of the students in their study stressed that they felt ill at ease not knowing when the teacher would enter their break-out room.

Some studies (i.e., Beyer et al., 2021; Chanpet et al., 2020; Arantes do Amaral & Fregni, 2021; Peng et al., 2022) described feedback provision outside of class settings. Arantes do Amaral and Fregni (2021) and Beyer et al (2021) provided detailed accounts in terms of how they provided feedback. Arantes do Amaral and Fregni (2021) attempted to meet students' needs and expectations in a remarkably extensive way. Specifically, the students in their study were requested to fill in weekly questionnaires aiming at a three-folded goal: "to foster the students' reflection about the week's learning … to identify what concepts the students didn't learn well … to give the students the opportunity to suggest course improvements" (p. 147). Based on the responses provided in the questionnaire, every week the teacher would create feedback in the form of videos and strive to continuously adapt and improve the course for the following weeks. Similarly, Beyer et al.'s (2021) study illustrates another labor-intensive strategy of feedback provision: the authors described how in order to optimize students' progress in two-day workshops, each group had a project mentor who "read through each team's project book overnight and left written feedback in the student's online process books or Google Jamboard sketches that students can address the next day" (p. 45). Furthermore, Beyer et al. (2021) also included peer feedback (i.e., team members had to evaluate each other) as a useful strategy for instructors to identify any potential issues and intervene in a timely manner if necessary. In addition, Chanpet et al. (2020) referred to providing feedback in a discussion forum and specified that this was a useful option both in whole group or smaller group discussions. Peng et al. (2022) also provided comments and feedback on artifacts created by students via the online learning system.

Technology-Related Assistance Throughout the Implementation of PBL. Two studies employed high-technology tools in order to implement PBL online (e.g., Baudin et al., 2022; Hayashi et al., 2023). The instructors in Baudin et al.'s (2022) study described how assistance with handling technological solutions was provided. Specifically, Baudin et al. (2022) used biological samples that had to be operated using imaging systems Picroscope and Streamscope that are based on Internet of Things (IoT) technology. Therefore, the facilitators in the study "prepare[d] the appropriate samples and set up the remote imaging device"; as a result, this

enabled the students "to make observations from their own cell phones or computers at any time" (p. 4). In Hayashi et al.'s (2023) study, computer engineering students worked on creating a variety of applications and tools (e.g., academic activities scheduler, sleep health assistant, shopping list app, academic tests app) using the LabEAD (Remote Lab for Engineering); each student studying from home could access "the laboratory benches by connecting to an IoT platform using their smartphones and computers" (p. 4). However, the authors of the article did not elaborate to what extent instructor facilitation was required in order to manage the participants' use of the remote laboratory.

Poonpon's (2021) article is yet another example of technological assistance provided while implementing online PBL. The participants in this study, preservice teachers in a Linguistics and Language Teaching course, were required to create online English lessons to secondary school students; however, the participants lacked experience in terms of designing multimedia videos and proactively requested to be equipped with this knowledge. To this end, a three-hour training session led by an expert in educational technology was organized and the students received information scaffolded into six steps on how to "(1) choose a teaching topic based on CEFR A2 level for secondary school students in Thailand (Office of Basic Education Commission, 2014), (2) design an online lesson plan, (3) write a storyboard, (4) choose appropriate multimedia tools, (5) develop materials, and (6) record and edit their video"

(pp. 190–191). In addition, Beyer et al. (2021) pointed out that in their activities, they relied on technical support staff who helped to facilitate the process of video conferencing as well as assisted students with technical issues.

Provision of Instructions. The authors of several studies (e.g., Beyer et al., 2021; Guo et al., 2021; Mielmann, 2021) underlined the importance of providing students with detailed guidelines. According to Beyer et al. (2021), providing students with written instructions is crucial as they are used to "introduce the collaborative tools that will be used during the design sprint … [and] highlight deadlines and outline the concrete steps and requirements for each part" (p. 40) of PBL. Alongside suggesting ideas on how to handle the different steps involved in implementing the project, Guo et al. (2021) also provided their participants with the assessment criteria. While Mielmann (2021) explicitly referred to the PBL implemented in the study as "self-directed and -regulated learning", an exceptionally detailed overview of the guidelines that the students received is provided (see Appendix D).

