

# A Systematic Review on the Effectiveness of Project-Based Learning for Teacher Preparation During the COVID-19 Epidemic

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## Abstract

The COVID-19 pandemic has had a major influence on educational institutions all across the globe, including programs that prepare teachers. Teachers in teacher preparatory programs have looked at alternative instructional methodologies including project-based learning (PBL) in response to the difficulties presented by remote learning and the lack of in-person contacts. This research seeks to evaluate the efficacy of PBL in teacher training throughout the COVID-19 pandemic using a systematic review approach. To gather data for the study, several electronic databases were searched, including Google Scholar, Scopus, Education “Research Information Center (ERIC), ProQuest, Science Direct, and Taylor & Francis Online. The researchers exclusively opted for articles listed in Scopus index, thoroughly scrutinizing them through the “Scopus resource system”. Employing Boolean search filtering and specific search strings such as “(pre-service teacher) and (project-based learning), (prospective teacher) and (project-based learning), and (teacher education) and (project-based learning)”, among others. The search eventually yielded 15 papers which were used for this review. While the participants showed a high degree of PBL utilization in their teaching methods during the pandemic, they also highlighted the value of supporting the project-based learning (PBL) environment. The results imply that PBL may have successfully train instructors for online and integrated learning settings during the COVID-19 pandemic. The findings emphasize the significance of including PBL into teacher preparation curriculum and giving teacher candidates continuous assistance and training to maximize the advantages of this teaching strategy. Further study is necessary to examine the long-term impacts of PBL on instructors’ effectiveness and student academic results after the pandemic.

**Keywords:** teacher preparation, COVID-19 pandemic, project-based learning (PBL)

## 1. Introduction

The emergence of the COVID-19 pandemic resulted in unprecedented disruption in the education system across the globe, compelling an abrupt shift to online learning as well as posing significant challenges in the preparation of teachers (Allen et al., 2020). Higher institutions - that perform a key function in the preparation of teachers (Hernández-Barco et al., 2021) – have taken up contemporary approaches to teaching that can link the education of student-teachers with their real-life future job (Martinez, 2022; Tsybulsky & Muchnik-Rozanov, 2023; Poonpon, 2021; Al-Busaidi & Al-Seyabi, 2021). In this context, project-based learning (PBL) has emerged as a promising pedagogical approach to enhance the skills of teachers as well as prepare them for demands of teaching in a rapidly changing landscape (Hmelo-Silver, 2004).

The project-based learning (PBL) approach encourages students to actively engage in real-world, hands-on projects as they advance their knowledge, competences, and abilities. Instead of using typical lecture-based teaching strategies, PBL encourages collaboration, active learning, problem-solving, and critical thinking (Sefton et al., 2020). In project-based learning, students often work on complicated and multidimensional assignments and call for them to examine, research, and use their knowledge to address a pressing issue or provide important insight.

PBL assignments often include interdisciplinary material, enabling students to draw links across many academic disciplines (Yusrizal & Pulungan, 2021). PBL promotes critical thinking by having students analyze material, evaluate supporting data, and develop solutions to complex problems. They build crucial reasoning, decision-making, and strategy modification capacity in response to feedback and new information. As the project

progresses, students assess their work, identify issues, and make adjustments (Sefton et al., 2020). PBL helps students by involving them in relevant, project-based activities that help them develop the knowledge, abilities, and competencies needed for success in the real world (Prasetiyo et al., 2023).

By immersing students in important, practical tasks, project-based learning (PBL) is a teaching strategy that encourages active learning and student participation. Some of the main advantages of PBL have been succinctly expressed in several studies (Manoban, 2021; Al-Busaidi & Al-Seyabi, 2021; Syawaludin et al., 2022). The capacity of PBL to help students acquire critical thinking (Diego-Mantecon et al., 2021), decision-making, and strategy modification abilities are among its main benefits. Students are exposed to complicated issues or obstacles when working on projects, which call for them to use critical thinking skills, information analysis, and decision-making (Al-Busaidi & Al-Seyabi, 2021; Randazzo et al., 2021). PBL helps students to weigh many viewpoints, assess the facts, and use their knowledge to address real-world issues (Chanpet et al., 2018).

This review argues that project-based learning has proven to be an effective pedagogical approach for teacher preparation during the COVID-19 pandemic, enhancing teacher candidates' skill in remote instruction, adaptability, and community engagement, and recommends its continued adoption in teachers' education programs. PBL encourages a lifelong learning process (Gutiérrez et al., 2006 as cited in Hernández-Barco et al., 2021; Shamma & Kadnozokova, 2024). The feedback and fresh material students experience when working on projects helps them to evaluate their work, spot any problems or gaps in their comprehension, and make the required corrections.

### *1.1 Research the Objective*

This review paper aims to ascertain the application, value, and difficulties of PBL in teacher education.

### *1.2 Research Questions (RQ)*

The following research questions were developed to specify the study's emphasis based on its objectives:

- What are the demographic details of the articles that are included (such as the year of publication, regional distribution, topics, project kinds, and technical support)?
- What tools are utilized to assess PBL's effectiveness?
- What are the major results of PBL in teacher education for pre-service
- What are the benefits and difficulties of adopting online PBL in the COVID-19 pandemic for teacher education?

### *1.3 Significance of the Study*

Evaluating the effectiveness of PBL for teacher preparation during the COVID-19 pandemic is significant for the following reasons:

- By focusing on these crucial contributions, assessing the efficiency of PBL for teacher preparation during the COVID-19 epidemic can offer insightful information about instructional practices, technology integration, and student engagement, improving the standard of teacher education programs and preparing teachers for the challenges of the digital age.
- By assessing the success of project-based learning at this time, we may better understand how this participant-centered and inquiry-based pedagogy might be used in online or blended learning settings.
- The usefulness of PBL in teacher training during the COVID-19 epidemic is examined based on 15 papers from pertinent databases.

## **2. Literature Review**

### *2.1 Overview of Project-Based Learning*

Project based learning (PBL) is a specific illustration of a potential approach that advances students' learning in higher education (Guo et al., 2020). Being an inquiry-based, student-centered teaching approach, project-based learning enables students to take part in the process of knowledge formation by identifying and propounding solutions to real-life problems (Hunter-Doniger, 2018; Chanpet et al., 2018), this is an anticipated strategy for teaching that is capable of promoting student-teachers' digital citizenship competencies (Prasetiyo et al., 2023).

The PBL is a successful strategy that fosters in students critical thinking, decision-making, and flexibility (Gutiérrez et al., 2006 as cited in Hernández-Barco et al., 2021). Students acquire the practical skills and abilities required for success in real-world environments by participating in relevant, project-based activities. PBL's iterative structure, which incorporates feedback and correction, enhances the learning process and encourages

continual development.

As shown in Figure 1, project-based learning (PBL) helps aspiring teachers gain critical skills and adapt to the changing educational environment, making it a potentially effective technique for teacher preparation during the COVID-19 pandemic (Maksum & Purwanto, 2022). During the pandemic, when remote or hybrid learning modalities were prevalent, PBL helped future instructors experience and understand the challenges and advantages of distance education (Febiyanti et al., 2021).

