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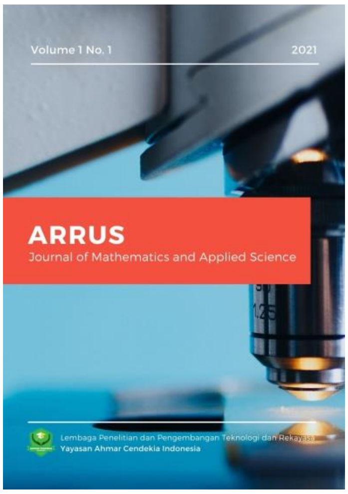

RESEARCH ARTICLE

Optimizing the Ability to Handle Toxic and Hazardous Waste Through Problem-Based Learning

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Abstract: The purpose of this study is to compare the efficacy of the Problem-Based Learning (PBL) learning model to traditional learning in developing the competence to manage Hazardous and Toxic Materials (B3) in basic laboratory courses. In this form of experimental research utilizing a Pre-Test and Post-Test Control Group Design, The N-gain values in the experimental (0.774) and control (0.8163) groups increased significantly, with g> 0.7 indicating a high category. The N-gain percent in the experimental (77.4026) and control (81.627) courses topped 76%, showing that both learning approaches were effective. Even though the Mann-Whitney non-parametric test revealed no significant difference between the experimental and control groups on the posttest and pretest, the conclusion that PBL had no meaningful impact must be regarded in the context of this study. Overall, both PBL and traditional methods improved B3 handling abilities, and these findings may aid in the creation of more effective learning methodologies in the future.

Keywords: handle, toxic, hazardous, waste, PBL.

1. Introduction

The issue of hazardous and toxic waste (B3) is a severe concern in Indonesia, both at the national and international levels. Indonesia generates a significant amount of trash, including hazardous and toxic waste (Fatimah et al., 2020). This trash is generated by industry, homes, and other sectors. Toxic substances such as heavy metals, pesticides, industrial chemicals, and medical waste are included in this sort of garbage (Karri et al., 2021). The lack of an adequate waste management system is a big problem. Many businesses have yet to establish ecologically friendly waste management techniques, and unlawful dumping of hazardous garbage into rivers or open ground still happens in some areas.

Uncontrolled hazardous waste disposal can harm the environment and jeopardize human health. Water and soil contamination, as well as long-term health effects from hazardous material exposure, are challenges that must be addressed (Anjum et al., 2021). Global environmental challenges, such as hazardous and toxic waste, are causing rising worry

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among the worldwide population (Naidu et al., 2021). Countries and international organizations take an active role in encouraging countries to improve waste management. In Indonesia, civil society is likewise becoming more conscious of environmental repercussions and plays a role in monitoring and regulating environmentally harmful actions. Environmental activists and non-governmental organizations (NGOs) are engaged in lobbying for legislative reforms and sustainable practices. The Indonesian government is working to strengthen hazardous waste management rules, law enforcement, and public awareness. Nonetheless, significant problems exist (Almulhim, 2022).

Various government legislation in Indonesia involves hazardous and toxic waste (B3) restrictions. Among the applicable rules are: The primary environmental law in Indonesia is Law No. 32/2009 on Environmental Protection and Management (Sapsudin et al., 2023). It establishes the legal framework for the handling of hazardous and toxic waste. Hazardous and Toxic Waste Management Regulation No. 101/2014: Establishes rules and processes for hazardous and toxic waste management, including hazardous and toxic waste registration, inventory, and destruction. Companies are required to report on the creation and management of hazardous and toxic waste (Xavier et al., 2021).