Nevertheless, there were also a few studies that referred to areas that need to be considered more carefully while implementing PBL in an online environment. For example, Paviotti (2020) and Peng et al. (2022) pointed out that some of the participants in their studies indicated a perceived lack of guidance, despite the efforts the instructors invested into trying to ensure appropriate supervision. This points to another conclusion drawn by Beyer et al. (2021) as they concluded that online networking is more complicated and therefore extra steps are needed to guarantee that it functions properly. For example, clear instructions should be provided; in addition, using both asynchronous communication channels and videoconferencing tools that are easy to operate are of key importance (Beyer et al., 2021, p. 45). This point is also related to an issue raised by Krishnakumar et al. (2022) who referred to their participants' mixed perceptions as far as student-student interaction was concerned—while some of the students in the study failed to engage in online meetings and establish functioning work relationships with their teammates while working on the projects, others felt they could communicate more openly online rather than in face-to-face situations and therefore became closer with their peers.

Effects of Online PBL

In their summaries of the key findings, some of the authors of the articles reflected on various positive aspects of online PBL implementation. For example, a number of authors (e.g., Baudin et al., 2022; Chanpet et al., 2020; Peng et al., 2022; Sola-Guirado et al., 2022; Sun et al., 2023) emphasized that the students enjoyed the process of engaging in online PBL, and the activities helped to spark an increase in their interest in the topics in question. Moreover, Beyer et al. (2021) stressed that not only the students, but also their instructors experienced PBL as more rewarding. Peng et al. (2022) also referred to the high motivation of the participants during the process, while Sola-Guirado et al. (2022) highlighted the high satisfaction that the students felt about realizing their work. Hayashi et al. (2023) noted that online PBL helped to mitigate the effects of COVID-19 as the students were able to engage in the content offered during the period of emergency remote teaching. Similarly, Baudin et al. (2021) stated that there was no difference in terms of effectiveness between PBL implemented remotely or in face-to-face classes. Arantes do Amaral & Fregni (2021) also pointed out the positive effects of the online environment: participating in the online forum was instrumental in learning together with other students, while video feedback provided by the teachers contributed to "an intense knowledge sharing and improved the connection between theory and practice" (p. 149).

Importantly, in the discussion of their findings, Chanpet et al. (2020) and Peng et al. (2022) referred to their participants' academic achievements. Chanpet et al. (2020) analyzed not only the students' perceptions of online PBL, but also compared the students' achievements in terms of "the results

of the PBL knowledge and skills"; the post-test indicated a "higher achievement for the online versus the face-to-face section" (p. 700). Peng et al. (2022) stated that the students' "performances in subject knowledge, product quality, and programming thinking skills were significantly improved at the end of the course" (p. 19).

Discussion

We reviewed 16 studies that included relatively rich descriptions of PBL implementation online and were published during the period between 2020–2023. Since this period overlaps with the COVID-19 pandemic to a great extent, the research reported in the studies largely represents educators' attempts to handle "emergency remote teaching" (Hayashi et al., 2023, p. 3). It may be for this reason that many of the authors of the studies included only sporadically referred to the efforts that they took to ensure proper functioning of activities taking place online or solutions that they adopted in order to address any challenges encountered. Instead, they placed more focus on how discipline- and content-related aspects of the PBL activities could be implemented successfully. While the articles reviewed provided insights into how online PBL can be implemented across a range of fields, it is highly likely that in the future, additional and possibly even more sophisticated solutions will be reported. In addition, only three of the articles reviewed reported on online PBL being implemented in courses within teacher education, which means that the vast majority of the studies did not rely on collaboration with professionals from educational sciences.

Nevertheless, in our scoping review we managed to identify a number of recurrent aspects with regard to conducting PBL in an online environment. One of them is the use of software employed. The majority of the studies under review provided lists of tools, applications, and platforms that were used in order to facilitate interaction and activities online and/or that were needed to implement content-related aspects of their projects. The fact that aside from identifying these tools, relatively little information is provided in the studies most likely implies that no major problems or challenges arose when using them. At the same time, one conclusion that can be drawn is that the advances in educational technology at this point in time ensure that a relatively smooth, effective, and efficient running of team activities online is more often than not the expected and usual result.