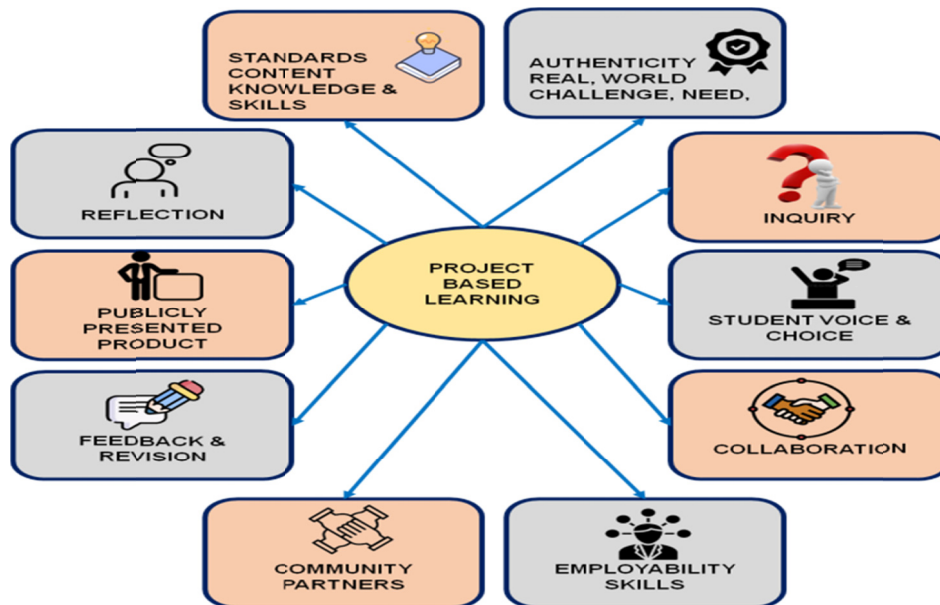


Figure 1. Analysis of project-based learning

Generally, based on the studies of Nava and Park (2021), Alromaih et al. (2022) and Martinez (2022), project-based learning, as represented in figure 1 above can be said to be made up of these five phases:

- 1) Selecting the project—often emerging from a problem the teacher has initially discussed,
- 2) Planning of project – students plan the execution of the project and consider the necessary conditions through the teacher’s guidance,
- 3) Project implementation/credibility – students apply their experience and knowledge to execute the projected plan,
- 4) Reflection and project assessment – this process is conducted by the student and the teacher together, taking place concurrently during the execution of project and after the completion of the project, and
- 5) “Public product”.

Project based learning thus requires the ability of students to set goals, make comprehensive plans, strategically implement projects, be creative and collaborate (Sefton et al., 2020).

An essential component of the learning system is course assessment. A solid foundation for course execution choices is provided by evaluation, which also includes suggestions for long-term adjustments and processes (Wahyuningsih et al., 2021). The main goal of the evaluation process should be to determine how effectively and efficiently educational policy is implemented. Evaluation of educational program goals, content, approaches to local, national, and worldwide challenges, and outcomes are possible. Academic stakeholders have previously advised it to maintain their emphasis on evaluating classroom-based courses (Paristiowati et al., 2022).

The COVID-19 pandemic has introduced numerous educational challenges, such as learning loss, social-emotional well-being, and equitable access to education. PBL allows future teachers to address these challenges through meaningful projects focusing on real-world problems (Habibi et al., 2022; Shamma & Kadrozokova, 2024). They can design projects that promote student well-being, address learning gaps, or explore issues related to remote learning, fostering critical thinking and problem-solving skills. PBL encourages

collaboration and communication skills, essential for effective teaching in remote or hybrid settings (Kamali & Kocaoz, 2021).

## 2.2 Theoretical Foundation

Project based learning which takes its root from the “Piaget’s and Dewey’s constructivist theory”, identifies students’ real-life practices as the hubs for academic activities (Hawari & Noor, 2020), and utilizes projects as an avenue for teaching (Hujjatusnaini et al., 2022). Project based learning usually presents a situation that is realistic at the onset of a course (Miller et al., 2021; Lee & Galindo, 2021), then students investigate, evaluate, interpret, and compound information to gather and integrate novel experience-based knowledge as well as skills (Miller et al., 2021; Martinez, 2022; Chung & Li, 2021; Hujjatusnaini et al., 2022), and then go on to create the product, like a report on a performance or an artifact (Sefton et al., 2020).

Several studies have indicated that project-based learning improves the teaching effectiveness of educators as well as builds the attitudes, knowledge and skills of the students. Project based learning enhances students’ understanding of a subject, thus improving the outcomes of learning (Manoban, 2021; Habibi et al., 2022; Al-Busaidi & Al-Seyabi, 2021). Furthermore, the process of implementing projects with steps like self-inquiry, self-planning and examination helps students to exercise autonomous learning skills (Goldstein, 2016; Prasetyo et al., 2023; Al-Busaidi & Al-Seyabi, 2021; Randazzo et al., 2021; Alromaih et al., 2022; Manoban, 2021) as well as skills in carrying out scientific research (Chung & Li, 2021; Al-Busaidi & Al-Seyabi, 2021; Rusmini et al., 2021; Charania et al., 2020). In addition, several studies have established the positive impact of project-based learning in building the cognitive capabilities of students (Diego-Mantecon et al., 2021), including creative thinking (Baran et al., 2021; Paristiowati et al., 2022; Anggito et al., 2021; Habibi et al., 2022), “higher-order thinking” (Baran et al., 2021) such as creativity (Wijaya et al., 2021; Baran et al., 2021), as well as skills for solving problems (Baran et al., 2021; Paristiowati et al., 2022). Moreover, fundamental soft skills of the twenty-first century citizens (Martinez, 2022; Morrison et al., 2020; Puspitasari, 2020; Prasetyo et al., 2023) like teamwork (Paristiowati et al., 2022; Aksela and Haatainen, 2019; Manoban, 2021; Baran et al., 2021), time-management (Kamali & Kocaoz, 2021), communication (Baran et al., 2021), digital (Baran et al., 2021; Al Mulhim, 2022; Prasetyo et al., 2023) and technical skills (Charania et al., 2021) were as well confirmed with improvement after engaging project based learning. In addition, project based learning increases motivation for learning (Aksela & Haatainen, 2019; Manoban, 2021; Goldstein, 2016), positive attitude to learning (Van Loi & Hang, 2021; An, 2020; Paristiowati et al., 2022; Goldstein, 2016; Diego-Mantecon et al., 2021; Tsybulsky and Muchnik-Rozanov, 2021; Brown and Jain, 2020) and belief in self-efficacy (Randazzo et al., 2021; Ilyas & Saeed, 2021), engagement (Umar & Ko, 2022) as well as the value of constructivist and active methods of teaching learners (Brown & Jain, 2020; An, 2020). Furthermore, integrating other educational methods with project-based learning has as well produce several significant outcomes, including blended learning (Yustina et al., 2020), STEM (Morrison et al., 2020), and STEAM (Diego-Mantecon et al., 2021).