1.1. Ability to Handle Toxic and Hazardous Waste

The capacity to manage toxic and hazardous waste (B3) is a critical competence for S-1 Chemical Education Study Program (Prodi) students. Students in chemistry education will participate in practicum or research activities with potentially dangerous compounds. The capacity to correctly handle B3 waste is critical to ensuring the safety and health of oneself, peers, and the surrounding environment (Kutralam-Muniasamy et al., 2022). Students must comprehend and adhere to government standards governing hazardous waste management (Sridharan et al., 2021). Handling, storing, and disposing of hazardous waste in compliance with recognized criteria is part of this. Students who want to be chemistry instructors should comprehend the environmental consequences of hazardous waste. As a result, teachers may teach their pupils about the necessity of environmental conservation and trash management.

The competence to handle hazardous waste also requires knowledge of the most recent waste management technologies and practices (Hantoko et al., 2021). Students must be able to continue studying and stay up with scientific and technological advancements in the field of waste management. Students in chemical education must comprehend the professional ethics of hazardous waste management. This involves societal and environmental duties, as well as a grasp of the legal ramifications of improper hazardous waste management (Klemeš et al., 2020). Students can also contribute to community empowerment by being able to handle hazardous garbage. They can become change agents who guide the community in the proper disposal of hazardous waste, both individually and organizationally (Nguyen et al., 2022). Overall, the ability of Chemistry Education Study Program students to handle hazardous waste not only contributes to their own safety and health, but also develops future teachers who are responsible, have a deep understanding of the environment, and can educate the next generation on the importance of sustainable waste management.

Hazardous and toxic waste (H&T) management capabilities are critical to the survival of life on Earth. Implementing this degree of competence is critical not just for the environment, but also for human health and the overall ecosystem (Litvinenko et al., 2022). Good hazardous waste management capabilities will aid in the prevention of environmental contamination and the preservation of ecosystem equilibrium. This is critical for the survival of diverse plant and animal species, as well as the long-term viability of the Earth's ecosystem. A well-implemented hazardous waste management capability includes preventative actions to safeguard human health from hazardous material exposure (Blundo et al., 2021). Poorly handled hazardous waste can harm human health, causing serious and chronic illnesses.

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The amount to which people, businesses, and governments comply with applicable rules and laws reflects the level of implementation of hazardous waste management capabilities. This compliance contributes to environmental and public health objectives. A high degree of competence can stimulate waste management technology and process innovation. These innovations might include the creation of environmentally friendly technology, more efficient recycling processes, and long-term management methods (Ikram et al., 2021). Hazardous waste management competency comprises not only technical techniques but also public education and awareness. The degree of knowledge and implementation of the capacity may be increased by increasing public awareness of the effects of hazardous waste and teaching sustainable practices.

Good hazardous waste management may aid in lowering the carbon footprint and greenhouse gas emissions. Some hazardous wastes, if not adequately handled, might emit toxic gasses. Effective hazardous waste management can assist in mitigating the harmful effects of climate change. Recycling and green technology sectors, for example, can benefit from hazardous waste management innovation (Ankit et al., 2021). This not only promotes environmental sustainability but also boosts economic competitiveness in a global market where sustainable practices are becoming increasingly important (Tang et al., 2022). Implementing a comprehensive and long-term degree of hazardous waste management capabilities not only helps environmental sustainability but also benefits society and the economy as a whole. This demonstrates the need to empower citizens, governments, and industries to comprehend and act on hazardous waste.

Hazardous and toxic (B3) waste management may be a very important and helpful issue to incorporate into learning, particularly at the higher education level, such as at universities (Sharma et al., 2021). The incorporation of hazardous and toxic waste management into instruction can assist in enhancing students' knowledge of their responsibility in ensuring the long-term viability of life. give an awareness of what hazardous and toxic waste is and why it is critical to handle it appropriately. This might include a discussion of the environmental and human health risks posed by hazardous waste (Alengebawy et al., 2021). Introduce pupils to hazardous waste management legislation and policies at the national and international levels. This involves knowledge of government legislation and industry standards concerning hazardous waste (Arya & Kumar, 2020). Describe the numerous sources of hazardous waste from companies, labs, and households. Identify the common categories of hazardous trash, such as poisonous substances, medical waste, and electronic waste.