A considerable part of the studies we reviewed reported overall participants' satisfaction in terms of online PBL (importantly, none of the authors of the articles under review referred to overwhelmingly negative students' perceptions and/or reactions; a mild drop-out rate of two students out of 58 was mentioned in one study only, Chanpet et al., 2020); one crucial reason for this positive trend can be seen to be related to another main finding that emerged from our analysis. Specifically, implementing PBL activities online is a highly intensive exercise for instructors. Our analysis illustrates that the authors who referred to the different ways in which instructor facilitation was provided did invest a considerable amount of time and energy into guiding students, assisting them with technology-related aspects, and providing clear instructions and feedback. Their accounts represented very conscious attempts to think about how they can serve their participants' needs in the most effective ways. Communication online is much more complex in online, rather than face-to-face, settings and it is important to be aware of this fact while thinking about the different aspects of organizing activities online. Attempts to consider possible challenges and ways in which they can be mitigated realistically and effectively are therefore crucial in order to limit any negative effects online settings might have on students' teamwork and well-being, handling of misunderstandings, or addressing other issues.

Limitations

It should be pointed out that our scoping review has some limitations. In order to access publications of high quality, we searched only a limited number of databases. Another related limitation is the fact that we excluded publications whose full texts were not accessible through our universities' library services. A possible threat for scoping reviews, including ours, might be the fact that it is challenging to identify all possible search terms that are synonymous to the main ones. It is therefore possible that this may have also affected our search results. One final limitation that should be mentioned is the timing of our study. Specifically, aiming to conduct our scoping review on the implementation of online PBL, we applied the time filter that starts with 2020 and ends with 2023. Given the fact that most of the studies related to implementation of activities in online settings were situated within the framework of the COVID-19 pandemic that had started in 2019, it is likely that a (considerable) part of them is still not published. Researchers who consider conducting scoping reviews on this topic in the future should therefore take these limitations into account and explore ways they may be avoided or compensated for.

Conclusions

Our article had a two-fold aim: to present an in-depth discussion of the scoping review methodology and to illustrate its application in practice. For those researching PBL,

conducting a scoping review might be especially useful in the cases when research questions are broad, when there is a need to determine the potential and more specific research questions for a full systematic review, when diverse types of sources (e.g., non-scholarly sources such as blogs or websites) need to be reviewed, or when researchers want to focus on emerging topics in order to synthesize the existing body of literature. We illustrated how to conduct the review by following the most recent PRISMA-ScR (Tricco et al., 2018) checklist for completing scoping reviews. While we admit that the present scoping review has several limitations and our conclusions are drawn based only on the range of studies reviewed (as it is the requirement for scoping reviews), it nevertheless reveals a number of significant aspects. First, the articles reviewed highlight the potential and value of online PBL across a broad variety of fields, as the method is praised by both students and instructors and no insurmountable obstacles have been reported in terms of its implementation within online settings. Second, the present scoping review points towards a promising venue for a number of further systematic reviews with narrower research questions focusing on the implementation of PBL online. For example, various specific aspects (e.g., provision of feedback online, online interaction, holding online discussions, etc.) could be reviewed separately in order to identify the characteristics of their effective use towards the advancement of PBL as a valuable instructional method.

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Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Appendix A

List of Resources to Distinguish Among and Conduct Different Types of Reviews

1. A summary of literature review types with the lists of major readings about each of them: https://unimelb.libguides.com/whichreview/scopingreview.
2. An alternative summary of literature review types with the lists of major readings about each of them: https://whatreviewisrightforyou.knowledgetranslation.net/site/methods.
3. *Decision Tool* or *Review Comparison Chart* for deciding which review type to embark on: https://unimelb.libguides.com/whichreview/decisiontool.
4. An alternative tool to select the appropriate literature review type: https://whatreviewisrightforyou.knowledgetranslation.net/.
5. *JBI Manual for Evidence Synthesis* (Aromataris & Munn, 2020) explaining how to conduct various types of systematic reviews and evidence syntheses (including scoping reviews): https://jbi-global-wiki.refined.site/space/MANUAL.
6. See Sutton et al.'s (2019) paper for the list of review producing international organizations (e.g., Cochrane, Centre for Reviews and Dissemination, Campbell Collaboration, Joanna Briggs Institute, Agency for Healthcare Research and Quality, etc.).

Appendix B

Table 3

Aspects Related to Online PBL Implementation Discussed in the Articles Included in the Scoping Review

