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Systematic Literature Review: The Effectiveness of Socio-Scientific Problem-Based Learning Models in Chemistry Learning

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Abstract
This study is a *systematic literature* review (SLR) that aims to analyze the effectiveness of the integrated Socio-Scientific Issues (PBL) Problem-Based Learning (PBL) model or PBL-SSI in improving students' scientific abilities in chemistry learning in secondary school. The background of this research is the dominance of traditional lecture methods that fail to strengthen 21st century critical thinking and skills, demanding a change in a more contextual and participatory approach. The SLR procedure follows systematic, transparent, and replicable guidelines, with literature searches via Google Scholar (time range 2020–2025) using the keyword "SSI; PBL; Chemistry Learning". Based on strict inclusion criteria, as many as eight articles deserve comprehensive analysis. The results of the synthesis of findings show that PBL-SSI has proven to be significantly effective in strengthening students' science literacy, critical thinking skills, creative thinking skills, and science process skills. The highest effectiveness is found in materials that have a strong relationship with social and environmental issues, such as acid-bases and green chemicals, which dominate the application of this model (about 25% each). The conclusion states that PBL-SSI is a very relevant approach to create meaningful and competency-oriented chemistry learning in the 21st century.

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INTRODUCTION

Chemistry learning is a scientific process that aims to help students understand the material, structure, and various changes in substances that occur in daily life (Khairrunisa et al., 2025). At the secondary school level, chemistry learning is not solely directed at mastering theoretical concepts, but is also expected to be able to relate these concepts to social and environmental issues relevant to students' lives (Hulyadi et al., 2025a; Maulidiningsih & Kusumaningsih, 2023) The relationship between chemical concepts and real context is an important foundation in building meaningful understanding and increasing students' scientific awareness. Therefore, the integration of chemistry content with an authentic learning experience is seen as an essential strategy to continuously improve the quality of chemistry learning (Bambut & Tangpen, 2024)

However, the practice of chemistry learning in schools in general is still dominated by conventional teacher-centered learning methods. In this learning pattern, teachers play the role of the main source of information, while students tend to be passive recipients of learning materials. This condition limits students' opportunities to actively engage in the thought process, ask questions, and explore chemical concepts through investigative activities. As a result, the development of critical thinking, analytical, and problem-solving skills that should grow through learning chemistry is not optimally facilitated (Ashari et al., 2025; Hulyadi et al., 2025b). In addition, one-way learning and minimal meaningful experience have the potential

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to reduce students' motivation to learn. This situation shows the need to transform chemistry learning towards a more innovative, interactive, and participatory approach so that students can be actively involved in the process of knowledge construction and be ready for the demands of modern learning (Harahap, 2024).

One of the recommended learning models to answer these challenges is Problem Based Learning (PBL). The PBL model places real problems as the starting point for learning, thus encouraging students to build their own understanding through the problem-solving process (Fareza et al., 2024). The PBL model is a model that facilitates students to find problems in a situation. In this model, students work in groups collaboratively to identify things that need to be learned to solve problems. In this case, connecting the problem with the learning material makes students think more critically through their responses (Aisy et al., 2024a). Through PBL, students not only learn chemical concepts conceptually, but also relate them to phenomena they encounter in their daily lives. The learning process becomes more active, contextual, and meaningful, in line with the principles of constructivism in science education that emphasizes the active role of students in building knowledge (Joronavalona et al., 2025).

(Hulyadi et al., 2025b) state the application of the PBL model in chemistry learning has been proven to be able to improve students' high-level thinking skills. Through the stages of PBL, students are trained to identify and formulate problems, search for and evaluate relevant sources of information, and draw conclusions based on valid scientific evidence (Utami & Herawati, 2024). This series of activities contributes significantly to the development of logical reasoning, critical thinking, and the ability to scientifically evaluate chemical phenomena. In addition, PBL also encourages students to manage their learning process independently through planning, implementation, and reflection activities, thereby fostering academic responsibility and readiness to face the challenges of 21st century learning (Agustina et al., 2025).

