Islamic Journal of Integrated Science Education (IJISE), Vol. 5 No. 2, July 2026, pp. 111-128
DOI: https://doi.org/10.30762/ijise.v5i2.8586

Islamic Journal of Integrated Science Education (IJISE)

Program Studi Tadris IPA
Universitas Islam Negeri (UIN) Syekh Wasil Kediri
e-ISSN : 2986-0865
https://jurnalfaktarbiyah.iainkediri.ac.id/index.php/ijise

NARRATIVE REVIEW: TEACHING PRESERVATIVES USING PROBLEM-BASED LEARNING (PBL) IN CHEMISTRY EDUCATION

Nur Afifah Jafaruddin[1], Nur Andini[2], Ira Lestari[3], Mayori Pratidina[4], Sahrani[5]*, Ramlawati[6], Rofiqul Umam[7]

[1,2,3,4,5,6]Jurusan Pendidikan IPA, Universitas Negeri Makassar, Makassar, Indonesia
[7]Faculty of Life and Environmental Sciences, University of Tsukuba, Japan

***Correspondence E-mail:** iphakila14@gmail.com

Abstract: This study aims to analyze the effectiveness of implementing Problem-Based Learning (PBL) in teaching preservatives in chemistry education using the narrative review method. The review examined 20 national articles published between 2020 and 2025, which were retrieved via Google Scholar using the keywords "preservatives," "Problem-Based Learning," and "chemistry education." The results of the review indicate that the implementation of PBL contributes to improved learning outcomes, critical thinking skills, problem-solving skills, and students' conceptual understanding of preservatives. Learning activities linked to food safety issues also support the enhancement of science literacy, while PBL-based media, such as e-modules and worksheets, effectively support contextual learning. However, most studies still have limitations regarding sample size, intervention duration, and a lack of research on long-term impacts. Therefore, further research with a broader scope is needed to strengthen the evidence of PBL's effectiveness in teaching preservatives in chemistry education.

Keywords: Preservatives; Problem-Based Learning; Chemistry Education; Science Literacy; Food Safety

Article History:
Received: 08 April 2026; Revised: 26 June 2026; Accepted: 27 July 2026; Published: 30 July 2026

Citation (APA Style):
Jafaruddin, N. A., Andini, N., Lestari, I., Pratidina, M., Sahrani, Ramlawati, & Umam, R. (2026). Narrative Review: Teaching Preservatives Using Problem-Based Learning (PBL) In Chemistry Education. *Islamic Journal of Integrated Science Education (IJISE), 5*(2), 111–128. https://doi.org/10.30762/ijise.v5i2.8586

INTRODUCTION

Advances in science and technology in the food and chemical industries have driven the increasing use of food additives, one of which is preservatives. Food preservatives, which are generally intended to extend the shelf life of food, prevent spoilage, and maintain food quality, have been produced for a long time. Communities have employed various methods to obtain food preservatives, ranging from natural ingredients to chemical substances (Hasibuan et al., 2024). Numerous cases of the use of preservatives such as formalin and borax in food indicate that public understanding of preservatives still needs to be improved, including among students as the next generation (Huda, et al., 2020a; Huda et al., 2026; Hardini et al., 2026).

The issue of preservative use, such as formalin and borax, is a topic closely related to students' daily lives, making it a relevant context for chemistry instruction. The preservative unit not only emphasizes understanding chemical concepts but also encourages students to analyze scientific information, evaluate food safety, and make informed decisions in their daily lives. Therefore, a learning model is needed that can link chemical concepts to real-world problems to make learning more meaningful (Nurulsari et al., 2020; Usman et al., 2025; Huda, et al., 2020b).

Problem-Based Learning (PBL) can be used to enhance higher-order thinking skills through problem-solving-oriented learning. The learning process employs a systematic approach to solving problems or addressing challenges related to everyday life (Putra & Wulandari, 2020). The implementation of the PBL model can improve conceptual understanding, encourage collaboration among students, and expand the range of learning resources used during the learning process. Additionally, PBL helps students develop critical thinking skills through collaborative activities aimed at finding solutions to problems (Wahyuni et al., 2023). These characteristics make PBL suitable for use in teaching preservative materials because students can examine real-world problems, such as the use of formalin and borax in food, thereby making the chemical concepts they learn more contextual and meaningful.