Practicum or demonstration on the proper disposal of hazardous waste. Teach pupils how to manage, store, and dispose of hazardous waste in line with safety and environmental regulations. Use real-world examples of environmental degradation or health effects caused by inappropriate hazardous waste handling (Yu et al., 2020). Discuss the ethical and societal responsibilities of garbage management. Concentrate on cutting-edge technology and breakthroughs in hazardous waste management. Discuss recycling techniques, the use of green technology, and other novel ideas to reducing the environmental effect of hazardous waste (Khoo et al., 2021). Allow students to create hazardous waste management solutions in the context of their individual courses or vocations. Discuss how they can contribute to future sustainable practices.

Teach students about the importance of their roles as educators and change agents in promoting public awareness of hazardous waste. Discuss public education techniques for sustainable hazardous waste management. The lecture should be concluded with an assessment and reflection session (Elzainy et al., 2020). Instruct students to assess their understanding of hazardous waste management and to consider how they might apply this information in their everyday lives and in the future. Involving students in hazardous waste management education not only gives practical knowledge, but it also builds good attitudes and understanding of environmental responsibility. Furthermore, including this issue into

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the curriculum may result in a generation that is more concerned about sustainability and the environment.

1.2. Ability to handle hazardous and toxic waste through problem-based learning

The problem-based learning model is a learning technique that focuses on presenting real-world issues or problems to students as a starting point for learning. Students learn not only facts and ideas under this approach, but also how to solve issues, discover solutions, and build critical thinking abilities. Real-world challenges or contextualized events are presented to students (Wickersham & Nachman, 2023). These challenges frequently reflect real-life circumstances or are concerned with contemporary topics. Students are the focal point of learning. They are actively involved in the formulation of questions, the identification of relevant information, and the resolution of provided difficulties.

Students are encouraged to conduct inquiries and study to obtain a better grasp of the topic. They can get knowledge from several sources, including books, articles, the internet, and interviews. Students are taught to think critically and critically assess the material that they discover (Dekker, 2020). They must identify assumptions, assess evidence, and get a better grasp of the problem. This strategy frequently incorporates student collaboration. They collaborate in groups to solve problems, discuss ideas, and establish a shared understanding.

Active learning experiences are emphasized in problem-based learning. Students participate in assignments and projects that involve active engagement, rather than simply listening to information (Ahmar et al., 2020). Students learn skills that they may use for the rest of their lives. They learn to solve issues, adapt to change, and keep learning throughout their lives. Student performance in problem-solving or project completion is used to assess students. The assessment focuses on students' conceptual comprehension, critical thinking abilities, and capacity to create successful solutions.

Students may build critical thinking, problem-solving, and teamwork skills through problem-based learning, which are useful abilities in everyday life and the workplace (Boelt et al., 2022). It also fosters an interesting and relevant learning environment for kids. Problem-based learning (PBL) can help students become more capable of dealing with hazardous and toxic waste. Here are some of the links between PBL and the capacity to handle hazardous and toxic waste. PBL guarantees that learning is related to real-world challenges (Sukackė et al., 2022). Students will be exposed to hazardous waste issues or difficulties that correlate to real-world circumstances in business or society in the context of hazardous waste. This helps kids comprehend the importance of hazardous waste concerns.

PBL frequently includes group work and cooperation (Hussein, 2021). When dealing with hazardous trash, student participation can result in more comprehensive and varied solutions. This partnership replicates teamwork that may be faced in the workplace, as dealing with hazardous waste frequently necessitates a collaborative effort. PBL allows for the development of critical and analytical thinking abilities (Aránguiz et al., 2020). Students must examine the effects of hazardous waste, comprehend alternative management choices, and choose the most effective and sustainable solution.