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
1. Baudin et al., 2022	Biology	Effects of caffeine on development; Effects of agriculture byproducts on development and physiology; Biocompatibility of nanoparticles; Toxicity of chlorine	Zoom	Python; IoT-based imaging systems: "Picroscope" and "Streamscope"; The devices are set up in such a way as to allow students to make observations from their own cell phones or computers at any time	Facilitators taught supplemental lessons on various scientific topics; Facilitators introduce the available biological samples and then guide students through defining a testable question and designing an experiment to address that question; set up of remote imaging devices; help interpret the data	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
		dioxide; teams of students produced working interactive visualisations				
2. Beyer et al., 2021	Visualization course CS171 (www.cs171.org)	Visualization design sprints	Zoom and Zoom breakout rooms for video conferencing, Google Docs to document each step of the sprint, and Google Jamboard for collaborative sketching.	Tableau, Java, D3	Found it crucial to have technical support staff to manage our online video conferencing tool, set up breakout rooms, and help students with technical issues. All online design sprint sessions are scheduled to be synchronous during class time, while teaching staff gives feedback and answers questions; online courses have clear written instructions available to students prior to class. A project mentor is assigned to each team that guides them through the design sprint and makes students aware of the strengths and weaknesses in their designs. For example, in the two-day workshops, we read through each team's project book overnight and left written feedback in the student's online process books or Google Jamboard sketches that students can address the next day. In all our design	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
					sprints, we track students' progress through weekly submissions. Weekly submissions ensure that project teams stay on track and do not fall behind, and they allow the teaching staff to provide timely written feedback. Additionally, we include peer feedback into the design sprint process.	
3. Chanpet et al., 2020	Education (English as a foreign language)	Creating learning resources (artifacts) that, as pre-service teachers, they might subsequently use in contexts of teaching and learning	A discussion forum and CHAT rooms on a learning management system; an internal e-mail system	Not specified	Learners have extensive responsibility for managing their own projects. This means that they must take responsibility and develop metacognitive skills to learn about their learning. The instructor provided feedback using the discussion forum which allowed for both individual (private) conversations as well as whole group or smaller group conversations and exchanges. The group discussion was relevant where the instructor identified feedback that pertained to more than one individual. The system was preprogrammed to compile information related to each learners' activity and place it into a report	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
					accessible to the instructor. The report included quantitative information related to learners' participation such as number and duration of logins, tools accessed when and for how long, number of discussion and CHAT messages/conversations posted and read, emails sent and received, and content accessed. The instructor could then use this information for each student to validate, triangulate, or to complement information provided by the learners in their e-portfolio.	
4. Arantes do Amaral & Fregni, 2021	Teacher education/ "Project-based Learning "	Two simple projects that lead to the creation of short videos	A course platform with an online forum	Not specified	Every week, the students had an online meeting (approximately two-hours long) with the teacher to discuss the activities accomplished during the week, clarify issues, and discuss the readings and videos and share experiences. After the meeting, the students were asked to answer a questionnaire. Every weekend the teacher read all the questions and created a short video providing feedback to the students. In addition to that (based on students' suggestions of course improvement), the	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
					teacher made adaptations in the way the course would be conducted in the following week.	
5. Guo et al., 2021	Introductory Course of Mental Health	Film analysis project: a film analysis report	WeChat groups	Not specified	The researcher and teacher provided students with the grading criteria for the report and some suggested steps to complete the report, such as to first form small groups and create private WeChat groups, to select the film to be analyzed and the theory to be used, and to discuss how to write each part based on the grading criteria; The teacher mainly reminded students to log in the course every week and answered students' questions about the videos on the MOOC platform.	Teachers might consider assisting students with the direction of the discussion. For example, they could help students to narrow the scope of the topics and knowledge to be used and guide them to find the associations between film clips and content knowledge. Furthermore, teachers could design and propose some questions that students could debate.
6. Halaweh, 2021	Innovation and Entrepreneurship	Prototyping: students were working on creating prototypes for a product, website, mobile application, house, park or whatever the project domain entailed; small	Online platform used for teamwork		The instructor was able to easily move between the group meetings, observe each group's discussion and ways of thinking about their project problems, and intervene when necessary to give feedback and guidance.	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
		groups of 5-6 students				
7. Hayashi et al., 2023	Computer Engineering courses (Engineering Introduction Course; Digital Electronics Lab; Scientific Initiation	Creating a range of tools and applications, such as: Academic activities scheduler; Sleep health assistant; Shopping list app; Academic Tests app; Smart Medicine box; News Listener app; Smart Agro platform; Event Promoter app; Educational Game for kids; Restaurant Scheduler; Beekeeping assistant; Water management app; Smart Home Locker; Smart Trash Bin; Automatic Gel Alcohol Dispenser; Safety for Puppies; Vacancy	Miro: students could actively interact with the teacher without the need to turn on their webcams or microphones, using mouse cursors	Internet of Things technologies: LabEAD (Remote Lab for Engineering); Blynk IoT Platform	Not specified	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
		Sensor; Parking Sensor; Smart Door				
8. Krishnakumar et al., 2022	Engineering	Hands-on projects; not applicable; teamwork	Canvas, Zoom	3D CAD modeling	Not specified	
9. Mielmann, 2021	Consumer Sciences	Food projects	e-Fundi platform; Zoom	Not specified	Students received a number of resources to initiate self-directed- and self-regulated learning on the eFundilearning management system, i.e., the university's e-learning and -teaching platform that connects registered students and educators online. Students received the following resources to complete the food research project: (1) sufficient literature on the background and methodology of the research project; (2) recorded Zoom lectures with Microsoft PowerPoint slides to explain the research project; (3) four incomplete objectives; (4) a questionnaire template; (5) a work schedule guideline; (6) a recorded Zoom lecture to explain data analysis on Microsoft Excel; (7) a Microsoft Excel template for data	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
					analysis and outlay of tables; (8) a Microsoft PowerPoint template for the presentation; (9) evaluation criteria for the report and presentation; and (10) recorded Zoom meetings to address questions and/problems.	
10. Paristiowati et al., 2022	Chemistry	Projects oriented to issues of sustainable development	ZOOM, WhatsApp, Google Classroom, and YouTube		Instructor facilitation not specified. The participants were asked to complete a reflective journal. Reflective journals are a useful student-centered activity that provides opportunities for self-education	Activities reported: virtual fieldtrip to Cibualo coffee village
11. Paviotti, 2020	Cultural Heritage and Tourism	The project-based exercise is designed as a consultancy project of groups of students to entrepreneurs of the agri-food field.	OLAT platform and Microsoft Teams		The role of the teacher was to facilitate relations during online presentations with entrepreneurs, to provide further insights to interpret data, and to motivate active discussions during lessons about topics related to the task (e.g. case studies on agrifood in tourism with invited experts, tools' analysis, apps, etc.).	
12. Peng et al., 2022	Computer Science	An authentic programming project—membership management: developing	Online learning system	Frontend coding languages (HTML, CSS, and JavaScript) were used to construct the client-side applications.	The students were asked to learn at their own pace and spend about 2 h per day or 10 h per week on the project based on the workload of the project. In the meantime, the teacher monitored students'	Future studies will refine the learning system and improve the course design and implementation —for example, by enhancing teacher–student