In addition to the cognitive aspect, PBL also makes a positive contribution to the development of students' social skills. In the process of solving problems based on group work, students are required to collaborate, discuss, and communicate effectively to achieve the right solution. This interaction gradually improves students' scientific communication skills, both in presenting arguments and in responding constructively to the opinions of others (Ikmatul Nisa1, Ardianik1, 2025). The collaborative learning environment formed through PBL is able to create a cooperative learning atmosphere, increase student confidence, and foster intrinsic motivation to actively participate in learning. Thus, PBL not only enriches the chemistry learning experience, but also plays a role in the overall development of students' social-emotional competencies (Arifin, 2025).

Overall, the Problem Based Learning model has great potential in creating contextual, meaningful, and student-centered chemistry learning. The integration of PBL with socio-scientific issues (Socio-Scientific Issues (SSI) further strengthens the relevance of chemistry learning to the real problems faced by society. (Mulyani & Heliawati, 2025). Socio-Scientific Issues (SSI) are controversial issues related to science and have a relationship with social, environmental, technological, and ethical aspects, so that they require students to analyze real problems and make decisions based on scientific evidence and consideration of social values (Amelia et al., 2025). Therefore, this study aims to analyze the effectiveness of the socio-scientific issue-based Problem-Based Learning (PBL-SSI) model in chemistry learning in secondary schools through the Systematic Literature Review (SLR) method with PRISMA guidelines for articles published in the 2020–2025 period. The novelty of this research lies in the comprehensive synthesis of empirical findings regarding the impact of PBL-SSI on various students' scientific abilities, including science literacy, critical thinking, creative thinking, and science process skills in various chemical materials. The results of this study are expected to make a conceptual contribution in mapping the effectiveness and characteristics of the implementation of PBL-SSI as a reference for the development of contextual and skill-oriented chemistry learning in the 21st century (Fadilla & Ulfa, 2025).

METHODS

The type of research applied in this article is literature research, with a methodological approach in the form of a systematic literature review (SLR). SLR is a method of literature review that is carried out in a systematic, transparent, and replicable manner. Through SLR, researchers systematically identify, select, evaluate, and interpret all previous research findings relevant to a particular topic, resulting in a comprehensive synthesis of available evidence (Lusianti et al., 2024).

This study uses a systematic literature review approach, where data analysis is carried out by applying special choice reporting guidelines and meta-analysis. Through PRISMA, the literature selection and analysis process follows systematic stages: identification, screening, feasibility assessment, and fulfillment of inclusion criteria. Thus, all relevant articles were collected, carefully selected based on inclusion/exclusion criteria, and then comprehensively analyzed to evaluate the contribution of previous research to improve science process skills in students' chemistry learning (Aisy et al., 2024b).

The literature search in this study was conducted through the Google Scholar database with a publication time range of 2020–2025. The search strategy uses the key keyword "SSI; PBL; Chemistry Learning"; Initial results were then selected to eliminate publications that did not meet the inclusion criteria. The inclusion and exclusion criteria applied include:

Table 1. Article Inclusion and Exclusion Criteria

Inclusions	Exclusion
Articles are available in open access to enable a thorough and transparent review process of research methods, data, and findings.	Articles that are not available in open access or are not fully accessible, thus hindering the methodological analysis process and research results.
Articles are published in Indonesian or English, as these two languages are the main scientific languages used in international and national academic publications, as well as to minimize the risk of misinterpretation due to language limitations.	Publications that use languages other than Indonesian and English, due to limited linguistic access, may affect the accuracy of understanding and analyzing the content of the article.
Articles are published in national and international journals that are indexed at least SINTA 5, with the aim of ensuring scientific quality, methodological validity, and source credibility, considering that indexed journals have gone through a process of assessment and standardization of publication quality.	Articles published in journals that are not indexed by SINTA or indexed below the SINTA 5 rating, as well as publications that do not have clarity of indexing status and peer-review quality.
Articles are empirical research (quantitative, qualitative, or mixed methods) that present data on research results, making it possible to synthesize evidence-based findings.	Non-empirical publications, such as conceptual articles, opinions, editorials, or narrative reviews without systematic procedures, as they do not provide empirical data that can be analyzed in SLR.

