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Implementation of Project-Based Learning in Improving Students' Problem-Solving in Chemistry Learning: A Systematic Literature Review

Halimatuzzahra*, & Isana Supiah Yosephine Louise

Department of Chemistry Education, Yogyakarta State University, Indonesia

Abstract: One of the 21st-century skills that needs to be developed is problem-solving. Problem-solving ability is understanding problems, planning solutions, applying solutions, evaluating, and finding solutions to problems. In fact, problem-solving ability in chemistry learning is still low, so a strategy is needed to overcome this problem, one of which is the application of project-based learning. Project-based learning is a learning model that involves students directly in the learning process through research activities. This study aims to evaluate the effect of implementing the Project-Based Learning (PjBL) model on students' problem-solving skills in learning chemistry. The method used is a Systematic Literature Review (SLR). Articles were obtained from Google Scholar, Scopus, and DOAJ, and 9 articles met the inclusion criteria set and were analyzed further. The results of the analysis show that the PjBL model has a positive influence on students' problem-solving skills. Project-based learning allows learners to be creative, work together, and develop solutions within a particular time, improving their collaboration, communication, and critical thinking skills. Implementing PjBL also provides a more interesting and realistic learning experience, helping learners understand the learning material and practice practical skills. Overall, implementing PjBL shows positive results in achieving chemistry learning objectives in cognitive, affective, and psychomotor domains.

Keywords: chemistry learning, problem-solving, project-based learning.

▪ INTRODUCTION

In the 21st-century globalization era, we will always face problems that must be resolved (Purwaningsih et al., 2020). In facing these problems, several skills must be mastered to compete in this era of globalization. The skills in question include communication, collaboration, creativity, and critical thinking skills (4C) (Erdoğan, 2019), Problem-Solving (Rahman, 2019; Sari et al., 2021), Scientific Writing Skills (Sari et al., 2021), innovation, cooperation, adaptability, flexibility, curiosity, and imagination, as well as access and analysis of information (Alhothali, 2021). Skills related to problem-solving needed in the era of globalization can be improved through education (Kanbay & Okanlı, 2017) and the learning process at school (Sari et al., 2021).

Problem-solving ability is the ability to understand the problem, plan the problem-solving process strategy, apply the selected solution strategy, and evaluate and find a solution to the problem (Siagian et al., 2019). Mastery of problem-solving can improve student learning achievement, which includes elements of Strategy (cognitive), attitude (affective), and initiative (conative) (Omar et al., 2019).In addition, problem-solving can improve critical thinking skills and develop learning strategies (Raman et al., 2024). Therefore, problem-solving skills are very important for students to have anywhere, including in learning and achievement at school and outside school (Rahman, 2019).

In fact, students' problem-solving skills are still in the low category in chemistry (Valdez & Bungihan, 2019), biology (Jamari et al., 2018; Utami et al., 2023), physics (Abeden & Siew, 2022), and mathematics (Nursyahidah et al., 2018; Simatupang et al.,

Halimatuzzahra*, & Isana Supiah Yosephine Louise
*Email: halimah.zahra2000@gmail.com

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2019). This is caused by difficulties in understanding the units used, difficulties in making plans because they are unable to connect the known problems with the formulas to be used, difficulties in implementing plans, difficulties in doing, and difficulties in concluding the material that has been learned (Bayuningsih et al., 2017). Problem-solving ability is influenced by psychological factors such as motivation, perception, general self-efficacy, and teamwork skills have a positive influence on problem-solving skills (Bhadargade et al., 2020). In addition, the problem-solving ability is also influenced by external factors, namely the strategies, models, methods, and learning media used by teachers, the material's complexity, and the students' learning environment (Budianti et al., 2022).

