
Research Trends of Problem Based Learning (PBL) Model in Science Courses in Universities

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Abstract: The PBL model has relevance and potential in developing 21st-century skills. This study uses the Systematic Literature Review method to identify PBL research trends in science courses at universities. A literature search using the app Publish or Perish with the Scopus database and data from journals indexed by SINTA (Science and Technology Index) in the last 10 years, from 2012 to 2021. In this study, there are 32 articles about PBL research in science lectures, including physics, chemistry, biology, and natural science. The trend seen is a rise in publications addressing various facets of critical thinking abilities. Among research publications, quantitative research is the most common type. Quasi-Experimental designs are most often chosen by researchers, while R&D designs are still little used. Chemistry is a subject that is most often chosen as a research subject. Meanwhile, the test is the most commonly used instrument for collecting data on 21st-century student skills.

Keywords: Problem based learning; research trends; science; 21st century skills.

How To Cite: Roza, M., Azhar, M., Yohandri, Y., & Arsih, F. (2023). Research Trends of Problem Based Learning (PBL) Model in Science Courses in Universities. *Al-Ta'lim Journal*, 30(1). doi:<https://doi.org/10.15548/jt.v30i1.761>

Article info: Submitted: 31th July 2022 | Revised: 16th February 2023 | Accepted: 28th February 2023

INTRODUCTION

Changes in science and technology occur very quickly and are complex. Students must have 21st-century skills as they face changes in the period of the industrial revolution 4.0 and Society 5.0. In keeping with this phenomenon, the challenges and responsibilities of higher education are increasing. To meet these challenges, students in the lecture process must be equipped with 21st-century abilities. Students must develop 21st-century abilities like creativity and invention, communication, cooperation, critical thinking, and problem-solving to deal with global concerns. (Lufri et al., 2022; Moser, 2017; Mumford & McIntosh, 2017; A. D. Saputro et al., 2018; van Laar et al., 2018). In the context of 21st-century learning, lecturers also face the same challenges in optimizing learning processes and achievements.

Numerous studies have found that 21st-century student learning outcomes and skills are still low (Khoiri et al., 2021; Roza et al., 2022). Shishigu et al (2017) mentioned that the mastery of students' physics concepts in Turkey is still low and has an impact on the shells of precisely solving the problems carried out. Temel, (2014) mentions that students have difficulty solving problems and thinking critically, and creatively if passive learning is carried out. According to study by Baharom and Balachandran (2013), employers, particularly those in the private sector, frequently criticize Malaysian

university graduates for their lack of analytical, problem-solving, teamwork, and communication abilities.

Several studies in Indonesia also reveal that students' critical analysis, problem-solving, teamwork, and communication abilities need to be improved. When confronted with an issue, (Nurhayati et al., 2019) discovered that pupils are less independent and have trouble solving problems. One of the reasons for these issues is the usage of non-student-centered learning. (Karmana et al., 2019) discovered that prospective biology teacher students' higher-order thinking and problem-solving skills were still lacking. Another issue discovered was students' lack of critical thinking skills and self-confidence in completing lecture assignments (Fakhriyah, 2014; Hidayah et al., 2021; Kusumah, 2019; Maulida, 2020; Rezkillah & Haryanto, 2020).

The teaching model is thought to be the best way to solve these issues (Birgili, 2015; Jatmiko et al., 2018; Setyoko et al., 2019). Among the models that can be applied to answer the challenges of the 21st century is the Problem Based Learning (PBL) model. PBL is a type of learning that involves placing students in active roles as problem solvers who are presented with structured issues that are analogous to real-world problems. This helps students build their problem-solving techniques, knowledge of various subject areas, and abilities all at once (Edens, K. M., 2000).

According to Barrows & Tamblyn (1980), PBL is a learner-centered teaching approach that begins with real-world situations that are engaging and don't have obvious right or wrong answers. Learners work together to investigate problems and actively acquire knowledge and skills in critical thinking, problem-solving, and information literacy. The teacher doesn't lecture or give out the solutions when using PBL. Instead, students evaluate their present understanding of the issue, spot any gaps, and then choose a strategy to fill the information gap using inquiry-based methodologies. PBL has been effectively implemented in a variety of academic fields, levels, and institutions (Virginie Servant-Miklos, 2020). The same thing was expressed by Johnstone and Biggs (1998) that PBL is a student-oriented approach, teaches basic knowledge of real situations, and provides problem-solving skills to students (Moallem et al., 2019).