Apart from the benefits project-based learning offers, educators and students encounter several challenges to guarantee effective learning and teaching process. Lee and Galindo (2021) opined that creating a project-based learning-environment demands changing curricula, instruction and teachers’ teaching initiative (Miller et al., 2021) and is equipped with strong pedagogical and professional knowledge. Many other factors need to be taken into consideration at the same time, including resources, pedagogical strategies, assessment practices and instructional materials (Lee & Galindo, 2021; Goldstein, 2016; Shamma, 2018). Habibi et al. (2022) and Aksela and Haatainen (2019) established that the performance of teachers targeted at improving the quality of teaching can increase students’ motivation to learn as well as advance thinking capabilities. For students, the primary challenges are linked to know-how in utilizing IT to get information and execute projects (Al Mulhim, 2022; Aksela & Haatainen, 2019; Alromaih et al., 2022; Chung & Li, 2021), and authentic challenges like not being able to implement research steps (Al-Busaidi & Al-Seyabi, 2021), focus on taking part in project (Alromaih et al., 2022), as well as skills in time management (Aksela & Haatainen, 2019; Nava & Park, 2021; Kamali & Kocaoz, 2021). Nevertheless, during the COVID-19 pandemic, both learners and teachers were under serious pressure, and inadequate technological skills, inconvenient online communication, limited project time as well as lack of management skills stalled their work (Prasetyo et al., 2023; Poonpon, 2021). These were also among the notable challenges to project-based learning implementation. Furthermore, executing teaching strategies like project-based learning requires huge financial resources, devices and tools for educational institutions, students and teachers as well as references (Alromaih et al., 2022; Shamma & Strongoli, 2023).

One of the reasons for educating teachers is to advance their professional competencies, such as academic skills and knowledge, content knowledge, as well as building of cognitive capability, right attitudes and notions (Buchholtz et al., 2018). University education assumes a critical role in the development of citizens that are

responsible. Therefore, sustainable policies and practices should be established in order to encourage “green attitudes” at institutions of higher learning as well as encourage the attainment of long-lasting management systems to create realistic patterns of thinking by students (Gutiérrez et al., 2006; as cited in Hernández-Barco et al., 2021). According to Prasetyo et al. (2023), project-based learning is a teaching strategy that promotes the competences of digital citizenship in student-teachers. Tsybulsky and Oz (2019) and Tsybulsky and Muchnik-Rozanov (2021) noted that preparing teachers with project-based learning affects teachers’ pre-service impressions and correct attitudes towards the ability to utilize project-based learning in future education of teachers. However, in terms of education technology courses for pre-service teachers, this adaptation poses even more difficult challenges (Umutlu, 2022). Umutlu gave the implications for design of online courses in teachers’ education fostering pre-service teachers’ technological academic content knowledge with the Technology, Pedagogy, and Content Knowledge (TPACK) Model. According to Yadav et al. (2017, pp. 55-62), “TPACK model indicating that teachers learn to effectively integrate technology by combining academic knowledge and their content area, is proper to be applied in preparing courses for pre-service teachers’ preparation to build teachers’ knowledge needed to create significant pedagogical experience in classes that are inter-woven with technology”.

Charania et al. (2021) analyze the preparation for the new primary teacher’s class differences depending on online learning environments and the influence of the PBL learning model. Hernández-Barco et al. (2021) discussed teaching and learning techniques used by secondary government school instructors and pupils in Eastern India during the COVID-19 lockdown. These instructional approaches were examined in light of their participation in the integrated approach to technology in education programs. Nava and Park (2021) described 19 aspiring primary teachers enrolled in scientific topics that would benefit them emotionally and cognitively, which is a qualitative one, is concerned with higher education for sustainable development. Chung and Li (2021) extracted the future math and science instructors in community-focused project-based learning, allowing them to include community resources, voices, and needs in their pedagogical practice. Pre-service in this setting engage pupils by relating STEM-related concerns to their own and communal experiences. Hujatusnaini et al. (2022) explored how study helped aspiring art educators’ use virtual reality to host a virtual art show in a project based learning atmosphere. In particular, study guided our pre-service through the completion of this virtual art gallery project using the High-Quality Project Based Learning framework. Our methodology has six components: reflection, cooperation, project management, authenticity, public output, and intellectual challenge and achievement. Yustina et al. (2020) suggested a quantitative descriptive methodology and a quasi-experimental study design, blended PBL integration with 21st-century abilities was used. Pre-service who are currently enrolled in educational institutions, particularly teacher faculties, and who are referred to as pre-service in this research.

Alromaih et al. (2022) suggested the PBL technique, where the standard class is the control. Brown and Jain (2022) aimed to highlight the significance of providing project-based learning for female early childhood educators to increase their understanding of educational design processes. The research also attempted to determine the benefits and drawbacks of project-based learning for instructional design training from the students’ perspectives and to provide ideas and recommendations to address any deficiencies. Al-Busaidi and Al-Seyabi (2021) evaluated using a mixed-methods research design after using a project approach with kindergarten and first-graders.

### **3. Method**

#### *3.1 Experimental Procedure*

This involves examination of the data analysis results to determine the effectiveness of PBL for teacher preparation during the COVID-19 pandemic; as well as interpretation of the findings, considering the study’s limitations and potential implications for teacher education programs.

#### *3.2 Data Collection*

To find relevant literature examining PBL in teacher education, databases were searched in February 2023. Due to their availability on the internet and the depth of education-related research, the study provides several electronic databases selected, including Google Scholar, Scopus, Education “Research Information Center (ERIC), ProQuest, Science Direct, and Taylor & Francis Online (Bland, 2020). Nonetheless, in order to focus the scope of this research and reduce the inclusion of studies with lower quality, we exclusively opted for articles listed in the Scopus index, thoroughly scrutinizing them through the Scopus resource system. Employing Boolean search filtering and specific search strings such as (pre-service teacher) AND (project-based learning), (prospective teacher) AND (project-based learning), and (teacher education) AND (project-based learning), among others, facilitated the retrieval of relevant articles. It’s worth noting that the syntax of these search strings may be adjusted as needed for different databases. To ensure an unbiased selection process, the authors independently conducted searches on these databases, employing the specified search strings. They meticulously screened full texts using

inclusion and exclusion criteria. Additionally, the review process involved a critical evaluation of the methodological aspects of the included articles, encompassing theoretical background, study design, data collection, data analysis, interpretation, and conclusions. Each criterion was initially assessed independently, with subsequent collaborative discussions among the authors to achieve consensus. Only articles garnering unanimous agreement were ultimately chosen for inclusion.

However, only the 15 articles mentioned in the index were picked after being scrutinized via the resource system to condense the focus of this research and reduce the number of lower-quality studies chosen. The number of articles included, the range of findings, and the capacity to generalize the patterns of the drawn conclusions may have been constrained by the limitations in the databases' selection. The studies use a variety of research methodologies, with sample sizes ranging from four to 350 participants depending on the study designs, which might range from two weeks to one year. On the other hand, while the research chose papers published in 2020–2023 to examine the condition of the online PBL implementation in teacher education during the COVID–19 pandemic, some of the chosen publications do not refer to the online components in the description of PBL implementation”.

### *3.3 Design for PBL for Teacher Preparation*

The study was conducted using the systematic study methodology. Systematic research may also help summarize the available data in a particular field and increase the precision of conclusions by demonstrating if results from several studies are reliable and consistent. The Preferred Reporting Items for Systematic studies and Meta Analyses (PRISMA) standards were followed in a systematic literature study to offer a complete picture of the knowledge on PBL teacher preparation. To answer the research questions, the researchers intended to study certain publications. A search methodology was initiated when the research questions for the study were completed. This procedure was required to reduce any potential for research bias.

#### *3.3.1 Search Limits of PBL*

The searches were restricted to peer-study English-language papers released between 2020 and 2023. Furthermore, the investigations were wider than the most recent works of academics. Thus, other papers by the same scholars might be included if they fulfilled the search parameters.