Various studies to measure problem-solving skills have been conducted using multiple learning models including the Discovery Learning model (Simamora et al., 2018; Syamsuri et al., 2023), Problem-Based Learning (Fitriani et al., 2020; Sari et al., 2021; Valdez & Bungihan, 2019), Project Based Learning (Chen & Chan, 2021; Karan & Brown, 2022; Tuan et al., 2020), Contextual Teaching and Learning (Rohimatunisa & Sudianto, 2023), and Numbered Head Together (Escajayanti & Setyaningsih, 2023). The ideal learning model to improve students' problem-solving skills is PjBL (Chen & Chan, 2021; Faizah et al., 2022; Jalinus et al., 2019; Sari et al., 2021; Tuan et al., 2020).

Project-based learning is a learning model that involves students directly in the learning process through research activities (Nurkanti et al., 2019). In the Project-Based Learning (PjBL) model, the learning process is centered on students and provides meaningful experiences in obtaining concepts and creating products in the learning process (Chintya et al., 2023; Rahmania, 2021). The PjBL model bridges different fields of study into projects that answer challenging questions or problems to encourage students to face problems with the concepts and principles of a discipline (Capraro et al., 2013; Chintya et al., 2023). The PjBL learning model centers on learners applying concepts when solving problems (Thomas, 2000). In addition, in project-based learning, learners are required to work together, share ideas, create, and manage the time needed to make products (Nurkanti et al., 2019).

One of the lessons that requires problem-solving skills is chemistry learning. Chemistry learning provides learning experiences about chemical concepts that exist in everyday life (Zakaria et al., 2020). In addition, chemistry learning includes scientific experiences from the laboratory and applied sciences that are useful for the future. The explanation of chemistry as a product and scientific process is related to the existence of practicum in the laboratory (Widarti et al., 2020). Understanding the relationship between one concept and another is very important when studying chemistry because these concepts are interconnected. Concepts in chemistry are important for students as a strong foundation for further learning (Harahap & Novita, 2021). Chemistry learning can be optimized by using the right learning model.

Literature review research related to the implementation of the PjBL model has been carried out previously by Kokotsaki et al. (2016) regarding PjBL as an approach; Nurhidayah et al. (2021) regarding the PjBL model in learning science learning; and Fisher et al. (2020) regarding PjBL in mathematics learning. However, until now, no literature has discussed implementing the PjBL model on students' problem-solving skills in learning chemistry, so that researchers can make a literature review on this matter. This study aims to explain how implementing the project-based learning (PjBL) model affects

students' problem-solving skills in chemistry learning. The problem formulations in this study, namely:

1. How does the project-based learning (PjBL) model affect students' problem-solving in chemistry learning?
2. How is the implementation of the PjBL model in chemistry learning?

▪ METHOD

Research Design

The method used in this research is a Systematic Literature Review (SLR). A systematic literature review involves the identification and synthesis of relevant research articles with specific criteria to provide insight into an issue (Xiao & Watson, 2019). The review was conducted systematically, starting with planning, the review process, and reporting the findings. Articles obtained in this study were recorded using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

Search Strategy

Research articles were obtained from the internet, especially Google Scholar, Scopus, ERIC, and DOAJ, from April 29, 2024, to May 18, 2024. The keywords used were “Project-Based Learning in Chemistry”, “Problem-solving skills in Chemistry”, and “Project-Based Learning and problem-solving skills”. The articles obtained were then reviewed based on the title and then the abstract, and a review of the complete article content was continued for the final review process.

Inclusion and Exclusion Criteria

The criteria for selected articles in this study are (1) the use of the PjBL model to improve problem-solving skills in chemistry learning; (2) Participants included are high school students and university students; (3) Research articles published between 2020 and 2024. Based on the article search results, 26 articles with titles included in the predetermined criteria were obtained. Therefore, a review was carried out on the abstracts of the articles that had been determined, so 17 relevant articles were obtained for further analysis. The articles were excluded because they were not journal articles or conference series, the articles were not in Indonesian or English, the articles were not open-access, and the full text of the articles could not be found. In addition, articles that did not meet the inclusion criteria, focused on implementing Project-Based Learning (PjBL) on students' problem-solving skills, were excluded. Articles with other disciplines, such as biology, math, and physics, were also excluded. The reviewed articles were only articles that used the discipline of chemistry. This leaves 9 articles that meet the criteria for articles to be discussed in the article and reviewed. The articles reviewed used quantitative, qualitative, and mixed methods. The article search process is depicted in the figure below.