PBL has relevance and potential in developing 21st-century skills (Ayyildiz & Tarhan, 2018; Gorghiu et al., 2015; Hestiana & Rosana, 2020; Kek & Huijser, 2015; Lufri & Asrizal, n.d.; Song et al., 2015; Sudarmin et al., 2019; Yuliati et al., 2018). PBL's fundamental idea emphasizes the integration and development of higher scientific disciplines, as well as organizing thinking skills by involving students in active learning and exposing them to unstructured real-world issues (Mustofa & Hidayah, 2020; S. Saputro, 2021).

Students and teachers have proved that PBL is an effective and preferred method of learning that improves learning processes and outcomes. PBL outperforms traditional teaching approaches in terms of student self-study outcomes, communication, team spirit, learning interest, analysis, knowledge scope, and expression (Liu et al., 2019; Servant-Miklos, 2020a). According to research by Roza, et al (2022), applying the PBL paradigm in high school had a very high effect size for biology courses, a high effect size for chemistry lessons, and a medium effect size for physics lessons. Research findings indicate that using the PBL model improves one's capacity for critical thought and problem-solving. Therefore, science learning in high school is more effectively applied with the PBL model. This study solely looked at the impact of the PBL model on science instruction in high schools; it did not look at the impact of PBL on science lectures in tertiary institutions.

A meta-analysis of the PBL model's impact on higher education was done by Liu, Y., & Pásztor, A. (2022). The results of the study found that PBL was effective in critical thinking skills. This research has examined the effects of PBL in tertiary institutions. However, it is not focused on learning science. The PBL effect study focused on critical thinking skills only. It has not been examined how PBL affects other 21st-century abilities including creativity, problem-solving, communication, and teamwork in higher education. According to research by Lufri, L., & Asrizal (2023), high schools and colleges can successfully implement the PBL approach for teaching biology, chemistry, and other scientific subjects. When the PBL paradigm is used, it has a significant positive impact on students' knowledge of science and the environment as well as their ability to think critically and creatively. This study integrates STEM with the PBL model. Based on previous research, it appears that how the influence of the PBL model on science learning in tertiary institutions has not been carried out yet. Therefore, analysis of the PBL model's impact on science education in universities is crucial, for this reason.

PBL is an innovative learning model, which is generally carried out in groups or through systematic teamwork (Baran & Sozbilir, 2018). Several studies also show that PBL has many advantages in addition to training critical thinking and problem-solving (Ahdhianto et al., 2020; Chan & Blikstein, 2018; Günter et al., 2017; Hursen, 2021).

There are 7 steps in the PBL stage (Wood, 2003), namely 1) Identifying and clarifying any unfamiliar words used in the scenario, a writer (student) enumerates undefined terms before discussing them; 2) Defining the issues to be discussed; while students may have different perspectives, each one must be taken into account. The opinion is registered/made a list of problems that are approved by all students; 3) Organize brainstorming sessions to discuss problems and suggest possible solutions based on prior knowledge. Discussions are recorded and all student participation and gains are assessed; 4) Viewed steps 2 and 3 in retrospect and acknowledged the justification for the development of interim solutions; If required, the teacher rearranges and reorganizes the explanations; 5) Formulates objectives for learning. The goal is agreed upon by the group; teachers make ensuring that the objectives of learning are sufficient, appropriate, and attainable.; 6) Independent learning (all students collect information about each learning objective); and 7) Disseminate the outcomes of self-directed learning (Students list their educational materials and discuss their findings with others); the teacher oversees the process of learning and has the authority to assess the class. With PBL, the lecturer does not give lectures or provide answers. In contrast, students analyze their knowledge of the issue, spot any gaps in their understanding, and then choose a course of action to fill in the information gaps and resolve the issue (Fitri, 2017; Rau et al., 2021).