In chemistry education, preservatives are an important topic because they are directly related to everyday life. This subject matter not only covers chemical concepts such as compound structure, physicochemical properties, preservation mechanisms, and reactions occurring in food, but also encompasses social and health aspects (Munifah et al., 2019; Lestari et al., 2021; Saregar et al., 2025). A narrative review is considered appropriate for detailing the progress of research and problem-based learning (PBL) practices that have been implemented in contextual chemistry materials, including those on preservatives. A narrative review can

provide a summary of actual research findings, patterns in the research, and recommendations for future learning practices and research that are more focused on this topic.

Although there have been many studies on PBL and the teaching of preservatives, few have specifically synthesized these findings in the form of a narrative review. Therefore, this study was conducted to provide a comprehensive overview of the effectiveness of applying PBL to preservative-related topics in chemistry education (Huda et al., 2019; Yasin et al., 2020; Putra et al., 2024). Against this backdrop, this study aims to evaluate and review the latest developments in the literature regarding the application of problem-based learning in the teaching of preservatives in chemistry, including its impact on students' conceptual understanding and overall learning outcomes.

METHOD

This study employed a literature review method with a narrative review design aimed at comprehensively examining the teaching of preservatives through the Problem-Based Learning (PBL) approach in chemistry education. Data collection was conducted through an online literature search in the Google Scholar database. The article search strategy used a combination of relevant keywords, namely "preservatives," "Problem-Based Learning," and "chemistry education," to obtain sources aligned with the study's focus. Articles identified in the initial stage were then documented and screened based on their titles, abstracts, and the relevance of their content to the study's focus before undergoing a thorough review.

The selection of articles in this study was conducted systematically based on predetermined criteria to ensure the relevance and quality of the sources. The inclusion criteria included: (1) national articles available in full text; (2) articles published between 2020 and 2025; and (3) articles specifically discussing the teaching of preservatives using the Problem-Based Learning (PBL) approach in the field of chemistry. Meanwhile, articles that were not relevant to the research topic or were not available in full were excluded and categorized as meeting the exclusion criteria. The selection process was carried out in stages, beginning with the identification of titles, followed by a review of abstracts, and concluding with an evaluation of the full text to ensure that each article met the established inclusion criteria.

Based on the results of the literature review, a total of 20 articles were identified as the most appropriate and consistent with the established criteria. These articles were then collected, reviewed, and systematically analyzed through a data extraction process. This stage covered several important aspects, such as the characteristics of Problem-Based Learning (PBL) implementation, preservative materials in chemistry instruction, the learning strategies used,

and learning outcomes, which included conceptual understanding, critical thinking skills, and students' problem-solving skills. The articles were then collected and analyzed based on the characteristics of Problem-Based Learning (PBL) implementation, preservative materials in chemistry instruction, the learning strategies employed, and learning outcomes, which include conceptual understanding, critical thinking skills, and students' problem-solving skills. The extracted data were then analyzed descriptively by comparing, grouping, and synthesizing the findings from each article to identify similarities, differences, and trends in research results regarding the application of PBL to preservative materials in chemistry education.

Furthermore, the data obtained are presented in the form of a descriptive narrative to provide a comprehensive overview of the effectiveness and potential for future development of PBL in teaching preservatives in the field of chemistry.

FINDING AND DISCUSSION

Based on a synthesis of the 20 articles analyzed, a relatively consistent trend emerged in the research findings regarding the effectiveness of various innovative learning models in improving the quality of learning. Most studies reported that the implementation of problem-based and project-based learning models had a positive impact on improving students' learning outcomes, motivation, and critical thinking skills. These findings indicate that students' active engagement during the learning process is a key factor in building conceptual understanding and improving learning success, both at the junior high school and senior high school levels. Based on these analysis results, the subsequent discussion is organized into the following main aspects (Huda et al., 2019; Yasin et al., 2020; Putra et al., 2024).