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
		a computer program that can be used for member registration, password setting and resetting, user login, login validation, and updating member information.		C#, a class-based, object-oriented programming language was used to establish the data processing logic and server-side web services. Microsoft SQL Server, a database management system, was used to store, retrieve, and manipulate the data in the system	progress and provided comments and feedback on their artifacts via the online system. Considering the complexity of PjBL, two face-to-face consultations were arranged in Week 3 and Week 5, respectively. Each consultation session lasted for one hour.	interactions during the study.
13. Poonpon, 2021	Linguistics and Language Teaching course	Online English lessons for secondary school students (in groups of 4 or 5)	Line, Zoom, Phone, Google Forms	Powtoon or Canva	The pre-service teachers had no experience of making an ELT multimedia video, they requested to be equipped, in a three-hour training session, with practical knowledge about designing an online lesson and using multimedia to create the lesson. In the training session, with an expert on educational technology, the teachers were guided with six easy steps on how to: (1) choose a teaching topic based on CEFR A2 level for secondary school students in Thailand (Office of Basic Education Commission, 2014), (2) design an online	

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
					lesson plan, (3) write a storyboard, (4) choose appropriate multimedia tools, (5) develop materials, and (6) record and edit their video	
14. Sakamaki et al., 2022	Data Scientist Educational Program	the project was based on the problems discussed in a consultation from an existing local government	Zoom, Teams, Learning Management System (LMS)	Azure notebooks (Azure is a cloud service provided by Microsoft) were used for R (or Python) execution; VPN connection	It was difficult for teachers to take a view of the whole groups at the same time in distance education. Therefore, a leader was determined in each group and the leader reported progress during and at the end of the class.	The points that the students designed to facilitate group work were: sharing roles, showing your face on Zoom, using communication tools, and respecting each other's opinions. More specifically, to eliminate the difficulty of communicating using Zoom, they considered speaking a little more positively than face-to-face, reacting as loudly as possible, and devising the timing to start speaking. Some groups used Slack other than Teams, but some found it confusing to use a variety of communication tools. In group work outside of the lecture hours, synchronic communication was difficult for