To enhance students' 21st-century skills, it is necessary to analyze how PBL is used in universities. Literature reviews on PBL research in universities, especially in science courses, have not been found. This study's objective is to evaluate the current state of PBL research in university science courses, in terms of 1) the upward trend in PBL research numbers over the past ten years, 2) the trend of PBL research in 21st-century skills, 3) the diversity of PBL research designs, 4) types subjects that often use PBL, as well as 5) research instruments used by researchers to measure the effectiveness of PBL.

METHOD

This research employs a qualitative approach. The method used is Systematic Literature Review (SLR). The stages in the review process are 1) formulating the research problems; 2) establishing and approving review protocols; 3) search of the literature; 4) filtering of articles; 5) evaluating the article's quality; 6) data mining; 7) analyze and synthesize data; and 8) report conclusions (Xiao & Watson, 2019). SLR uses the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework by completing all standard PRISMA checklists (Margot, KC, & Kettler, T., 2019; Page et al., 2021). The review protocol includes database and keywords, as well as eligibility criteria (Graulich, N., et al., 2021). The PRISMA flowchart is used as a reference in the implementation phase to document a standardized systematic review process (Figure 1).

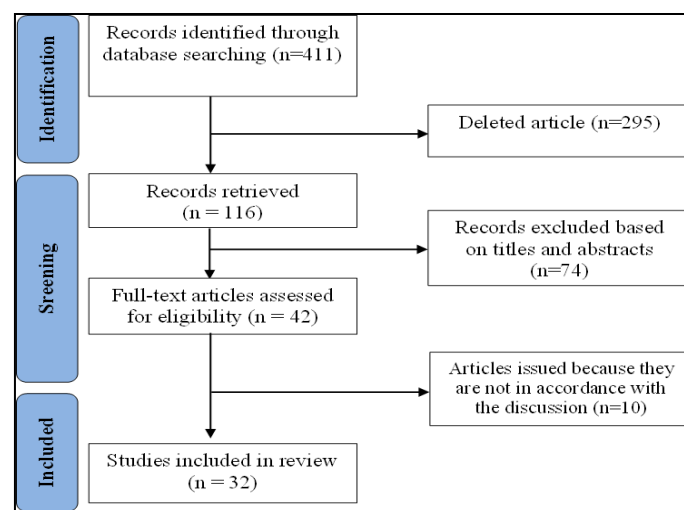


Figure 1. Flowchart of the literature review process

The first step is a systematic literature search. Articles relevant to the research question were tracked using Publish or Perish software with the Scopus database and data from SINTA (Science and Technology Index) indexed journals in the last 10 years, from 2012 to 2021. Second, the researcher filtered by title and abstract, eliminating irrelevant literature. Relevant literature is identified and selected. All articles that pass the selection process are reviewed and summarized into a critical analysis table based on the name of the journal, author's name, year of publication, purpose, research subjects, instruments used, data analysis, and research results. PICOS (Problem, Intervention, Comparison, Outcome, and Setting) was used to review the relevant articles (Santos et al., 2007; Wahono, 2015). Third, full-text articles were screened, taking into account the inclusion and exclusion criteria. This study's inclusion criteria are as follows: 1) range from 2012 to 2021, 2) research subjects are students, 3) the subjects studied are physics, chemistry, biology, and science, 4) types of literature, namely quantitative, qualitative, mixed methods, development research, and action research class. Exclusion criteria in this study were research related to personal opinion, literature review or meta-analysis, research not relevant to the purpose, and conducted other than in universities. Then the relevant articles are exported and saved to Mendeley. Fourth, the researcher extracted and synthesized data from the articles found. Furthermore, the data is displayed in the form of diagrams and tables and then examined following the objectives established.

RESULT AND DISCUSSION

Number of publications

Figure 2 shows the number of PBL research in universities for science courses (physics, chemistry, biology, and natural science) from 2012 to 2021, based on the review's findings.