Inclusions	Exclusion
The article explicitly discusses chemistry learning, including the application of Problem Based Learning (PBL), socio-scientific issue integration (SSI), or related variables such as science literacy, critical thinking, and science process skills.	Articles that do not directly address chemistry learning, including research in other fields or non-international proceedings that are not relevant to the context of chemistry education.
The article was published in the 2020–2025 period to ensure that the findings analyzed are up-to-date and relevant to the development of 21st-century chemistry learning.	Articles published outside the 2020–2025 time frame, as they may not represent current learning conditions and approaches.

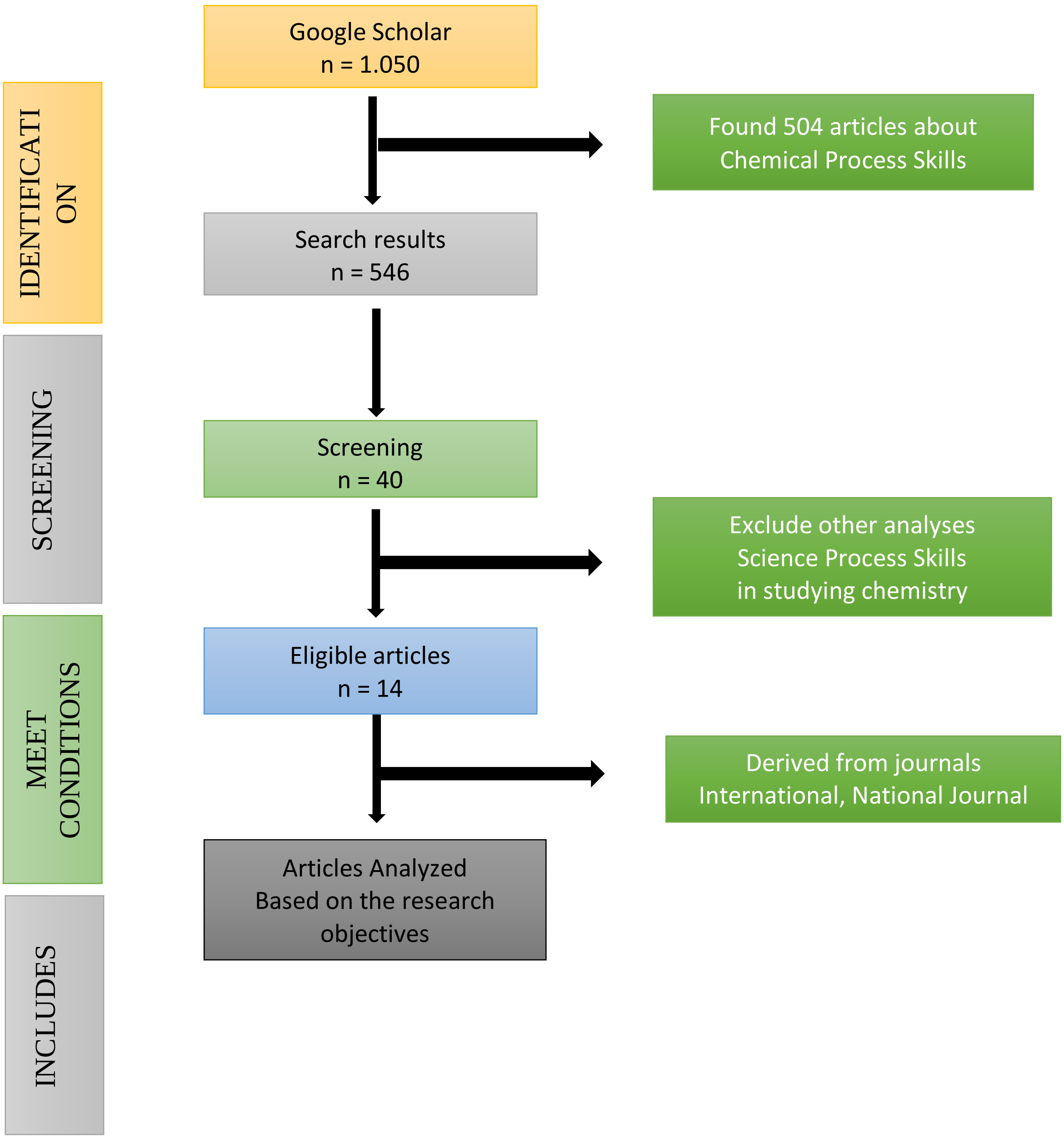

Figure 1. Article Selection Procedure Chart

The data analysis in this study was carried out through systematic thematic synthesis in accordance with the objectives of the Systematic Literature Review (SLR). The initial stage of analysis includes data extraction from each selected article, which includes research objectives, design and methods, the context of chemistry learning, and key findings related to the application of socio-scientific issue-based Problem Based Learning (PBL-SSI). The data are then compiled in the form of a structured summary to facilitate comparison between studies. Furthermore, a critical assessment of research quality was carried out by examining the suitability between the objectives, methods, and results of the research to identify the strengths and methodological limitations of each study.

The results of this assessment are used as the basis for cross-study comparative analysis to identify patterns, linkages, and differences in findings, which are then formulated into key themes inductively. The reliability and validity of the synthesis are maintained through the application of consistent analysis procedures throughout the article, the use of clear inclusion and exclusion criteria, and the iterative process of coding and grouping of themes. With this approach, the resulting synthesis represents empirical evidence in a systematic, accurate, and scientifically accountable manner (Runtuwarow et al., 2020).