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
						some groups because the activity time of group members was different. There was active discussion even remotely, data analysis could be performed remotely, screen sharing was successful, and some had experiences of online meetings at the company. .
15. Sola-Guirado et al., 2022	Industrial Engineering: Advanced Design in Mechanical Engineering (ADME) and Advanced Manufacturing Engineering (AME)	A project with a focus on developing an arm gripper to be inserted in a robotic arm that allows the gripping of a part.	Cisco Webex Meeting ® platform where the contents are shared effectively, annotations can be done on the screen and even the control of the student's virtual machine can be taken if needed.	SolidWorks CAD/CAM/CAE software platform; A virtual desktop infrastructure generated by Citrix machine creation system has been configured. The system presents users with remote desktop sessions through a Citrix XenDesktop platform and Citrix Workspace client (Citrix Systems, Inc., United States) running on virtual machines (VM) through	The teacher approaches the first 30 min in class by making a quick simulation of the tasks to be done, exposing an example of the final result. The project was sequenced in different stages that force the students to go through the product development phases. Later, they are expected to do their projects with their own specifications, working in sessions based on synchronous face-to-face classes through online videoconference with the teacher assisting them in all the product development process.	The implemented platform has allowed students and teachers to connect remotely through their devices in an efficient way. The main problems were not due to the functioning of the system per se, but to the students' internet connections (bandwidth, WIFI, etc.).

Number, author(s), year of publication	Study field	Project topic description	Tools/software used to implement online PBL	Discipline-specific tools/software used	Instructor facilitation	Additional information/ Suggestions for online PBL
				a VCenter virtualization platform		
16. Sun et al., 2023	Biology	A saliva microbiome project	not specified	Online virtual simulation experiment website (http://oc.zju.owvlab.net/login); bioinformatics tools VSEARCH and MicrobiomeAnalyst	Classroom sessions consisted of short lectures and discussions of the reading assignments.	The virtual simulation experiments can overcome the limitations of laboratory devices and reagents, or spatial and temporal limitations during the COVID-2019 pandemic. Furthermore, the metagenomic data analysis could be practiced using many publicly available datasets. Several public databases exist for this purpose, including NCBI's short-read archives (SRA), MG-RAST, and IMG/M.

Appendix C

Table 4

Conceptual Categories of the Articles Included in the Scoping Review

Number, author(s)	Country of origin	Aims/purpose	Study population/sample size	PBL duration	Key findings
1. Baudin et al., 2022	Multiple countries: United States, Latin America (Bolivia, Brazil, Mexico, Peru), Spain	To describe the implementation of Internet-of Things technologies in the biology classrooms of Latinx communities in the United States and Latin America using examples relevant to their local surroundings … [to] demonstrate the capability of this framework to perform a single shared experiment for several groups around the world simultaneously. Furthermore … [to] provide a framework for interested parties to remotely perform their context-informed PBL-based courses.	183 students in total from Latinx communities: first-year students of Biotechnology students; second-year students of Biochemistry; 4th year high schools of Advanced Placement (AP) Biology course	Not specified	IoT-enabled remote PBL is an effective and scalable approach for serving underrepresented students in STEM and provides a novel platform for comparative experimental STEM education studies; remote PBL is as effective as in-person PBL at increasing interest in science, and the students enjoyed participating in the remote project.
2. Beyer et al., 2021	USA	To illustrate how design sprints for college-level and professional education data visualization courses can be incorporated and adjusted	Not specified	Semester-long (15 weeks) course (Guided Projects and Final Projects) and Two-Day workshops	Visualization design sprints are more engaging for students and more rewarding for instructors and teaching staff; in online teaching students feel less connected. Therefore, clear communication is critical. Networking does not work as well in online settings. Therefore, proper asynchronous communication channels (e.g., Slack or Piazza) are essential to connect students and teaching staff. Furthermore, a video conferencing system that allows fast and easy assignment and re-assignment of breakout rooms is essential. Timely and continuous feedback throughout the course is vital.
3. Chanpet el al., 2020	Thailand	To investigate the role that online technologies can play	58 students (28 in online section; 30 in	16 weeks	Results of the surveys of learners' perceptions suggested overall learner