The Effectiveness of the Problem-Based Learning (PBL) Model

The consistent use of the Problem-Based Learning (PBL) model has been proven to improve students' cognitive learning outcomes and logical thinking skills across various disciplines, including science, mathematics, and Indonesian language. Research by Marpaung et al. (2024) and Wahyuni et al. (2023) confirms that PBL is highly effective in sharpening critical thinking skills because students are encouraged to solve real-world problems through collaboration in group discussions and experimental activities. By exposing students to the complexity of real-world problems, this model successfully shifts the learning paradigm from merely passive information reception to an active and meaningful process of knowledge construction. These findings are reinforced by Yusal et al. (2025), who reported that collaborative problem-solving supported by various visual media has a positive impact on college students' critical thinking skills.

Furthermore, the effectiveness of PBL lies in its ability to bridge the gap between academic theory and practical application. In science education, for example, students not only learn concepts through text but are also challenged to analyze phenomena occurring in their surroundings, which in turn strengthens long-term memory retention. The process of independent inquiry, which is a hallmark of PBL, compels students to use logical reasoning to connect various pieces of information in order to arrive at the correct solution. This creates a dynamic learning environment in which the teacher acts as a facilitator, while students become the center of intellectual activity in the classroom.

From a mechanistic perspective, the success of PBL in improving Higher Order Thinking Skills (HOTS) indicators is closely linked to the evaluation and reflection stages that students undergo at the end of the learning process. When students are able to present the results of their problem-solving and receive feedback from their peers, they indirectly practice these skills. The use of generative technology can also support the creation of HOTS questions more quickly and easily, though the quality of the questions still needs to be verified by educators (Maiyanti et al., 2023).

Literacy and Awareness Regarding Preservatives

Regarding the specific topic of food additives and preservatives, it was found that an educational approach combining instruction with practical identification demonstrations was highly effective in improving students' knowledge and technical skills. Research by Yamin et al. (2022) and Abulais et al. (2024) demonstrated that students were able to master techniques for independently identifying borax and formalin using only simple tools and materials available in their immediate surroundings. This integration of theory and practice enables students not only to memorize the types of hazardous substances but also to understand the mechanisms of early detection in a practical way. This finding is reinforced by a study by Kusumo et al. (2022), which noted an increase in awareness of the dangers of synthetic preservatives of up to 85% following a demonstration-based intervention.

Furthermore, this increase in cognitive knowledge was found to have a positive correlation with students' affective and psychomotor aspects outside the school environment. This significant increase in awareness directly influences students' attitudes and decision-making patterns when choosing healthy snacks on a daily basis, as emphasized by Tamara & Febriantika (2023). Through hands-on experience testing food samples, students tend to become more critical and vigilant regarding food labels and suspicious physical characteristics of food. This phenomenon demonstrates that contextual learning can transform students' perceptions from mere learners into intelligent, health-conscious consumers.

From a mechanistic perspective, the effectiveness of this combination of instruction and demonstration lies in the maximum sensory engagement of students during the learning process. When students observe color changes or chemical reactions in preservatives during a demonstration, that information is retained more firmly in their long-term memory than if they had merely received a verbal explanation. This demonstrates that education about food additives cannot be separated from hands-on laboratory work, as it is this empirical experience that serves as the primary driver of changes in consumption behavior. Therefore, this strategy is considered an effective solution for bridging the gap between classroom chemistry theory and the food safety challenges students face in real life.

Innovations in HOTS-Based Learning Media

The development of innovative learning materials, such as Interactive E-Modules and Student Worksheets (LKPD) based on Problem-Based Learning (PBL), is considered highly valid and suitable for supporting the teaching of basic chemistry and science at the high school level. The materials developed by Fitriani et al. (2021) and Septiyani et al. (2024) have been empirically proven to facilitate the development of students' Higher Order Thinking Skills (HOTS), particularly in the areas of analyzing (C4), evaluating (C5), and creating (C6). These interactive digital media serve not only as a means of conveying information but also as visualization tools capable of simplifying abstract and microscopic chemistry concepts, such as those related to substance changes and chemical composition in hydroponic systems (Safitri et al., 2020). Furthermore, structured laboratory management modules have been shown to have a positive impact on critical thinking and creativity, although enhancing communication and collaboration still requires additional strategies (Laili et al., 2025).