#### *3.3.2 Inclusion Criteria of PBL*

According to the goals of the research, publications were taken into consideration for inclusion, provided they met the following three requirements:

- Associated with the theme of teacher education,
- Associated with the use of PBL in pre-service;
- Elucidate an empirical educational survey or intervention on implementation, challenges and effectiveness of project based learning in educating pre-service teachers.

#### *3.3.3 Exclusion Criteria of PBL*

Articles were excluded if

- The article in the publication wasn't original,
- Neither an experiment nor a survey was used in the research design,
- PBL-style instruction was not used.
- The outcomes had nothing to do with how PBL was used, how well it worked, or how difficult it was to train pre-service.
- The scenario did not include teacher education.

#### *3.3.4 Search Outcomes of PBL*

There were 210 relevant articles found after searching. The “End-Note reference management program” compiled these articles into a database, including their entire texts, abstracts, and titles. One hundred and forty articles were removed when duplicate papers were found, and article names and abstracts were checked. A full-text analysis and eligibility evaluation were done to choose the articles to be included. 35 items were eliminated from consideration because they needed to fit the requirements. 15 pertinent papers were kept after the procedure to be examined in this organized analysis. Figure 2 outlines the PRISMA-recommended method for choosing articles.

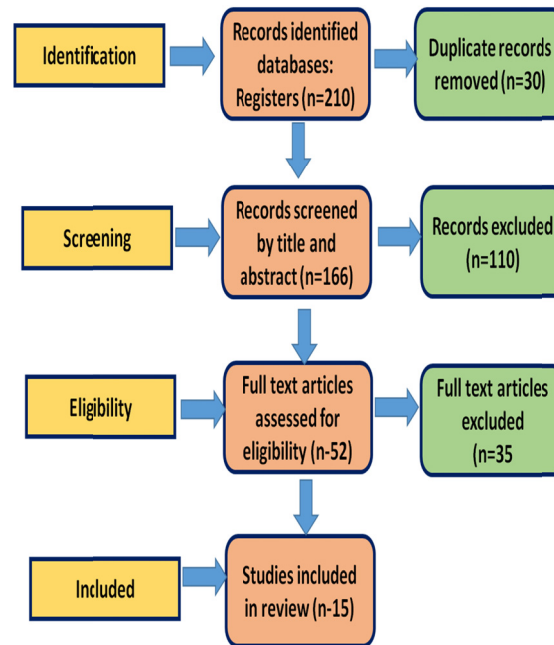


Figure 2. PRISMA diagram for included articles

### 3.4 Typical Technological Instruments Employed in the Included Articles (IE)

The technology components used for presenting lectures and those used for the project may be separated into two categories when utilizing PBL in the included articles. In general, the platforms above may be used on different devices, enabling students to study whenever and wherever they want, to the demands of autonomous learning due to the COVID-19 pandemic. On the other hand, including technology in the project's implementation allows instructors to engage in "hands-on" learning and meets their demands.

### 3.5 Learning through Online PBL: Pre-Service Findings

The usefulness of PBL for enhancing pre-service knowledge, abilities, and attitudes via learning and project execution was studied in 15 articles as presented in Table 1.

Table 1. Pre-service of learning with online PBL

Pre-service findings	Selected Articles
Cognitive & skill aspects of instructional design	Alromaih et al. (2022), Brown and Jain (2022), Chuang and Jamiat (2023)
Increasing learning outcomes	Hujjatusnaini et al. (2022), Yustina et al. (2020), Martinez (2022)
Increasing understanding & constructing specific knowledge	Charania et al. (2021), Hernández-Barco et al. (2021), Nava and Park (2021), Chung and Li (2021)
Self-directed learning	Syawaludin et al. (2022)
Self-awareness	Al-Busaidi and Al-Seyabi (2021), Habibi et al. (2022), Paristiowati et al. (2022)

The Cognitive & skill aspects of instructional design (five articles), Increasing learning outcomes (three articles) and Increasing understanding & constructing specific knowledge (one article), Self-directed learning (three articles), and Self-awareness (one article).

## 4. Results

The results highlight the implications of the study for teacher preparation programs, emphasizing the importance of integrating PBL as an effective instructional strategy to enhance teacher preparedness and adaptability during crises like the COVID-19 pandemic.

### 4.1 Factors Influencing the Publication Year's Demographics

Table 2 and Figure 3 show a list of publication years for the papers that were considered. There are 15 articles with

a number of participants greater than 50. It can be seen that, out of a total of “15 included articles, the most published articles were from 2022 (7 articles, 82.4%). Only 1 article (accounting for 18.2%) were published in 2020, only 6 articles (accounting for 65.3%) were published in 2021 and 1 article (accounting for 10.2%) were published in 2023 (as of February). The number of studies conducted in 2020 appears to be significantly low when compared to those conducted in 2021 & 2022. This inequality is probably due to the suspension of academic activities in each country, especially during the peak of the pandemic. Nevertheless, after an initial adjustment period, online project-based learning (PBL) learning accelerated significantly from 2021 to 2023 in response to the need to meet learning needs amid the pandemic (Paristiowati et al., 2022; Tsybulsky & Muchnik-Rozanov, 2023; Prasetyo et al., 2023; Poonpon, 2021; Rusmini et al., 2021; Schina et al., 2021; Yustina et al., 2020).

Table 2. Numerical Outcomes of publication year distribution of the included articles

Publication Year	Percentage (%)
2020	18.2
2021	65.3
2022	82.4
2023	18.2

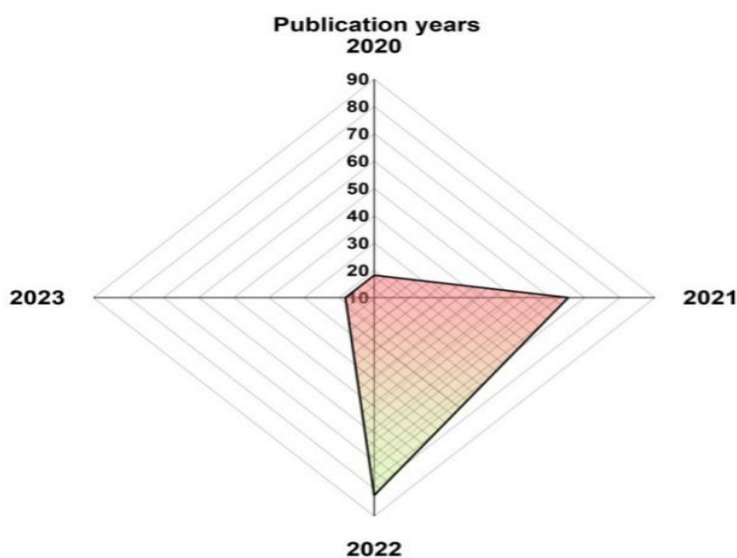


Figure 3. Comparison of publication year distribution

#### 4.2 Subject Distribution of BPL for Teacher Preparation

PBL may be used in a variety of teacher education settings (see Table 3 and Figure 4). Each participant was included in this data when some studies reported looking at the use of PBL across several subjects. Out of the 15 articles, Mathematical and Science Education have the most studies, with seven articles covering Mathematics and Science Education (88.4%). The training of teachers for natural subjects has also been the subject of numerous studies, including Elementary Education (1 article, accounting for 33.7%), Biology Education (2 articles, accounting for 42.4%), Preschool Education (2 articles, accounting for 56.8%), English Language Education (3 articles, accounting for 74.8%), and Instructional Technology (3 articles, accounting for 62.6%).