Number, author(s)	Country of origin	Aims/purpose	Study population/sample size	PBL duration	Key findings
		in FA [formative assessment] in PBL	face-to-face section)		satisfaction with the form of learning and few barriers. The results of the PBL knowledge and skills post-test showed higher achievement for the online versus the face-to-face section.
4. Arantes do Amaral & Fregni, 2021	Brazil	To understand how to maximize the learning experience in an online PBL centered course in the COVID-19 context…; to use neuroscience findings to discuss our results based on our course experience.	20 graduate students from the Faculty of Education (i.e., teachers from several public and private schools)	A course conducted over seven weeks	The teaching approach followed (i.e., flipped classroom) worked very well; the videos, the accomplishment of the projects' activities, the reflection about the teacher's weekly feedback, and the readings helped the students associate the theoretical concepts with real-life experiences; the students' participation in the online forum helped the students learn with each other. Also, the video feedback from the teacher promoted an intense knowledge sharing and improved the connection between theory and practice.
5. Guo et al., 2021	China	To characterize student social and cognitive presences in online discussions during PjBL and investigate how they are related to student performance	24 groups consisting of 3-4 students	8-week online course	The expressions of effectiveness and exploration are the most frequently used social and cognitive presences during students' online group discussions, respectively. In addition, students' group academic performance was positively related to the social presence of affective expressions, humor use, and vocatives and the cognitive presence of exploration and offering opinions. The type of students' social presence when using WeChat to communicate is more than that when using online forums. Regarding the expression of emotions, students used many emojis and stickers to express their emotions.

Number, author(s)	Country of origin	Aims/purpose	Study population/sample size	PBL duration	Key findings
6. Halaweh, 2021	United Arab Emirates	To suggest that project-based learning (PBL) assessment could be an effective alternative to online examinations … and advocate the adoption of PBL	30 students	14 weeks	This project allowed for deep learning; The students also had opportunities to reflect on their experience of creating a prototype. To adopt project-based learning successfully, instructors might need training on how to design and evaluate team projects as well as on how to ensure that projects comprehensively provide students with opportunities to meet course learning outcomes.
7. Hayashi et al., 2023	Brazil	To describe how the PjBL was applied in the Computing Engineering remote courses during the COVID-19 pandemic at a Brazilian University	81 students	Courses conducted in 2020-2021	The completion of 31 projects by students from our multi-case study shows that the students could engage in discipline despite the limitations of online learning during COVID-19; using PjBL can mitigate the effects of emergency remote teaching, making student performance similar to face-to-face offerings. when combined with remote labs, home labs and virtual labs, Project-Based Learning can engage students by allowing them to integrate emerging technologies into their projects and choose themes of interest.
8. Krishnakumar et al., 2022	USA	To investigate the perceptions of first-year engineering students enrolled in an introductory engineering design course during the rapid transition to online working environments	13 first-year Engineering students	One semester	Data revealed how some students saw the digital divide as a barrier, noting that either they or their teammates would still not attend meetings and engage in other activities during Zoom lectures and meetings. These challenges in self-regulation may also be considered emblematic of the blurring of home and work environments for students. Some students reported being able to communicate more openly with their teammates online as compared to in-person,

Number, author(s)	Country of origin	Aims/purpose	Study population/sample size	PBL duration	Key findings
					which led to them becoming closer with their teams.
9. Mielmann, 2021	South Africa	To provide educators with a basic 10-step approach to complete an online food research project and to consider students' engagement, reflections and experiences.	39 students	15 weeks	Student-content interaction in online education refers to students' perceptual and cognitive contact with various types of e-content (e.g., e-journals, websites, audio-video) that should be studied in the course. An important determinant of students' positive experience and satisfaction in online learning is their ease of access to e-content. Therefore, developing interactive e-content is vital; building relationships in the online learning context was challenging with the lack of contact between students and the educator. Evoked emotions such as interest, enjoyment and a sense of belonging is an indication of students' emotional engagement which improves their classroom engagement. During the completion of the online food project, it was difficult for students to achieve this emotional engagement as they were less engaged due to other responsibilities and less time spent with educators.
10. Paristiowati et al., 2022	Indonesia	To develop the sustainability competencies of preservice chemistry teachers through the use of a project-based learning model	26 preservice chemistry teachers	October 5, 2020, until November 14, 2020 (6 weeks)	The preservice chemistry teachers engaged in creating a project-based learning solution through an online summer course program that developed students' sustainability perspective and environment awareness, higher-order thinking skills, and communication and collaboration skills.
11. Paviotti et al., 2020	Italy	To analyze the degree of openness of education in the frame of the course "Economics and Marketing of Agri-food" carried out	54 students in the undergraduate program degree "Cultural	Not specified	Students reported about a perceived lack of guidance and feeling of disorientation within the project-based learning process. 30% of respondents to the