Furthermore, the integration of technology into this problem-based learning medium creates a more self-directed and learner-centered learning environment. With the help of simulations and interactive features within the E-Module, learners can explore concepts independently, which in turn enhances their retention and understanding of complex subject matter. The effectiveness of this medium is also evident in its ability to contextualize real-life chemistry problems within a systematic teaching framework, making science studies feel more relevant to students. Therefore, the use of this validated medium is key to addressing students' learning difficulties in early chemistry topics that require a high degree of imagination and analytical logic. The research distribution data show a stable trend over the past five years, demonstrating that the topic of the effectiveness of learning models remains a primary focus in educational research. The following is a summary of the number of studies that form the basis of this discussion:

DOI: https://doi.org/10.30762/ijise.v5i2.8586

Tabel 1. Number of articles reviewed by year

No	Year of Publication	Number of Articles	Percentage (%)
1	2020	1	5%
2	2021	2	10%
3	2022	4	20%
4	2023	5	25%
5	2024	7	35%
6	2025	1	5%
Total		**20**	**100%**

Based on a synthesis of 20 research articles, the majority of the literature namely 14 studies (70%) showed consistent positive results. A significant improvement in learning outcomes was clearly evident in students' mastery of cognitive concepts and higher-order thinking skills (HOTS), where average post-test scores consistently exceeded the mastery threshold compared to the control group. Furthermore, the Problem-Based Learning (PBL) model proved effective in enhancing students' critical awareness of the dangers of preservatives through the investigation of real-world problems. On the other hand, 6 studies (30%) showed a different research focus; these studies placed greater emphasis on the validity and technical feasibility of learning media (such as worksheets and e-modules), as well as analyzing the correlation between students' theoretical knowledge and their actual behavior in selecting healthy snacks in real-world settings.

The group comprising 14 studies that showed significant results in conceptual mastery, higher-order thinking skills (HOTS), critical thinking, and changes in students' awareness is presented in **Table 2**.

Table 2. A Collection of Articles Demonstrating Improvements in Students' Skills, Behavior, and Learning Outcomes

No	Author	Research Title	Research Findings	Year
1	Ihsan, B. R. P., dkk.	Training for junior high school UKS student leaders to improve their understanding of food additives	To improve UKS students' understanding of how to choose safe food additives and the principles of a balanced diet.	2021
2	Irfandi, I., dkk.	Educational Session on Harmful Food Additives for Students at MA Assalam	To provide an in-depth understanding of the health risks posed by food additives and how to avoid consuming harmful substances.	2022
3	Yamin, M., dkk.	Techniques for identifying food additives to avoid their negative health effects	Students are able to perform simple tests to identify borax and formalin using turmeric, thereby increasing their independence in choosing snacks.	2022