Table 3. Numerical Outcomes of subject distribution of BPL for included articles

Subject distribution	Selected articles	Percentage (%)
Elementary education	Syawaludin et al. (2022)	33.7
Mathematics & Science education	Charania et al. (2021), Hernández-Barco et al. (2021), Nava and Park (2021), Chung and Li (2021)	88.4
Biology education	Hujjatusnaini et al. (2022), Yustina et al. (2020)	42.4
Preschool education	Alromaih et al. (2022), Brown and Jain (2022)	56.8
English language education	Al-Busaidi and Al-Seyabi (2021), Habibi et al. (2022), Paristiowati et al. (2022)	74.8
Instructional technology education	Kamali and Kocaoz (2021), Martinez (2022), Chuang and Jamiat (2023)	62.6

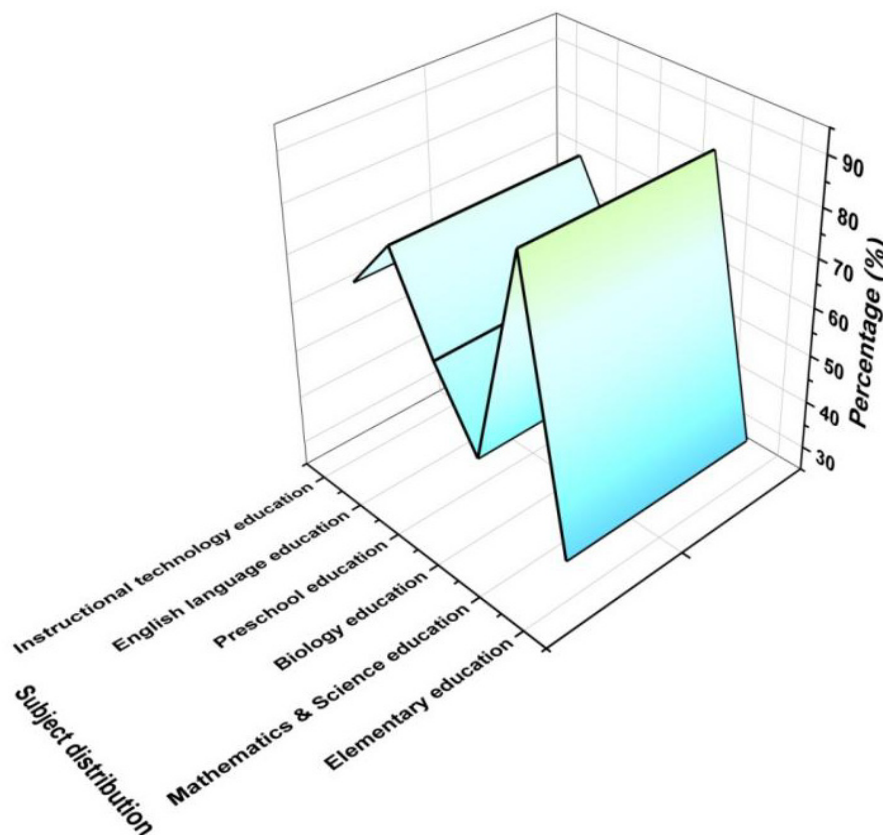


Figure 4. Comparison of subject distribution of BPL

#### 4.3 Benefits and Difficulties of Online PBL During the COVID-19 Pandemic

PBL has several benefits for the teaching procedure and “the development of students’ knowledge, abilities, and attitudes, but it also poses numerous difficulties for instructors to apply it successfully. The quality of their work on PBL and projects is impacted by issues with technology and multimedia skills, content and pedagogical knowledge, project management skills, time management skills, science process skills, and pressure”, as shown in Table 4 and Figure 5. This is true for both students and teachers. Specifically, the knowledge and skill required for creating a PBL environment pose a significant challenge for teacher preparation programs. It is also seen to be challenging for instructors to apply PBL because of the time constraints on skill training for students and project execution, which has an impact on students’ capacity to finish projects.

Irrespective of the difficulties that came with concerns about health safety and social distancing in the heat of the COVID 19 pandemic, educational institutions have taken advantage of several potentials in the online project-based learning environment (Schina et al., 2021). Rusmini et al. (2021) opined that during the pandemic, when students independently carried out academic activities, education had increased students’ competencies, particularly research skills and scientific inquiry as well as boosted positive learning attitudes and motivation. According to Schina et al. (2021), the pandemic enabled educators to rethink and modify digital technology

content and teachers' online education. The integration of blended education and project based learning also facilitates the development of pre-service teachers' creative abilities.

Table 4. Numerical outcomes of challenges of BPL for included articles

Challenges of online PBL	Selected articles	Percentage (%)
Technology & multimedia skills	Kamali and Kocaoz (2021)	28.2
Science process skills	Charania et al. (2021), Hernández-Barco et al. (2021), Hujjatusnaini et al. (2022), Yustina et al. (2020)	76.3
Pedagogical knowledge	Nava and Park (2021), Chung and Li (2021), Paristiwati et al. (2022)	42.2
Teacher's training	Martinez (2022), Chuang and Jamiat (2023)	38.6
Project time limitations	Syawaludin et al. (2022), Al-Busaidi and Al-Seyabi (2021), Habibi et al. (2022),	62.4
Information resources	Alromaih et al. (2022), Brown and Jain (2022)	58.2

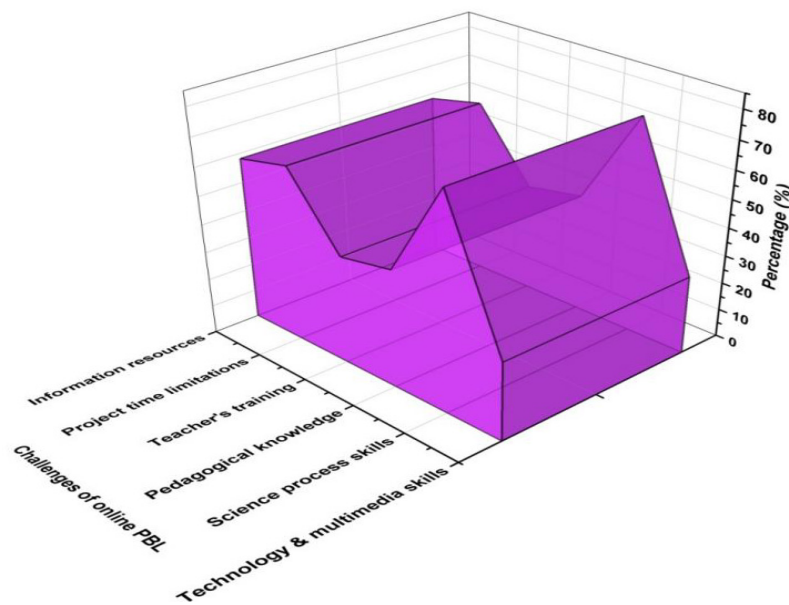


Figure 5. Comparisons of challenges of BPL

#### 4.4 Implication of the Findings

Project based learning has become a prominent teaching strategy in teacher education; this was evident during the casue of the COVID-19 pandemic. PBL can be effectively used a variety of subjects ranging from Mathematics, Science Education, Technology Education, Instructional Technology, Elementary, Preschool, Arts, English Language, Biology, Chemistry, Science, and Curriculum and Instruction, amongst others. It can as well be adapted to different types of projects, thus, promoting academic prowess and skills.