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		during the Academic Year 2019-2020	Heritage and Tourism		questionnaire stated that they would have needed more examples on how to do and how to proceed, even if the two introductory lessons of the description of process and tools were recorded and available, and the tutors were ready to provide support also to link with entrepreneurs.
12. Peng et al., 2022	China	To identify whether and how computer-based scaffolding might benefit students of different levels of academic achievement (e.g., high-, medium-, and low-achievers) to sustain their PjBL.	69 Year 3 computer science students	6-week online course	With the support of computer-based scaffolding, all participating students maintained a high level of motivation in the PjBL course; their performances in subject knowledge, product quality, and programming thinking skills were significantly improved at the end of the course. Most students mentioned technical problems of the learning system (42%) and insufficient interaction with the teacher during the study (25%). Some students mentioned the learning difficulties (22%), the lack of sufficient learning time (17%), and the lack of supervision from the teacher (13%) during the study. Among them, more low-achieving students, compared to high-achievers, commented on the weakness regarding inadequate teacher–student interactions during the study.
13. Poonpon, 2021	Thailand	To explore how self-generated online projects were integrated into an ELT class at a Thai university and examine their impact on pre-service teachers' learning experience during the unexpected COVID-19 situation	58 pre-service English language teachers	One semester/ six weeks	The pre-service teachers believed that the online projects increased their 21st century skills, such as problem-solving, creativity, collaboration skills. More importantly, the projects helped the students to apply their teaching knowledge and digital skills to real-world practice. Obstacles encountered during the

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					project included a sudden change of learning and teaching modes from onsite to being 100% online. This was a shock for them. They also believed that their limited technology and multimedia skills, inconvenient online communication, project time limitations, and inexperienced management skills delayed their work in the COVID-19 lockdown. The results suggest that technology or multimedia knowledge and skills should be included in ELT courses as it is important for pre-service English teachers to adjust themselves for the technology-oriented society and classrooms
14. Sakamaki et al., 2022	Japan	To research the feasibility and problems of distance education for data science education from the practice of synchronous distance education of PBL and questionnaire survey in 2020	37 students	15 weeks	Although there are some issues to be improved, distance education for PBL could be sufficiently implemented based on our practice. Distance education for PBL in data science has a great advantage for future education regardless of the pandemic of COVID-19. The good points reported were ease of participation, effective use of time, viewing recorded lectures, ease of group working online after classes, and explicit role sharing. There were some opinions that it was possible to plan tightly with a sense of crisis and share the roles clearly due to the difficulty of distance education. Improvements included lack of casual communication with teachers, of casual use of Zoom after classes, of use of chat, and of time for group work, communication tools not being unified, and

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					inability to grasp the progress of other groups. Some students were worried because they did not know when teachers would come to the breakout room.
15. Sola-Guirado et al., 2022	Spain	To evaluate the usefulness of this work strategy, to obtain a high performance in postgraduate teaching using CAD/CAD/CAE tools through a practical methodology and distance work so that students can learn by doing and enhance the assimilation of global competencies. Likewise, this work describes the basis and functionality of the cloud-based server system and aims to discuss its impact on distance learning.	25 students	6 weeks	The students showed a high level of satisfaction in the realization of the work. All this has been achieved through virtual teaching and work from home of students thanks to the virtualization system launched for this purpose in the University. The operation of CAD/CAM/CAE tools, which usually requires significant computing resources, has worked well in this environment with very good results in the surveys conducted by students.
16. Sun et al., 2023	China	To provide evidence on the impact of virtual labs on learning outcomes in undergraduate science education.	27 students	6 weeks	This study found that the PBL-based approaches help students to understand better about a microbiome project going from bench to public health applications. All the students were able to complete the laboratory steps by using the pedagogic approach of first learning theoretical knowledge in the classroom, then practicing virtual simulation experiments online, and finally analyzing real metagenomic data. The learning outcomes indicate that this course can spark an interest in students to learn.

Appendix D

Mielmann's (2021, p. 7) Overview of the Guidelines Provided to Students Engaged in PBL

1. Sufficient literature on the background and methodology of the research project
2. Recorded Zoom lectures with Microsoft PowerPoint slides to explain the research project
3. Four incomplete objectives
4. A questionnaire template
5. A work schedule guideline
6. A recorded Zoom lecture to explain data analysis on Microsoft Excel
7. A Microsoft Excel template for data analysis and outlay of tables
8. A Microsoft PowerPoint template for the presentation
9. Evaluation criteria for the report and presentation
10. Recorded Zoom meetings to address questions and problems