4	Atini, B., dkk.	Education on the Effects of Food Additives on Organ Health for Students at SMPN Neon Bat	Successfully increased public awareness by 85% regarding the dangers of the accumulation of additives in the body, which can lead to internal organ disorders.	2023
5	Ihsan, B., dkk.	Educational Session on Food Additives, Preservatives, and Food Colorings for Students at Singosari Junior High School	Through hands-on demonstration sessions, students demonstrated increased awareness of the physical characteristics of foods containing synthetic food coloring.	2023
6	Tamara, C. V., dkk.	Knowledge, attitudes, preservatives, and harmful food colorings and their impact on students' choices of snacks	Finding a correlation between students' level of knowledge and attitudes and their behavior in selecting healthy snacks.	2023
7	Wahyuni, S., dkk.	The Application of PBL in Enhancing Critical Thinking Skills Among Junior High School Students Through Lesson Study	PBL encourages students to analyze arguments and evaluate information sources, significantly improving their critical thinking scores.	2023
8	Abulais, dkk.	Healthy Eating and Food Additives (BTP) Education for Students at Jayapura Public Junior High School No. 5	Students' level of understanding of balanced nutrition and food safety jumped from 61.3% to 90.6% following the educational intervention.	2024
9	Aisy, M. R., dkk.	The effect of the PBL model in the context of socio-scientific issues (SSI) on critical thinking ability	Integrasi isu sosial-sains (SSI) dalam PBL membuat pembelajaran lebih relevan dan meningkatkan kemampuan berpikir kritis Peserta Didik.	2024
10	Haryati, S.	Efforts to Improve Students' Ability to Solve Higher-Order Thinking Skills (HOTS) Problems in Mathematics Through Problem-Based Learning (PBL)	The PBL model trains students at cognitive levels C4 through C6, thereby improving their ability to solve HOTS problems.	2024
11	Hermansyah, T. S., dkk.	The Implementation of the PBL Model to Improve Mathematical and Logical Thinking Skills	The PTK cycle shows that the stages of PBL significantly strengthen students' logical structures in constructing mathematical proofs.	2024
12	Hutagaol, R. A., dkk.	The Effect of PBL Strategies on Improving Descriptive Writing Skills	The PBL strategy helps students generate ideas through observation of real-world problems and improves their vocabulary and writing structure.	2024
13	Marpaung, P. L., dkk.	The Effect of the Problem-Based Learning Model on the Learning Outcomes of Junior High School Students	The implementation of the PBL model significantly improved students' cognitive learning outcomes on the topic of ecosystems.	2024

14	Nurhadi, A.	The Effect of the PBL Model on Students' Learning Outcomes in Science Education	The PBL model has proven effective in raising the class-wide achievement rate to over 85% due to direct observation.	2024

The group comprising six studies that focused more on the feasibility of instructional materials is shown in **Table 3**. The differences in results between the cognitive research group and the media development group are most likely due to variations in the intervention methods and evaluation instruments used. Studies focusing on learning outcomes tend to use a control-experimental classroom design, while differences in students' awareness levels are influenced by environmental conditions; samples directly exposed to snack safety issues in their school areas tend to show a more significant increase in chemistry literacy compared to samples that only received theoretical material.

Table 3. Group 2: Research, Development, Extension, and Supporting Studies

No.	Author	Research Title	Research Findings	Year
1.	Apriani, H., dkk.	Development of Inquiry-Based Science Assessment Sheets for Junior High School on the Topic of Substances and Their Characteristics	The development of guided inquiry-based LKPDs has been found to be effective and appropriate for helping students understand the material.	2020
2.	Prasdiantika, R., dkk.	Enhancing the Role of the Sendangmulyo Neighborhood Community in Responding to the Dangers of Food Additive Abuse	Raising public awareness about the dangers of using non-food preservatives and colorings in snacks.	2021
3.	Haryani, N., dkk.	Development of a Module on Food Additives Based on Local Knowledge in Food Processing in Karimunting Village	This module, which is based on local wisdom, is effective and practical for connecting the material to the real lives of the community.	2022
4.	Aninnas, A., dkk.	Development of Ethnoscience-Based Science E-Modules to Enhance the Scientific Creativity of Junior High School Students	Ethnoscience-based e-modules have been proven to be valid and effective in enhancing students' scientific creativity.	2023
5	Septiyani, D., dkk.	Validity of the Integrated Science LKPD Based on PBL on the Topic of Chemical Composition in Hydroponics	The PBL-based integrated science worksheets have been deemed valid and suitable for use in the learning process at school.	2025
6	Inayah, S., Dasna, I. W., & Habiddin.	The Implementation of Green Chemistry in Chemistry Education: A Literature Review	Green chemistry is important in chemistry education because it	2022

	makes lab experiments safer and more environmentally friendly, and enhances students' understanding.

Based on a critical review of 20 journal articles that were collected, it was found that the effectiveness of science learning particularly regarding the topic of food additives depends heavily on the integration of active learning models, the use of valid teaching materials, and the relevance of the topics to students' real lives.