The initial literature search process identified approximately 1,050 articles obtained through a search of several scientific databases, namely Google Scholar and Scopus, to ensure a more comprehensive coverage of national and international publications. Furthermore, the selection process is carried out based on the inclusion and exclusion criteria that have been set, as shown in Figure 1. Through this screening stage, 8 articles were obtained that were considered worthy of analysis because they had direct relevance to the discussion of science process skills in chemistry learning at the high school level (Suardana et al., 2024). The selected articles were then analyzed using a combination of qualitative and quantitative analysis to produce a comprehensive and evidence-based synthesis of findings.

RESULTS AND DISCUSSION

This study uses the Systematic Literature Review (SLR) method, where the literature selection process is carried out based on predetermined eligibility criteria. As a result, 8 articles were obtained that met all the inclusion criteria and were worthy of further analysis.

Table 2. Results Analysis

No	Journal Materials and Authors	Dominant Aspects of PBL-SSI	Effectiveness Chemical Materials	Challenges/ Limitations
1	Acid–Base (Azizah et al., 2021)	Real-world issues (environmental health, water pollution), group discussions	Significantly improve science literacy and critical thinking skills because students easily associate the concept of pH with everyday phenomena	Relatively longer learning time for exploration of contextual problems
2	Green Chemistry (Arthamena et al., 2025)	Global socio-scientific issues (sustainability, eco-friendliness), collaboration	Highly effective in fostering environmental awareness, critical thinking, and science-based decision-making	Requires teachers' readiness to design authentic and relevant issue scenarios
3	Garam Hydrolysis	Contextual problem-solving, guided group work	Improve understanding of science process concepts	Abstract concepts are still difficult to