Technology plays a crucial role in PBL with the employment of a number of tools to enhance independent learning, flexibility, project implementation, as well as lecture delivery. The study highlights the need of teacher education programs to integrate PBL and technology in order to prepare teachers for innovative and efficient teaching approaches.

#### 5. Discussion

According to PRISMA principles, a systematic literature study was carried out to address the research questions. The first research question looks at the topics, project kinds, and technical support mentioned in the 15 selected papers, as well as their publication year, regional distribution, and demographic characteristics. The analysis's findings indicate that from 2020 and February 2023, research on the use of PBL in teacher education was published most often in 2022, with online PBL also being noted. As at 2022, a lot of educational institutions have adapted to the changes in the requirements for students' learning as well as changes in the teaching environment that came with the pandemic thereby fostering the development of new and better-quality teaching strategies. The second

research topic investigates the instruments employed by the chosen studies to evaluate the efficacy of PBL. The usage of various study designs and methodologies, as well as various sample sizes, time periods, and tools, is shown by statistical findings. Research designs that were often employed include surveys, interviews, phenomenology studies, case studies, and experimental investigations. Furthermore, a plethora of information on how to set up PBL, its effectiveness, and the difficulties it poses had been produced via research approaches including qualitative, quantitative, and mixed methods.

In terms of the various subjects that project-based learning has been incorporating into teaching for teacher education, the statistical outcomes indicate that project-based learning can be employed in various subjects including Technology Education, Instructional Technology, Elementary, Mathematics, Preschool, Arts, English Language, Biology, Chemistry, Science, and Curriculum and Instruction. Students can be organized by educators to carry out various projects. From the result of the analysis, 8 different types of projects were utilized, they included projects that arm learners with academic prowess and abilities like lesson plan/instructional design, curriculum design and learning material design, projects on product creation (like artifacts/or construction and final product design), practice project like laboratory experimentation and writing of worksheet as well as self-assessment projects like practice report and final reflection. With these educational practices and project implementations during the pandemic, various technological components had been employed in the project-based learning setting with two significant roles which include implementation of projects and delivering lectures. Technology elements employed for pre-service teachers' project implementation included Hawgent dynamic mathematics software, 3D visual virtual reality, educational robotics tools and GeoGebra software. Technological components used for lecture delivery consisted of digital platforms like WhatsApp, collaborate ultra experience LTI virtual classroom, Zoom, Google Classroom and YouTube. The platforms listed above could be used on different devices enabling students to learn anytime and anywhere, according to the requirements for independent learning during the pandemic (Huo et al., 2021).

The third study question focused on the results of PBL-based topic instruction for future teachers. According to the study, pre-service teachers had better knowledge, abilities, and attitudes. In terms of knowledge, all 15 publications demonstrated the beneficial effects of PBL in raising pre-service teachers' comprehension and enhancing knowledge in a specific subject area. In general, the people element and the equipment component are the two aspects that determine how well the PBL implementation process works. According to the description of PBL's benefits and drawbacks above, the research suggests that in the future, it should be standard practice for instructors to be knowledgeable about the structure of PBL, technical advancements, and its use in distant online classrooms. During the pandemic, several opportunities had however been exploited by universities in the area of online project-based learning. Thus, the pandemic prompted educators to re-evaluate and enhance the digital technology and the content of online teachers' education (Schina et al., 2021). In addition, students' competencies in research and scientific enquiry abilities were boosted and motivation as well as positive attitudes towards learning were enhanced (Rusmini et al., 2021). These findings are also consistent with the other research findings like Donitsa-Schmidta and Ramot (2021).

## **6. Conclusion and Recommendation**

### *6.1 Conclusion*

During the COVID-19 pandemic, the systematic research examines the use, efficacy, and limitations of PBL in teacher preparation. By analyzing the 15 included publications, the researchers were able to draw a few general findings concerning the research on the use of PBL during the COVID-19 pandemic. The pandemic had posed a number of difficulties for the education sector, including programs for teacher development. Teachers and institutions had to swiftly adjust to remote and online learning settings since conventional methods of teaching and field experience were disrupted. In these uncharted times, project-based learning (PBL) has become a viable option for involving and educating aspiring teachers. Thus, the majority of the studies were conducted between 2020 and 2023 in several nations across the world, and in fields related to teacher education. Studies demonstrate that PBL, when implemented in this manner, has a beneficial effect on pre-service teacher's growth of subject and pedagogical knowledge, cognitive abilities, pedagogical skills, and required skills in learning in the 21st century. Nevertheless, studies also showed that in order to implement PBL successfully, educators and students must overcome obstacles such as the lack of equipment facilities, the lack of time, and the knowledge and skills needed to conduct projects and PBL.

### *6.2 Limitations of Study*

There were also certain limitations on the research. These includes: the number of articles included in the study; the range of findings; and the capacity to generalize the patterns of the drawn conclusions may have all been

constrained by the limitations in the databases' selection. To examine the condition of the online PBL implementation in teacher education during the COVID-19 pandemic, the research chose publications published in 2020–2023. However, some of those pieces omitted any reference of the online components. The systematic study with more diverse article research databases on the technological aspect employed in online PBL are thus not very lengthy.

### 6.3 Recommendation

The findings of this review can be used as basic guidelines for further research in project based learning, offering industry and academics experts a summary of the research on the application of project based learning in teacher education. The findings can also be used by practitioners who aim to used project-based learning to teach as a reference to better their teaching blueprint by selecting appropriate teaching strategies, technological supports and project types, that have the potentials to improve students' performance.

According to the results of this study, the researchers recommend the following:

- Teachers should be equipped with the skills and knowledge of project-based learning.
- Pre-service teachers should be given the opportunity to participate in field experience based on what they have been taught in teacher preparation program.

### 6.4 Suggestions for Further Studies

For further research in project-based learning, the following are suggested:

- Conducting a systematic review on the use of project-based learning on an online project-based learning in particular subjects of teacher education.
- Carrying out a systematic review that focuses on the impact of project-based learning on particular types of students' competences.

## References

- Aksela, M., & Haatainen, O. (2019). Project-based learning (PBL) in practice: Active teachers' views of its' advantages and challenges. In *Proceedings of the International STEM in Education Conference* (pp. 9-16).
- Al Mulhim, E. N. (2023). Technology fatigue during the COVID-19 pandemic: The case of distance project-based learning environments. *Turkish Online Journal of Distance Education*, 24(1), 234-245. <https://doi.org/10.17718/tojde.1034006>
- Al-Busaidi, S., & Al-Seyabi, F. (2021). Project-based learning as a tool for student-teachers' professional development: A study in an Omani EFL teacher education program. *International Journal of Learning, Teaching and Educational Research*, 20(4), 116-136. <https://doi.org/10.26803/ijlter.20.4.7>
- Allen, J., Rowan, L., & Singh, P. (2020). Teaching and teacher education in the time of COVID-19. *Asia-Pacific Journal of Teacher Education*, 48(3), 233-236. <https://doi.org/10.1080/1359866X.2020.1752051>
- Alromaih, M. A., Elsayed, S. A., & Alibraheim, E. A. (2022). Study of project-based learning to improve the instructional design process of pre-service early childhood teachers. *International Journal of Information and Education Technology*, 12(12), 1381-1389. <https://doi.org/10.18178/ijiet.2022.12.12.1762>
- An, S. (2020). The impact of STEAM integration on pre-service teachers' disposition and knowledge. *Journal of Research in Innovative Teaching & Learning*, 13(1), 27-42. <https://doi.org/10.1108/JRIT-01-2020-0005>
- Anggito, A., Pujiastuti, P., & Gularso, D. (2021). The effect of video project-based learning on students' critical thinking skills during the COVID-19 pandemic. *AL-ISHLAH: Jurnal Pendidikan [Journal of Education]*, 13(3), 1858-1867. <https://doi.org/10.35445/alishlah.v13i3.772>
- Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The influence of project-based STEM (PjBL-STEM) applications on the development of 21st-century skills. *Journal of Turkish Science Education*, 18(4), 798815. <https://doi.org/10.36681/tused.2021.104>
- Bland, L. R., (2020). *Teacher Perspectives of Project-Based Learning Implementation in Middle-Grade Classrooms* (Doctoral dissertation, Walden University).
- Brown, A. L., & Jain, P. (2022). Doing projects with young children in a field-based early childhood education course. *Educational Studies*, 48(5), 692-707. <https://doi.org/10.1080/03055698.2020.1798743>
- Buchholtz, N. F., Krosancke, N., Orschulik, A. B., & Vorhölter, K. (2018). Combining and integrating formative and summative assessment in mathematics teacher education. *ZDM*, 50(4), 715-728.