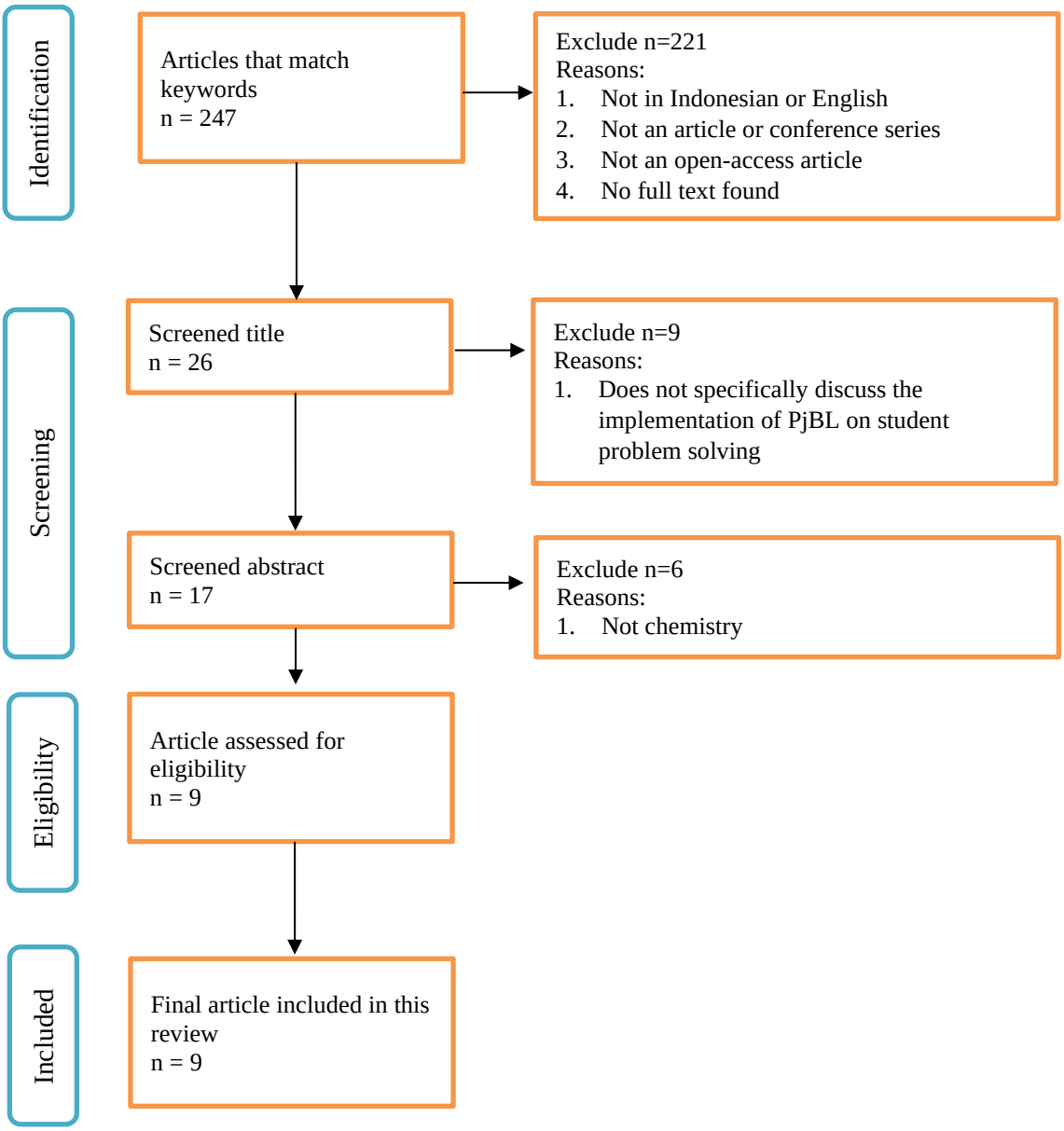

Figure 1. PRISMA selection

Data Analysis

Articles that meet the inclusion criteria will be analyzed using a qualitative descriptive analysis approach. The qualitative descriptive analysis consists of four steps, namely: (1) understand each article reviewed to get a complete picture of the application of PjBL and its relation to chemistry education issues and research relevance; (2) summarize the findings contained in each article, focusing on how PjBL is implemented and how much impact it has on student problem-solving in chemistry learning; (3) connect findings to identify common themes to answer research questions; (4) draw conclusions based on the synthesis of findings about the contribution of PjBL to improving student problem-solving in chemistry learning.

▪ RESULT AND DISSCUSSION

This study uses 9 articles on implementing Project-Based Learning (PjBL) on students' problem-solving skills in chemistry learning that have been selected using the PRISMA Technique. Articles obtained from selection using the PRISMA Technique include: (1) Milian, (2023) conducted research using a case study design entitled "Developing Problem-Solving Skills In Chemistry Students Through Project-Based Learning"; (2) Ling et al. (2024) also used a case study design in a study entitled "Developing middle school students' problem-solving ability through interdisciplinary project-based learning"; (3) Faizah, et al. (2022) conducted experimental research with a pretest-posttest control group design entitled "The Influence of Project Based Learning Model on Students' Problem-Solving Competence in Learning of Acid-Base"; (4) Suyantiet al., (2022) used a pre-experimental design approach of experimental research in a study titled "The Effects of Collaborative Learning Oriented Project Based Learning (PjBL) and Learning Cycle Models using Animation Video on Students Problem Solving"; (5) Harefa & Purba, (2020) used a quasi-experimental design (nonequivalent control group design) in a study entitled "Problem solving skills improvement and the impact on students' learning outcomes: learning based on e-project"; (6) Tuan et al. (2020) conducted a case study research entitled "Project Based Learning in General