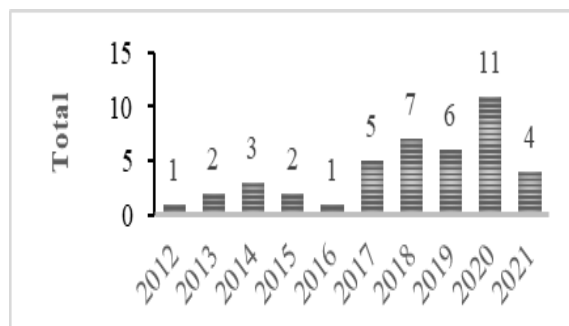


Figure 2. The Trend of Increasing Number of PBL Research in Higher Education

The data in Figure 2 shows that the most PBL research for science courses in universities was found in 2020, with 11 articles. In addition to the medical and medical fields, Educators in the domains of science and education are now interested in PBL (Aryulina & Riyanto, 2016; Baran & Sozbilir, 2018; Fidan & Tuncel, 2019; Ismoyo, 2017; Uzunboylu & Aşıksoy, 2014). PBL is regarded by lecturers as one of the most successful teaching strategies. Because PBL adopts a problem-solving approach and has many advantages over traditional didactic lecture-based teaching (Miterianifa et al., 2019a; Sumarni, 2018; Syamina et al., 2021). In comparison to traditional learning, PBL adoption has a considerable favorable effect. PBL is used at the undergraduate and graduate levels of education and is used successfully in many disciplines, levels, and educational environments (Chan & Blikstein, 2018; Loyens et al., 2015; Major, 2018; Servant-Miklos, 2020b).

Figure 3 shows the trend of PBL research on 21st-century skills in higher education, especially for science subjects (Physics, chemistry, biology, and science). Problem-solving and critical thinking skills are topics that are frequently researched. 16 articles look at the impact of PBL on students' critical thinking, and 7 articles look at problem-solving.

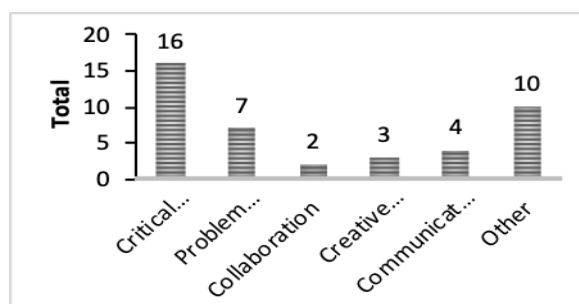


Figure 3. Trends in PBL Research on 21st-Century Skills

In line with multiple research findings, the PBL paradigm offers numerous benefits, including a focus on active involvement, problem-solving, and critical thinking abilities (Fidan & Tuncel, 2019; Guerra, 2017). The characteristics of PBL are following the

flow of critical thinking skills and problem-solving. The seven qualities of critical thinking are seeking the truth, being open-minded, analytical, methodical, critical thinking, self-assurance, curiosity, and cognitive maturity (Rusmansyah et al., 2019; Temel, 2014).

In general, critical thinking skills are correlated with problem-solving and creative thinking (Fatmawati et al., 2019). Other PBL characteristics that contribute to training 21st-century skills are real-life context, interdisciplinary, authenticity, motivation, student concentration, self-directed and self-regulated existence, and reflective learning (Fidan & Tuncel, 2019).

Types of research

The type of PBL research in universities for science courses is shown in Figure 4 below.