No	Journal Materials and Authors	Dominant Aspects of PBL-SSI	Effectiveness Chemical Materials	Challenges/ Limitations
	(Mutmainnah et al., 2025)		and skills, especially in data interpretation	understand for low-ability students
4	Chemical Equilibrium (N. A. Putri et al., 2025)	Problem-based discussions, analysis of industry phenomena	Effective in improving analytical thinking skills and scientific argumentation	The integration of socio-scientific issues is less than optimal due to the abstract nature of the material
5	Buffer Solution (Putri Nadlifah Tiara Nita & Nada, 2024)	Contextual case studies (biology and environment), collaboration	Improve conceptual understanding and ability to relate chemistry to biological systems	Requires intensive guidance to keep the discussion focused on the core concepts
6	Stoikiometers (Zamri et al., 2025)	Context-based quantitative troubleshooting	Provides a moderate boost to critical thinking skills	Strong mathematical focus limits the exploration of socio-scientific issues in depth
7	Environmental Chemistry (A. J. H. Putri et al., 2025)	Local and global issues, reflective discussions	Very effective in developing students' science literacy and scientific attitudes	The availability of valid contextual data is an obstacle
8	Reaksi Kimia (Hajijah et al., 2025)	Problem-based collaboration and experimentation	Improve science process skills and understanding of reaction concepts	Class management becomes more complex in large group discussions

Based on the results analyzed in table 1, it can be analyzed about the materials, methods, and media used. The first article uses acid-base materials that have a strong relationship with environmental problems such as acid rain and pollution. The research method applied was an experiment with a control group design, thus allowing for an objective comparison of learning effectiveness. The learning media used is in the form of student worksheets (LKS) which are designed to follow the stages of Problem-Based Learning based on scientific social issues (PBL-SSI), so that it can support the process of problem identification, discussion, and scientific conclusions drawn.

In the second article, the materials used are green chemicals, which are relevant to sustainability and environmental issues. The research method applied was in the form of a quasi-experiment with a pretest-posttest design of the control group, so as to allow the measurement of changes in students' abilities after the application of the learning model. The learning media used include LKPD based on socio-scientific issues enriched with videos, images, and contextual news as triggers for problems.

The third article applies PBL-SSI to chemical equilibrium materials. The research method used was quasi-experimental with an unequal pretest-posttest design of the control group. The learning media used is in the form of LKPD and science literacy test instruments in the form of essays, which support discussion, investigation, and contextual problem-solving activities during the learning process.

The fourth article focuses on green chemicals with Research and Development (R&D) research methods using the ADDIE model. The learning media developed is in the form of Problem-Based Learning e-modules with the context of scientific social issues, which are designed to facilitate independent and contextual learning and support the understanding of chemical concepts in an applicative manner.

In the fifth article, the material used is salt hydrolysis. The research method applied is Research and Development (R&D). The learning media used is in the form of PBL-SSI-based LKPD which contains practicums or experimental activities, so that students can develop science process skills through direct investigation activities.

The sixth article uses buffer solution materials with quantitative descriptive research methods using a pre-experimental one-shot case study design. The media used include essay tests and observation sheets, which function to measure student involvement and creative thinking skills during the implementation of the PBL-SSI model.

In the seventh article, the learning material used is acid-base. The research method applied is in the form of quasi-experiments. The learning media used include teaching modules, student worksheets (LKS), and chemical literacy test instruments, which are designed to support the implementation of PBL-SSI systematically and contextually.

The eighth article uses stoichiometric material with a quasi-experimental research method using a non-randomized pretest-posttest control group design. The learning media used is an essay test based on critical thinking indicators, which is designed to support problem analysis and the preparation of solutions in PBL learning based on scientific social issues.