Chemistry to Develop the Problem-Solving and Creativity"; (7) Chu et al. (2023) also used a case study design in a study entitled "An Inorganic Chemistry Laboratory Technique Course using Scaffolded, Inquiry-Based Laboratories and Project-Based Learning"; (8) Hanifa, (2022) conducted a class action research with the title "Application of Project Based Cooperative Learning Integrated with STEM to Improve Problem Solving Skills on Electrolyte Solutions and Optical Devices in Class X MIA 3 SMAIT Raudhatul Jannah Cilegon"; (9) Makuasa et al. (2024) used a one-shot case study design in a study entitled "Development of a Chemistry Learning E-module Based on Project-based Learning with a STEM Approach to Improve Students Problem Solving and Communication Skills on Solubility and Solubility Product Material Approach to Improve Students Problem Solving and Communication Skills on Solubility and Solubility Product Material".

Question 1 - How does the project-based learning (PjBL) model affect students' problem-solving in chemistry learning?

Based on the results of the review of articles on implementing Project-Based Learning (PjBL) on problem-solving in chemistry learning, it was found that the Project-Based Learning (PjBL) model influences students' problem-solving skills in chemistry learning. Milian, (2023) found that Students who are free to make their own choices during the project improve their initiative, self-confidence, problem-solving, and time management skills. Ling et al. (2024) concluded that Interdisciplinary project-based learning activities, such as making "home-made oxygenators," can improve students' problem-solving abilities, academic performance, and interest in Chemistry and Chemical Engineering. In addition, Interdisciplinary project-based Learning effectively improves students' skills and interest in related fields. Faizah et al. (2022) also found that the PjBL model influences students' problem-solving skills in acid-base Learning. Similar findings were revealed by Suyanti et al. (2022), which showed that the problem-solving ability of students taught with collaborative learning-oriented PjBL and supported by e-modules exceeds the KKM standard of 75. Harefa & Purba (2020) showed that Learning using