- <https://doi.org/10.1007/s11858-018-0948-y>
- Chanpet, P., Chomsuwan, K., & Murphy, E. (2020). Online project-based learning and formative assessment. *Technology, Knowledge and Learning*, 25(3), 685-705. <https://doi.org/10.1007/s10758-018-9363-2>
- Charania, A., Bakshani, U., Paltiwale, S., Kaur, I., & Nasrin, N. (2021). Constructivist teaching and learning with technologies in the COVID-19 lockdown in Eastern India. *British Journal of Educational Technology*, 52(4), 1478-1493. <https://doi.org/10.1111/bjet.13111>
- Chung, S. K., & Li, D. (2021). Pre-service art teachers' perspectives on building virtual art gallery exhibitions. *The International Journal of Arts Education*, 19(1), 1-26.
- Diego-Mantecon, J. M., Prodromou, T., Lavicza, Z., Blanco, T. F., & Ortiz-Laso, Z. (2021). An attempt to evaluate STEAM project-based instruction from a school mathematics perspective. *ZDM-Mathematics Education*, 53, 1137-1148. <https://doi.org/10.1007/s11858-021-01303-9>
- Donitsa-Schmidt, S., & Ramot, R. (2020). Opportunities and challenges: Teacher education in Israel in the COVID-19 pandemic. *Journal of Education for Teaching*, 46(4), 1-10. <https://doi.org/10.1080/02607476.2020.1799708>
- Febiyanti, N. W., Nitiasih, P. K., Budiarta, L. G. R., & Adnyayanti, N. L. P. E. (2021). Significant Effect of Project Based Learning Video on Students' Listening Skill in Pandemic Situation. *International Journal of Elementary Education*, 5(3), 425-433. <https://doi.org/10.23887/ijee.v5i3.34901>
- Goldstein, O. (2016). A project-based learning approach to teaching physics for pre-service elementary school teacher education students. *Cogent Education*, 3(1), 1200833. <https://doi.org/10.1080/2331186X.2016.1200833>
- Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, 102, 101586. <https://doi.org/10.1016/j.ijer.2020.101586>
- Habibi, A., Riady, Y., Alqahtani, T. M., Rifki, A., Albelbisi, N. A., Fauzan, M., & Habizar. (2022). Online projectbased learning for ESP: Determinants of learning outcomes during COVID-19. *Studies in English Language and Education*, 9(3), 985-1001. <https://doi.org/10.24815/siele.v9i3.24928>
- Hawari, A. D. M., & Noor, A. I. M. (2020). Project based learning pedagogical design in STEAM art education. *Asian Journal of University Education*, 16(3), 102-111. <https://doi.org/10.24191/ajue.v16i3.11072>
- Hernandez-Barco, M., Sanchez-Martin, J., Corbacho-Cuello, I., & Cañada-Cañada, F. (2021). Emotional performance of a low-cost eco-friendly project based learning methodology for science education: An approach in prospective teachers. *Sustainability*, 13(6), 3385. <https://doi.org/10.3390/su13063385>
- Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review*, 16(3), 235-266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., & Gofur, A. (2022). The effect of blended project-based learning integrated with 21st-century skills on pre-service biology teachers' higher-order thinking skills. *Jurnal Pendidikan IPA Indonesia*, 11(1), 104-118. <https://doi.org/10.15294/jpii.v11i1.27148>
- Hunter-Doniger, T. (2018). Project-based learning: Utilizing artistic pedagogies for educational leadership. *Art Education*, 71(2), 46-51. <https://doi.org/10.1080/00043125.2018.1414542>
- Huo, Y., Wang, A., & Zhao, Y. (2021). PBL-based VR course for pre-service teachers' designing skills in applied university under coronavirus. *Interactive Learning Environments*. <https://doi.org/10.1080/10494820.2021.1939061>
- Ilyas, A., & Saeed, M. (2021) Project-based learning in teacher education: Effect on prospective science teachers' science teaching efficacy beliefs. *Pakistan Social Sciences Review*, 5(2), 26-35. [https://doi.org/10.35484/pssr.2021\(5-ii\)03](https://doi.org/10.35484/pssr.2021(5-ii)03)
- Kamali A. T., & Kocaoz, O. E. (2021). Examining the mentoring process in collaborative project-based learning of pre-service instructional technology teachers. *Education Reform Journal*, 6(1), 47-61. <https://doi.org/10.22596/erj2021.06.01.47.61>
- Landau, S., & Chis Ster, I. (2010). Cluster analysis: Overview. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International Encyclopedia of Education* (3rd ed., pp. 72-83) Elsevier. <https://doi.org/10.1016/B978-0-08-044894-7.01315-4>