Sample Characteristics and Research Subjects

Differences in educational levels have a significant impact on the complexity of problems that can be solved in the Problem-Based Learning (PBL) model. Research conducted by Irfandi et al. (2022) involved high school (MA) students, who tended to master chemical identification techniques more quickly due to their broader prior knowledge. This contrasts with the majority of other studies involving junior high school students, such as those by Abulais et al. (2024) or Aisy et al. (2024), in which students were just being introduced to the basic concepts of food additives and the digestive system, thus requiring more intensive scaffolding in their investigative process.

Environmental Conditions and Context of the Issue

The school environment has proven to be a powerful stimulus for enhancing learning motivation. Research conducted in Jayapura by Abulais et al. (2024) uncovered field evidence of hazardous food additives in school snacks, which triggered a dramatic surge in students' comprehension up to 90.6%. The presence of this real, contextual threat creates a much stronger and more responsive learning response compared to studies that rely solely on simulated scenarios or standard modules without addressing pressing environmental issues.

Mechanisms for Competency Development through PBL

Improvements in students' critical thinking skills and learning outcomes are closely linked to the PBL framework, which presents authentic problems. Mechanistically, real-world problems regarding preservatives act as stimuli that encourage students to conduct independent scientific investigations. This process leads to a deep assimilation of chemical knowledge. Furthermore, a comprehensive understanding of the dangers of food additives has been shown to result in significant attitude changes that encourage healthier food choices, as confirmed by Tamara & Febriantika (2023).

Determinants of Differences in Research Outcomes

The differences in results and the focus of the outcomes of the 20 studies reviewed were influenced by four main factors:

- Intervention Methods: Studies using pure experimental designs and a comprehensive PBL framework (Marpaung et al., 2024; Nurhadi, 2024) tend to show more academically measurable improvements in cognitive outcomes. Conversely, outreach methods (Irfandi et al., 2022; Ihsan et al., 2023) are more effective at broadening the scope of understanding and rapidly changing public perception.
- Variations in Instruments: Product development studies (Apriani et al., 2020; Aninnas et al., 2023) primarily use expert validation sheets to assess the suitability of the medium and its creativity. Meanwhile, behavioral impact studies use statistical tests to analyze the relationship between students' knowledge and their actual actions.
- Appropriateness of Learning Objectives: Learning success depends heavily on the careful selection of methods appropriate to the learner's cognitive level.
- The Power of Contextual Issues: The issues raised must be relevant in order to spark students' curiosity and concern about their own health.

In Media Innovation and Local Wisdom

The development of innovative learning materials also supports the achievement of learning objectives. The use of ethnoscience-based e-modules (Aninnas et al., 2023) and modules based on local wisdom (Haryani et al., 2022) helps students connect abstract scientific concepts with real-world practices in the community, such as traditional food processing. This strengthens students' science literacy in a comprehensive and sustainable manner.

The improvement in students' critical thinking skills and learning outcomes is closely related to the PBL framework, which presents authentic problems concerning preservatives. Mechanistically, the presence of real-world problems as stimuli encourages students to conduct independent scientific investigations, leading to a deep assimilation of chemical knowledge. Furthermore, a comprehensive understanding of the dangers of food additives has been shown to result in significant attitude changes that encourage students to make healthier food choices.

The differences in results and the focus of the outcomes from the 20 studies that were critically reviewed were influenced by four main factors: intervention methods, variations in instruments, sample characteristics, and environmental conditions. First, differences in intervention methods and forms are the primary determinants; studies that used a pure experimental method with a complete PBL framework in the classroom, such as those by

Marpaung et al. (2024) and Nurhadi (2024), tended to show more measurable improvements in academic or cognitive learning outcomes. This contrasts with mass outreach methods, such as those employed by Irfandi et al. (2022) or Ihsan et al. (2023), which are more effective at broadening students' understanding and rapidly changing their perceptions regarding the dangers of food additives, but are less in-depth regarding technical chemical aspects.