Learning based e-project on thermochemistry is effective for improving students' problem-solving skills based on the acquisition of the average score of the experimental class, which is better than the average score of the control class, with a high category. Tuan et al. (2020) stated that project-based Learning effectively improves students' problem-solving skills and creativity. In addition, Chu et al. (2023) stated that inquiry-based laboratory and project-based learning modules improve students' problem-solving and critical thinking skills. Hanifa (2022) showed that project-based cooperative Learning integrated with STEM can improve students' problem-solving skills. Makuasa et al. (2024) stated that the implementation of Learning using the PjBL model and the STEM approach with the developed E-module is effective for improving students' problem-solving skills.

Theme 1 - PjBL and Problem Solving

Project-based learning is one of the ways that educators can choose to engage learners in the learning content (Hanifa, 2022). The problems given connect to life outside the classroom and address the real world, making project-based learning relevant to learners (Tuan et al., 2020). Project-based learning is designed to encourage problem-solving through creative thinking, where students are responsible for finding solutions to the problems they face while working on the project (Milian, 2023). Students can be creative and create projects that have been or will be created (Harefa & Purba, 2020) through a long-term research process in response to complex questions, problems, or challenges (Tuan et al., 2020). Projects given to students can encourage them to self-reflect, stimulating them to create other, more appropriate projects to solve a problem (Harefa & Purba, 2020). In addition, students who can analyze and evaluate the problems given effectively affect students' problem-solving skills. Students' problem-solving can be seen through pre-tests and post-tests (Faizah et al., 2022; Ling et al., 2024; Makuasa et al., 2024; Suyanti et al., 2022), surveys using the PjBL model (Chu et al., 2023; Milian, 2023), as well as pre-impact and post-impact observation assessments (Tuan et al., 2020). Problem-solving skills can train students to find holistic, meaningful, authentic, and applicable concepts (Faizah et al., 2022). In addition, they are expected to find solutions to their problems effectively and accurately using the problem-solving competencies they master (Faizah et al., 2022).

Theme 2 - The Effect of Project-Based Learning (Pjbl) on Students' Problem-Solving in Chemistry Learning

Project-based learning can affect students' problem-solving ability because it can provide opportunities for students to be creative, imagine projects to be made (Harefa & Purba, 2020), work together in groups within a specific time to solve problems, and develop solutions (Milian, 2023). In addition, the PjBL model provides learners with a more interesting and realistic experience (Chu et al., 2023). The project used in the PjBL model helps students learn learning material while practicing skills such as collaboration, communication, and critical thinking (Tuan et al., 2020).

Based on research conducted by Faizah et al., (2022); Hanifa, (2022); N. Harefa & Purba, (2020); Makuasa et al., (2024); and Suyanti et al., (2022) have measured the effect of PjBL on students' problem-solving skills in chemistry learning. Research conducted by Faizah et al. (2022); N. Harefa & Purba, (2020); and Suyanti et al. (2022) measured

students' problem-solving ability using N-Gain calculations which showed that the application of project-based learning increased students' problem-solving in the high category. In a study conducted by Suyanti et al. (2022) to examine the problem-solving ability of students who were taught thermochemical material using a collaborative learning model oriented to project-based learning and cycle learning with animated videos. This study used a pre-experimental design approach of experimental research. This study used project-based learning assisted by animated videos for orientation to collaborative learning, which distinguishes it from other articles. The findings in this study indicate that the problem-solving ability of students taught with project-based learning (PjBL) and collaborative learning cycle models with animated video media in chemistry subjects meets the N-Gain standard with a high category.