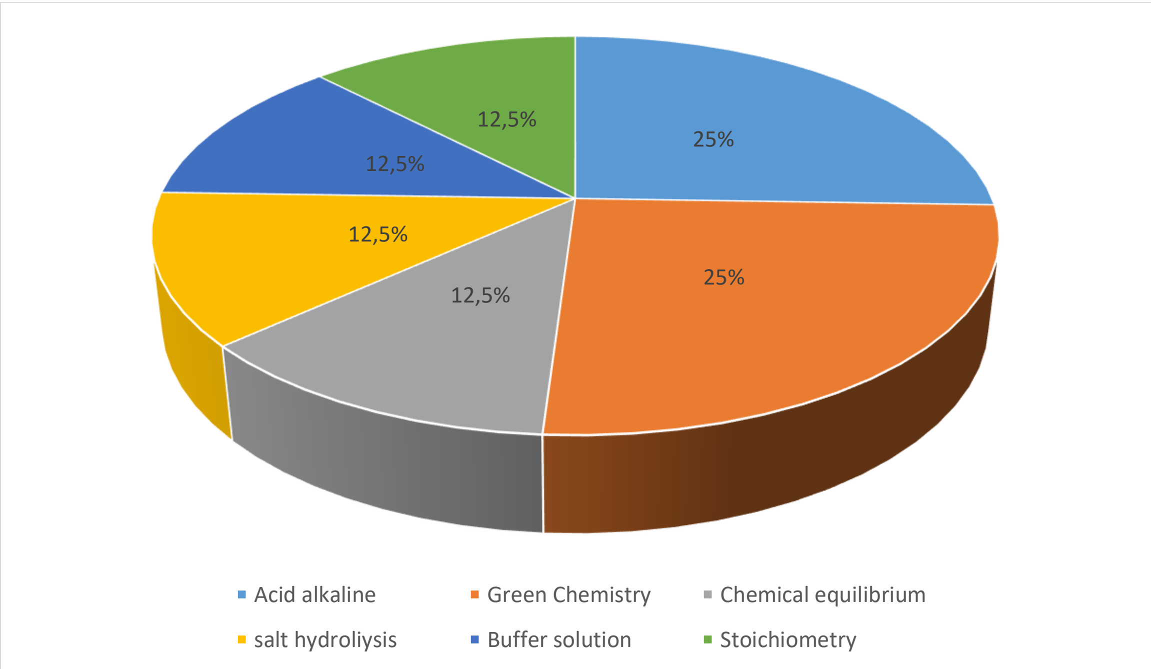

Figure 2. Materials Used in Problem-Based Learning Methods

A pie chart depicting the distribution of chemical materials in the PBL-SSI study shows that acid-base and green chemistry dominated the application of this model with a proportion of about 25% each. Meanwhile, salt hydrolysis materials, chemical equilibrium, buffer solutions, and stoichiometry each contributed about 12.5%. This difference in distribution indicates a variation in the degree of conformity between the characteristics of the chemical material and the PBL-SSI approach.

The topic of green chemistry and acid-bases tends to be taught more effectively through PBL-SSI because it is directly related to socio-scientific issues that are close to daily life, such as environmental pollution, waste management, chemical safety, and pH balance in biological and environmental systems. These characteristics allow students to relate chemistry concepts to real, multidimensional problems, thus encouraging deeper cognitive engagement, the development of science literacy, and the ability to think critically in solving contextual problems.

In contrast, materials such as stoichiometry and chemical equilibrium have a higher level of abstraction and often require mathematical understanding as well as strong symbolic representations. This condition can limit the exploration of socio-scientific issues directly if it is not accompanied by a well-structured contextual and structured problem design. Therefore, the application of PBL-SSI to these materials generally requires more complex problem scenarios in order to be able to integrate the social and scientific contexts in a balanced manner.

Thus, these findings suggest that the effectiveness of PBL-SSI is strongly influenced by the characteristics of the chemical material. Materials that are contextual, applicative, and close to environmental or social issues tend to have a more optimal learning impact when combined with PBL-SSI. These results underscore the importance of selecting and designing the right materials in implementing PBL-SSI so that the potential for 21st century skill development of students can be maximally achieved.