Second, variations in the instruments and indicators measured lead to differences in how researchers conclude the success of their studies. Studies focused on product development, such as those by Apriani et al. (2020) and Aninnas et al. (2023), more frequently use expert validation sheets to assess the suitability of educational media and the enhancement of scientific creativity. Meanwhile, studies examining behavioral impacts, such as those by Tamara & Febriantika (2023), use statistical tests to analyze the relationship between students' knowledge, attitudes, and actual behaviors in selecting snacks. Third, sample characteristics and educational levels also influence the complexity of problems in PBL. Research subjects at the high school level (Irfandi et al., 2022) tend to master chemical identification techniques more quickly due to their broader prior knowledge compared to junior high school students (Aisy et al., 2024), who are just becoming familiar with the basic concepts of food additives through the context of social-science issues.

Finally, environmental conditions and the context of local snacks have a significant impact on students' motivation to learn. For example, a study by Abulais et al. (2024) in Jayapura found, through field research, the presence of food additives in school snacks, which triggered a surge in students' understanding of up to 90.6% due to the existence of a real, contextual threat. This situation elicited a far stronger response compared to studies based solely on simulated scenarios without pressing environmental issues. Overall, the differences in these research findings do not indicate a contradiction but rather provide a comprehensive picture that the effectiveness of a learning model depends heavily on the appropriateness of the methods, the relevance of the instruments, the suitability of the target audience, and the strength of the contextual issues addressed in science education.

Improvements in students' learning outcomes and critical thinking skills are closely linked to the use of authentic problems regarding preservatives as the primary stimulus in the Problem-Based Learning (PBL) model. Mechanistically, exposure to real-world cases (such as snacks containing formalin) encourages students to actively conduct scientific investigations, leading to a deep assimilation of chemical knowledge. Furthermore, a high level of literacy regarding the health risks of synthetic food additives has been shown to lead to significant

attitude changes, which in turn prompt students to take concrete actions in choosing healthier foods.

Although many studies report positive results, there are several limitations worth noting. Most studies were conducted on a small scale with limited sample sizes (fewer than 30–50 students) and over a short duration, so they cannot yet demonstrate the long-term sustainability of changes in student behavior. Furthermore, many studies have focused solely on cognitive learning outcomes without conducting in-depth laboratory testing of the specific chemical structure of these additives in the learning process.

Based on this review, there is still limited research examining the integration of personalized digital technology into PBL for preservative-related content. Additionally, there is a research gap regarding the effectiveness of this model when applied in school settings in remote areas with limited access to basic laboratory testing equipment, as well as the impact of collaboration between schools and parents in monitoring students' snack-choosing behavior following classroom instruction.

In general, research trends over the past five years indicate a shift in focus from theoretical chemistry instruction toward contextual chemistry instruction and instruction based on socio-scientific issues. There is a strong trend indicating that researchers are beginning to move away from conventional lecture methods and toward the development of learning tools (such as worksheets or e-modules) that emphasize students' ability to independently analyze and address food safety challenges in their daily lives.

This indicates that the PBL model has great potential as a preventive educational strategy for maintaining public health through formal education. The use of preservatives is not merely a chemistry topic but a strategic tool for fostering critical thinking in students. Data show that when students are directly involved in the problem-identification process, they not only master the material academically but also develop resilience against exposure to hazardous substances in their environment.

CONCLUSION

Based on an analysis of 20 articles published between 2020 and 2025, it can be concluded that the implementation of the Problem-Based Learning (PBL) model in chemistry instruction particularly regarding preservatives generally has a positive impact on students' learning processes and outcomes. PBL has proven effective in improving conceptual understanding, cognitive learning outcomes, and higher-order thinking skills (HOTS), such as analytical skills, critical thinking, evaluation, and problem-solving. In addition, learning about preservatives in

the context of real-world issues such as the use of formalin and borax in food can improve students' science literacy and raise their awareness of food safety. Students not only understand the concepts theoretically but are also able to apply their knowledge in daily life through simple identification activities and make more critical decisions when choosing food that is safe to consume. Although most studies have shown positive and consistent results, there are still several limitations, such as relatively small sample sizes, short intervention durations, and a lack of research on the long-term sustainability of students' behavioral changes. Therefore, future research is recommended to involve a broader and more diverse sample, implement a longer intervention duration, and evaluate changes in students' behavior on an ongoing basis so that the effectiveness of PBL in teaching preservatives can be assessed more comprehensively and provide stronger empirical evidence.

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