Based on research conducted by Chu et al., (2023); Ling et al., (2024); Milian, (2023); Tuan et al., (2020); reported the implementation of PjBL on students' problem-solving with a case study research design. Research conducted by Chu et al., (2023); Milian, (2023); and Tuan et al., (2020) was conducted at the university level. Meanwhile, the research undertaken by Ling et al. was conducted in secondary schools. The research conducted by Ling et al. (2024) on developing the problem-solving skills of secondary school students through interdisciplinary project-based learning aims to discuss how students develop problem-solving skills in interdisciplinary project-based learning activities. This study's participants were 25 students divided into 7 groups. The project carried out by students was to make an oxygenator device. The findings of this study are that interdisciplinary project-based learning activities can improve students' academic level and interest in chemistry and chemical engineering. In addition, this study provides empirical evidence that interdisciplinary project-based learning can develop secondary school learners' problem-solving skills.

Question 2 - How is PjBL Implemented in Chemistry Learning?

In this study, the implementation of PjBL in chemistry learning was carried out by educators as a learning model and learning approach. Project-based learning in chemistry learning provides knowledge and experience of being directly involved in chemical practices related to daily life. The implementation of PjBL in chemistry learning in each study, namely (1) Milian, (2023) applied Project-Based Learning (PjBL) as a learning approach in Advanced Organic Chemistry courses at the university level; (2) Ling, et al. (2024) used PjBL as a learning approach in a project to make home-made oxygenators, although the level of education was not explicitly mentioned; (3) Faizah, et al. (2022) applied PjBL as a learning model in acid-base material at the junior high school level (4) Suyanti, et al. (2022) used PjBL as a learning model for thermochemical materials at the senior high school level; (5) Harefa & Purba (2020) also applied PjBL as a learning model on thermos-chemical material for high school students; (6) Tuan, et al. (2020) used PjBL as a learning method in General Chemistry courses at the university level; (7) Chu, et al. (2023) applied PjBL as a learning approach in an Inorganic Chemistry Laboratory Technique course at the university level; (8) Hanifa (2022) applied PjBL as an integrated learning model in electrolyte and non-electrolyte solution materials for high school students; (9) Makuasa, et al. (2024) used PjBL as a learning model for solubility and solubility product materials at the senior high school level.

Theme 1 - Implementation of PjBL in Chemistry Learning

Implementing project-based learning in chemistry learning is mainly used as a learning model. In chemistry learning, the PjBL model has different stages. However, implementing the PjBL model requires students to determine project construction, plan projects, carry out, report results, and conclude and evaluate the data obtained from the projects they do. Educators carry out Project Construction by providing situations or tasks that students must complete. Teachers, students, or groups can suggest and customize project titles based on learning objectives, materials, and practice conditions (Tuan et al., 2020). Projects are planned through student discussions to identify problems, set project objectives, search for and select specific solutions, divide tasks among each group member, and create a project schedule (Hanifa, 2022; Tuan et al., 2020). Project implementation is carried out by implementing the project design that has been developed. Students create tools while working on the project and test their effectiveness (Ling et al., 2024). Reporting project results is done by making reports, presentations, infographics, and other materials related to the products produced (Tuan et al., 2020), including the functions, principles, and innovations of the products developed (Ling et al., 2024). Summarizing and evaluating data is done through individual and group assessments of the results of group projects, individuals, and other groups. The educator is the last party to evaluate and comment on the project implementation process and the results obtained (Tuan et al., 2020).

In the research conducted by Ling, et al., 2024 research related to the application of Project-based Learning was carried out for 1 month at each stage of learning, students were allowed to adjust the order of implementation and time of each activity with guidance from the teacher. In the research conducted by Tuan, et al., 2020, projects in learning are carried out in groups by dividing tasks for each group and individual in a specific, detailed manner regarding the content of the work, how to proceed, and the time for completion. Lecturers provide advice and corrections based on project objectives, funds, project implementation time, and learner placement to help learners implement projects correctly.

The application of the PjBL model integrated with the STEM (Science, Technology, Engineering, Mathematics) approach was carried out by Hanifa et al, (2022); and Makuasa et al., (2024). The STEM-integrated PjBL model can encourage students' motivation and interest in learning, increase effectiveness, meaningful learning, and support students' future careers (Makuasa et al., 2024). Problem solving in the PjBL model with a STEM approach is carried out with practical activities in class (Makuasa et al., 2024) and assembling the equipment needed to solve the problem (Hanifa, 2022). The STEM approach with the PjBL model makes students active in learning, able to communicate and share findings with their friends (Makuasa et al., 2024).