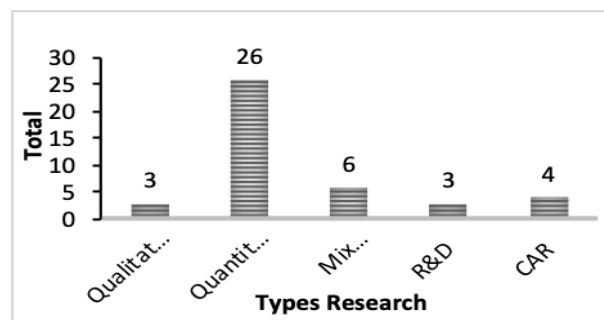


Figure 4. Distribution of PBL research types

In the application of PBL for science courses at universities, quantitative research is the most common type of research used by researchers. There are 26 articles with quantitative research designs, 6 mixed-method research articles, 4 articles for Classroom Action Research (CAR), and 3 articles each for Research & Development (R&D) and qualitative. Quantitative research designs are often used to see how PBL affects students' 21st-century skills. Relevant to research conducted by Susetyarini and Ahmad Fauzi (2020) is that the number of quantitative research is more chosen than other types of research in biology learning to improve 21st-century skills, especially critical thinking skills. A study (Alper & Altun, 2014) also found that PBL was mostly studied experimentally in higher education. According to relevant studies, postpositivists favor quantitative over qualitative research approaches while conducting educational research (Abutabenjeh & Jaradat, 2018).

Contrary to the findings of (Fauzi & Pradipta, 2018), R&D research was the most widely published form of study in 2017. One of the most recent trends in Indonesian education research is R&D research. These results provide an opportunity for future researchers to conduct R&D research in science courses at universities. This study also describes the distribution of quantitative research for the PBL model in science courses at universities which are the most chosen by researchers as the data in Figure 5.

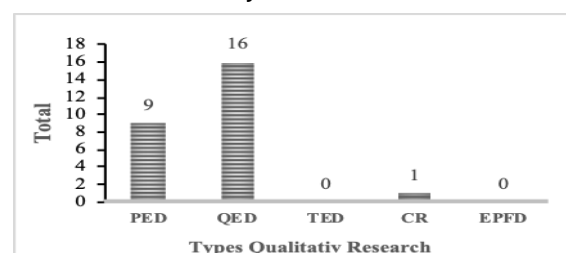


Figure 5. Distribution of quantitative research for PBL in Universities

Quasi-Experimental Designs (QED) are more often used by researchers than Pre-Experimental Designs (PED). For Correlation Research, only 1 article was found, and there were no True Experimental Designs (TED) and Ex-Post Facto Designs (EPFD) studies. It can be seen that QED is most commonly used to apply the PBL model to science lectures in universities. This is because, in this research design, the researcher can choose one of the two models by comparing which one is the most effective for empowering 21st-century skills.

The uniqueness of QED is that it is the only type of research that provides the opportunity for researchers to directly influence research variables and the only type of research that can test hypotheses about causal relationships. The researcher can determine which treatment is more effective by experimenting with different treatments and theories. This means that treatment can be used as a factor causing a change in an individual (Gopalan et al., 2020).

The subject of science

Quasi-Experimental Designs (QED) are the most commonly employed design by researchers based on information about the sort of investigation. This indicates that researchers are attempting to compare some of the greatest learning approaches for empowering students' 21st-century skills in general. In conducting research, researchers need research subjects to test hypotheses. In the field of science, in universities, students are majoring in chemistry, physics, biology, and science.

Based on Figure 6, the most frequently studied subjects for the application of the PBL model are chemistry courses, then biology, physics, and the least is science. This result is somewhat different from the research (Miterianifa et al., 2019b) who found that the PBL model was used more often for Physics. However, in this study, it was not explained whether the research was conducted at the elementary, secondary, or tertiary education levels. Meanwhile, in this study, the focus is only on the university level.

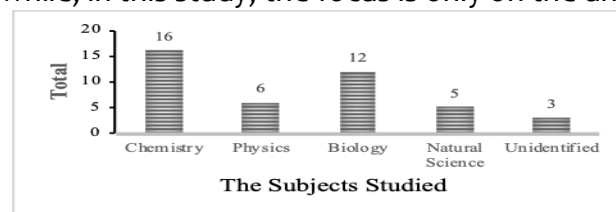


Figure 6. Subjects of the subjects studied

The research instrument used

Researchers used instruments to help them collect data about 21st-century skills. Table 1 lists the measures that researchers have used to assess critical thinking, problem-solving, teamwork, creativity, and communication skills.