- Lee, J. S., & Galindo, E. (2021). Examining project-based learning successes and challenges of mathematics pre-service teachers in a teacher residency program: Learning by doing. *Interdisciplinary Journal of Problem-Based Learning*, 15(1). <https://doi.org/10.14434/ijpbl.v15i1.28786>
- Manoban, A. (2021). Project-based learning and e-portfolios for pre-service teachers in Japanese language education. *Journal of Education and Learning*, 10(4), 40-50. <https://doi.org/10.5539/jel.v10n4p40>
- Martinez, C. (2022). Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum. *Cogent Education*, 9(1), 2024936. <https://doi.org/10.1080/2331186X.2021.2024936>
- Miller, E. C., Severance, S., & Krajcik, J. (2021). Motivating teaching, sustaining change in practice: Design principles for teacher learning in project-based learning contexts. *Journal of Science Teacher Education*, 32(7), 757-779. <https://doi.org/10.1080/1046560X.2020.1864099>
- Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2021). Teachers' role in students' learning at a project-based STEM high school: implications for teacher education. *International Journal of Science and Mathematics Education*, 19, 1103-1123. <https://doi.org/10.1007/s10763-020-10108-3>
- Nava, I., & Park, J. (2021). Pre-Service STEM Teachers and Their Enactment of Community-STEMProject Based Learning (C-STEM-PBL). *Journal of Higher Education Theory and Practice*, 21(9), 217-237. <https://doi.org/10.33423/jhetp.v21i9.4602>
- Nuswowati, M., Susilaningih, E., Ramlawati, R., & Kadarwati, S. (2017). Implementation of Problem-Based Learning with Green Chemistry Vision to Improve Creative Thinking Skill and Students' Creative Actions. *Jurnal Pendidikan IPA Indonesia*, 6(2), 221-228. doi:<https://doi.org/10.15294/jpii.v6i2.9467>
- Paristiowati, M., Rahmawati, Y., Fitriani, E., Satrio, J. A., & Putri Hasibuan, N. A. (2022). Developing pre-service chemistry teachers' engagement with sustainability education through an online project-based learning summer course program. *Sustainability*, 14(3), 1783. <https://doi.org/10.3390/su14031783>
- Poonpon, K. (2021). Integrating self-generated online projects in an ELT class at a Thai university during the COVID-19 pandemic. *Asia Pacific Journal of Educators and Education*, 36(2), 183-203. <https://doi.org/10.21315/apjee2021.36.2.10>
- Prasetyo, W. H., Sumardjoko, B., Muhibbin, A., Mahadir Naidu, N. B., & Muthali'in, A. (2023). Promoting digital citizenship among student-teachers: The role of project-based learning in improving appropriate online behaviors. *Participatory Educational Research*, 10(1), 389-407. <https://doi.org/10.17275/per.23.21.10.1>
- Puspitasari, E. (2020). Project-based learning implementation to cultivate pre-service English teachers' 21st century skills. *Indonesian Journal of English Language Teaching and Applied Linguistics*, 5(1), 191. <https://doi.org/10.21093/ijeltal.v5i1.638>
- Randazzo, M., Priefer, R., & Khamis-Dakwar, R. (2021). Project-based learning and traditional online teaching of research methods during COVID-19: An investigation of research self-efficacy and student satisfaction. *Frontiers in Education*, 6, 662850. <https://doi.org/10.3389/educ.2021.662850>
- Rusmini, R., Suyono, S., & Agustini, R. (2021). Analysis of science process skills of chemical education students through self-project based learning (SPBL) in the COVID-19 pandemic era. *Journal of Technology and Science Education*, 11(2), 371-387. <https://doi.org/10.3926/jotse.1288>
- Schina, D., Valls-Bautista, C., Borrull-Riera, A., Usart, M., & Esteve-Gonzalez, V. (2021). An associational study: preschool teachers' acceptance and self-efficacy towards educational robotics in a pre-service teacher training program. *International Journal of Educational Technology in Higher Education*, 18, 28. <https://doi.org/10.1186/s41239-021-00264-z>
- Sefton, T., Smith, K., & Tousignant, W. (2020). Integrating multiliteracies for pre-service teachers using projectbased learning. *Journal of Teaching and Learning*, 14(2), 18-32. <https://doi.org/10.22329/jtl.v14i2.6320>
- Shamma, F., & Kadrnokova, M. (2024). Israeli, Jordanian, and Czech Teachers' Perceptions of Using Blended Learning during COVID-19. *International Journal of Technology, Knowledge & Society*, 20(2), 47-66. <https://doi.org/10.18848/1832-3669/CGP/v20i02/47-66>
- Shamma, F., & Kadrnokova, M. (2024). *What is the teacher's perception towards using blended learning during Covid-19? Comparative study: Israel, Jordan, Indian and Czech Republic teachers*. Pedagogical

- Perspective, 27-44. <https://doi.org/10.29329/pedper.2024.42>
- Shamma, F., & Strongoli, R. (2023). Teachers' Job Satisfaction and Perceptions of Online Courses during Covid-19: A Comparative Study among Israel, Jordan and Lebanon. *European Journal of Educational Sciences*, 10(2), 292-313. <https://doi.org/10.19044/ejes.v10no2a292>
- Shamma, F. (2018). The Influence of Gender on the Teachers' Degree of Organizational Commitment in Arab Schools in Israel. *American Journal of Educational Research*, 6(4), 349-353. <https://doi.org/10.12691/education-6-4-8>
- Syawaludin, A., Prasetyo, Z.K., Jabar, C.S.A., & Retnawati, H., (2022). The effect of project-based learning model and online learning setting to analytical skills of discovery learning, interactive demonstrations, and inquiry lessons on the pre-service elementary teachers. *Journal of Turkish Science Education*, 19(2). <https://doi.org/10.36681/tused.2022.140>
- Tsybulsky, D., & Muchnik-Rozanov, Y. (2021). Project-based learning in science-teacher pedagogical practicum: The role of emotional experiences in building pre-service teachers' competencies. *Disciplinary and Interdisciplinary Science Education Research*, 3, 9. <https://doi.org/10.1186/s43031-021-00037-8>
- Tsybulsky, D., & Muchnik-Rozanov, Y. (2023). The contribution of a project-based learning course, designed as a pedagogy of practice, to the development of pre-service teachers' professional identity. *Teaching and Teacher Education*, 124, 104020. <https://doi.org/10.1016/j.tate.2023.104020>
- Tsybulsky, D., & Oz, A. (2019). From frustration to insights: experiences, attitudes, and pedagogical practices of pre-service science teachers implementing PBL in elementary school. *Journal of Science Teacher Education*, 30(3), 259-279. <https://doi.org/10.1080/1046560X.2018.1559560>
- Umar, M., & Ko, I. (2022). E-learning: Direct effect of student learning effectiveness and engagement through project-based learning, team cohesion, and flipped learning during the COVID-19 pandemic. *Sustainability*, 14(3), 1724. <https://doi.org/10.3390/su14031724>
- Umutlu, D. (2022). TPACK leveraged: A redesigned online educational technology course for STEM pre-service teachers. *Australasian Journal of Educational Technology*, 38(3), 104-121. <https://doi.org/10.14742/ajet.4773>
- Van Loi, N., & Hang, C. T. T. (2021). Integrating project work into English proficiency courses for pre-service teachers' training. *TESL-EJ*, 25(3).
- Wahyuningsih, S., Qohar, A., Satyananda, D., & Atan, N. A. (2021). The Effect of Online Project-Based Learning Application on Mathematics Students' Visual Thinking Continuum in Covid-19 Pandemic. *International Journal of Interactive Mobile Technologies*, 15(8). <https://doi.org/10.3991/ijim.v15i08.21565>
- Wijaya, T. T., Zhou, Y., Ware, A., & Hermita, N. (2021). Improving the creative thinking skills of the next generation of mathematics teachers using dynamic mathematics software. *International Journal of Emerging Technologies in Learning*, 16(13), 212-226. <https://doi.org/10.3991/ijet.v16i13.21535>
- Yadav, A., Stephenson, C., & Hong, H. (2017). Computational thinking for teacher education. *Communications of the ACM*, 60(4), 55-62. <https://doi.org/10.1145/2994591>
- Yusrizal, Y., & Pulungan, S. A. (2021). The Effect of Project Based Learning Model on Student Mathematics Learning Outcomes in the Covid-19 Pandemic Era. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, 4(4), 7810-7816. <https://doi.org/10.33258/birci.v4i4.2700>.
- Yustina, Y., Syafii, W., & Vebrianto, R. (2020). The effects of blended learning and project-based learning on pre-service biology teachers' creative thinking skills through online learning in the COVID-19 pandemic. *Jurnal Pendidikan IPA Indonesia*, 9(3), 408-420. <https://doi.org/10.15294/jpii.v9i3.24706>

**Competing interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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**Data sharing statement**

No additional data are available.

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