Research on PjBL implemented as an approach was conducted by Chu et al. (2023); Ling et al. (2024); Milian (2023). Project-based approaches contain strict but feasible deadlines, clear but general guidelines, and incorporate challenging situations for learners (Milian, 2023). Applying PjBL as an approach engages learners in an extended yet structured process of inquiry based on complex and authentic questions, and learning and applying content and skills simultaneously (Chu et al., 2023). In applying project-based learning, students face problems that must be solved. Therefore, project-based learning

influences the development of learners' problem-solving (Ling et al., 2024). In addition, problem-solving skills can help learners identify and overcome obstacles (Milian, 2023).

Theme 2 - Use of Learning Media in the Application of Project-Based Learning

In several articles in this research, learning media are used in the application of PjBL learning models, including handouts (Ling et al., 2024), modules (Chu et al., 2023; Makuasa et al., 2024), and animated videos (Suyanti et al., 2022). The provision of learning media is done to provide a problem situation to students (Ling et al., 2024). This will provide an authentic experience in proposing and designing experiments to answer research questions (Chu et al., 2023), improve learning quality (Makuasa et al., 2024), motivate, and involve learners in completing projects (Suyanti et al., 2022). Using learning media such as e-learning modules will train learners to plan their activities that emphasize the balance of cognitive, affective, and psychomotor development and develop concept understanding according to each learner's learning style (Makuasa et al., 2024).

Theme 3 - Project Activities with Laboratory Practicum

Project implementation in project-based learning that is carried out with laboratory practicum pays attention to the health and safety of students. Therefore, a pre-lab is conducted before conducting experiments to remember and ensure learners' readiness for laboratory activities. In the laboratory, learners are exposed to a learning environment that requires them to follow written and verbal instructions. Project work in the laboratory encourages learners to share knowledge and skills in the laboratory, such as how to use tools or perform certain techniques by safety standards in the laboratory, and be responsible for conducting experiments (Milian, 2023). Through project-based learning, learners can apply what they have learned and develop skills in identifying research questions, finding theories/information, and designing relevant experiments (Chu et al., 2023).

Based on the 9 articles reviewed, the implementation of PjBL has a positive influence on students' problem-solving skills. In addition, implementing PjBL also improves the overall quality of learning. Learners experience a more interactive and applicable learning process that supports 21st-century skills, one of which is problem-solving. The application of PjBL both as an approach and learning model, and the use of various teaching materials to assist learning activities, such as handouts, modules, and animated videos, show that PjBL learning is feasible to be applied and developed in chemistry learning. The article explains the stages of PjBL, aspects of problem-solving, the effect of PjBL implementation on students' problem-solving, and how to implement PjBL in chemistry learning. This provides information for educators to implement PjBL effectively and provide maximum benefits for students and the success of future research.

▪ CONCLUSION

In this literature review, 9 articles were analyzed and summarized based on the research questions formulated to determine the effect of Project-Based Learning (PjBL) implementation on students' problem-solving skills in chemistry learning. The results of the review of nine articles show that Project-Based Learning has a positive influence on students' problem-solving skills in chemistry learning. Project-based learning allows learners to be creative, work together, and develop solutions within a specific period,

improving their collaboration, communication, and critical thinking skills. Implementing PjBL also provides a more interesting and realistic learning experience, helping learners understand the learning material and practice practical skills. Further research shows that PjBL integrated with the STEM approach can increase learning motivation and effectiveness and support learners' future career development. In addition, using various teaching materials such as handouts, modules, and animated videos also proved effective in providing authentic problem situations and improving the quality of learning. In addition, implementing the project in the laboratory, which considers learners' health and safety, also provides an opportunity to share knowledge and practical skills. Overall, PjBL shows positive results in achieving chemistry learning objectives in terms of cognitive, affective, and psychomotor.

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