Table 1. Types of instruments used by Researchers

21st-century skills	Instrument type				
	Observation sheet	Interview guide	Questionnaire	Test	Tasks
Think critically	1	2	2	11	-
Problem-solving	2	1	-	4	-
Collaboration	1	2	-	-	-
Creativity	-	-	-	1	2
Communication	-	3	-	-	1

Based on the data in Table 1, critical thinking skills are mostly measured by tests. Relevant to the invention (Susetyarini & Fauzi, 2020) that in essence, a student's responses to challenging questions might be used to access or evaluate their critical thinking abilities. Furthermore, testing is thought to be a more objective method of data collection than surveys and casual observations.

Among the types of tests used is the California Critical Thinking Disposition Inventory (CCTDI). This test measures seven aspects of critical thinking: truth-seeking, open-mindedness, analytical, methodical, critical thinking, self-confidence, curiosity, and cognitive maturity (Facione, 1994; Temel, 2014). The Halpern Critical Thinking Assessment (HCTA) highlights five critical thinking scenarios, including verbal reasoning, argument analysis, thinking as hypothesis testing, employing probability and uncertainty, and decision-making and problem-solving skills. This characteristic is slightly different from the HCTA. The Cornell Critical Thinking Test (CCTT; Ennis et al., 1964) and the Thinking Skills Assessment (TSA), created by prominent colleges, are two additional regularly used scales to examine the efficacy of teaching CT skills (Liu, Y., & Pásztor, A., 2022).

The form of the test used is in the form essay test, reasoned multiple-choice, and multiple-choice. Other research examines five factors, including basic support, inference, advanced support, strategies and tactics, and elementary clarification, as factors that aid in the development of critical thinking abilities (Rezkillah & Haryanto, 2020). Unfortunately, several researchers failed to disclose the instrument they used to gather data on students' critical thinking abilities.

The instrument for collecting data on student problem-solving skills is mostly measured by a test. The Problem-Solving Inventory (PSI), created by (Heppner & Petersen, 1982), is one of the assessments used to assess problem-solving abilities. The inventory has 3 sub-scales, namely problem-solving confidence, approach-avoidance style, and personal control. However, this inventory does not test actual problem-solving abilities; rather, it assesses a person's assessment of beliefs and problem-solving methods (Heppner et al., 2004)). Some researchers also did not mention the type of problem-solving test used. Some researchers use observation sheets and interviews (Hastuti et al., 2018; Makiyah et al., 2021).

The collaboration and communication data collection instrument that is widely used by researchers is the interview guide Himmetoglu et al, (2020). Study Nonthamand, (2020) found that interviews obtained data about group processes, idea-sharing activities, interaction, and communication. Speaking skills are also more developed when presenting group findings. Creativity is measured through tasks and tests. Among the forms of tests used by researchers are the Torrance Tests of Creative Thinking (Torrance, 1990). The TTCT comprises six written exercises: predicting causes, predicting effects, improving products, imagining possibilities, and just presuming (Yoon et al., 2014). Other researchers measure the ability to think creatively with a description test that modifies the indicators of creative thinking skills (Guilford, 1977).

Creativity assessment involves seven aspects, namely clarification of the identification of group investigations, a description of the problem's origins, skills to predict the impact if not immediately addressed, fluently answering or responding to questions from other groups and collaborating in groups (Nuswowati et al., 2017). Another instrument used to measure student creativity is the student creativity assessment sheet for making pocketbook assignments (Oktaviani & Mellyzar, 2020).

CONCLUSION

In this study, articles on PBL research in science lectures, including physics, chemistry, biology, and science, on 21st-century skills from 2012 to 2021 were reviewed. The trend found is that there is an increasing number of publications on aspects of critical thinking skills. Among research publications, quantitative research is the most common type. Quasi-Experimental Designs (QED) are the most frequently chosen by researchers. Design R&D is still of little use in colleges. This is an opportunity to conduct development research in universities. Chemistry is a subject that is most often chosen as a research subject. Meanwhile, the test is the most commonly used instrument for collecting data on 21st-century student skills.

Some recommendations for further research are first, it is necessary to increase the frequency of R&D research aimed at developing instructional products to improve students' 21st-century skills. Second, researchers need to be informed about the research instrument, along with the validity and reliability of the instrument.

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