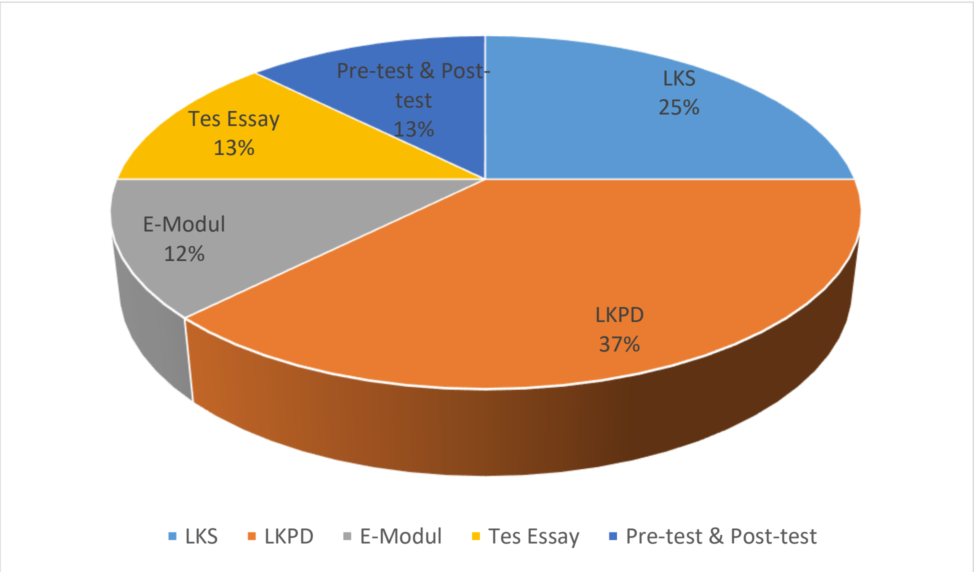

Figure 3. Media Used in Problem-Based Learning Methods

The learning media used in the application of *the Socio-Scientific* Issues-based Problem-Based *Learning* (PBL-SSI) model in eight articles were analyzed. The results of the diagram show that student worksheet media (LKS/LKPD) is the most dominant media used, with the largest proportion compared to other media. The dominance of the use of LKS/LKPD shows that this media is seen as effective in facilitating the PBL-SSI stages, especially in helping students identify problems, conduct discussions, and formulate solutions based on scientific social issues.

In addition, e-module media is also used with a smaller percentage, especially in Research and Development-based research, which emphasizes independent learning and the use of digital technology. Meanwhile, essay test instruments and observation sheets are used as supporting media to measure the achievement of students' critical thinking skills, creativity, science literacy, and science processes. Overall, the distribution of media in this diagram shows that the implementation of PBL-SSI tends to prioritize media that is contextual, interactive, and supports students' active involvement in the chemistry learning process.

CONCLUSION

The results of a systematic review of eight articles showed that the Scientific Social Issues-based Problem-Based Learning (PBL-SSI) model was effective in improving students' scientific abilities in chemistry learning. PBL-SSI has been proven to be able to strengthen science literacy, critical and creative thinking skills, and science process skills through problem-solving related to social and environmental issues. A variety of materials, such as green chemistry, acid-base, chemical equilibrium, buffer solutions, salt hydrolysis, stoicohometry, and electrolyte and non-electrolyte solutions can be implemented using PBL-SSI flexibly and contextually. In addition, the use of supporting media such as LKS, LKPD, and e-modules also strengthens students' active involvement in learning. Overall, PBL-SSI is a relevant approach to improving the quality of meaningful, skill-oriented chemistry learning for the 21st century.

RECOMMENDATIONS

The results of the Systematic Literature Review show that the Socio-Scientific Issue-Based Problem-Based Learning (PBL-SSI) model is effective in improving science literacy, critical and creative thinking skills, and science process skills in chemistry learning. The effectiveness of PBL-SSI is most prominent in materials that have strong links to social and environmental issues, such as green chemistry and acid-bases, as it allows for the integration of authentic and relevant real-world contexts for students. Practically, the implementation of PBL-SSI requires teachers to design contextual socio-scientific problems, facilitate collaborative learning, and utilize learning media that support the systematic problem-solving stages. The role of the teacher as a facilitator is crucial, especially in directing discussions and maintaining the relationship between the context of the issue and the chemical concepts studied. Therefore, the professional development of teachers in designing learning based on socio-scientific issues, collaborative classroom management, and assessment of high-level thinking skills is an important factor in the successful implementation of PBL-SSI. Overall, PBL-SSI has the potential to be a strategic approach to support contextual and competency-oriented chemistry learning in the 21st century.

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