Problem-based learning can provide a forum for discussing the ethical and social responsibilities associated with hazardous waste management. Students can examine the social and environmental ramifications of hazardous waste decisions, as well as the long-term consequences. PBL problem-solving is frequently assessed by student performance and solutions (Fitriani et al., 2020). Performance-based evaluation in the context of hazardous waste might involve students' capacity to propose realistic and effective

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solutions. PBL promotes environmental and sustainability awareness. Students may learn about the effects of hazardous waste on ecosystems and human health, as well as how to find sustainable and ecologically responsible alternatives.

Students may gain in-depth understanding, practical skills, and favorable attitudes toward hazardous waste management in the future by incorporating problem-based learning into the hazardous waste curriculum. This results in a more contextualized and meaningful learning experience that helps equip students to handle real-world issues in the workplace.

2. Literature Review

The capacity to handle hazardous and toxic waste (B3) encompasses a wide range of issues with the management and disposal of items that have the potential to harm the environment and human health (Ali et al., 2022). Understanding, avoiding, and managing hazardous and toxic waste safely and sustainably are some of the essential components of this competence. The capacity to recognize and comprehend typical categories of hazardous waste, such as poisonous chemicals, medical waste, electronic trash, and other sorts of hazardous waste (Xu & Yang, 2022). The capacity to detect hazardous waste sources, whether in the industrial environment, homes, or other sectors. Concerns about the harmful effects of hazardous waste on the environment and human health. Understanding how hazardous waste may pollute water, land, and air, as well as the potential threats to humans, is required. This comprises waste storage, management, and disposal in line with applicable laws and regulations (Agboola et al., 2020). Compliance with government hazardous waste management guidelines and regulations. This involves registration, reporting, and adhering to all relevant safety and environmental regulations.

Technical knowledge of hazardous waste management, including the use of personal protective equipment (PPE), waste physical handling, and correct disposal (Patrício Silva et al., 2020). Capability to educate and raise public knowledge about the dangers of hazardous waste. This involves the socialization of safe behaviors as well as an emphasis on long-term sustainability. Capability to seek out and implement cutting-edge ideas and technology in hazardous waste management. This involves the implementation of recycling technology, ecologically friendly treatment methods, and other novel solutions. Understanding of the ethical and social issues of hazardous waste disposal. This entails thinking about how decisions affect society and the environment, as well as committing to act ethically (Ayeh & Bleicher, 2021). The capacity to handle hazardous waste is a necessary skill in many industries, including manufacturing, healthcare, and government. Individuals with this talent can contribute to efforts to preserve sustainability and safeguard the environment and human health.

The capacity to handle hazardous waste should be knowledge and skill held by all parties, not only environmental professionals or certain industrial personnel. Toxicologists, environmental biologists, and medics, for example, should have a thorough awareness of hazardous materials and the competence to handle them properly (Amorim et al., 2023). Workers in various industrial sectors, particularly those involved in the manufacture or use of hazardous materials, should be taught in the management of hazardous waste so that production and waste disposal operations may be carried out safely and in line with rules.

Corporate leaders and managers must recognize the significance of hazardous waste management and advocate for the incorporation of environmentally friendly practices into corporate operations. Healthcare personnel in hospitals and other healthcare institutions must understand how to properly dispose of hazardous medical waste created during routine medical procedures (Omoleke et al., 2021). Government officials and regulatory bodies must comprehend hazardous waste management legislation and standards to assure firm and individual compliance. Teachers and researchers in environmental science, chemistry, and biology must incorporate an understanding of hazardous waste handling into their curriculum and pass this knowledge on to future generations.

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The general public should also be informed of hazardous trash and how they may help with waste management by separating garbage, adopting environmentally friendly goods, and supporting recycling activities (Naik & Satya Eswari, 2022). NGOs and environmental activists can help with lobbying and monitoring ecologically unfavorable hazardous waste handling techniques. Waste management trainers and consultants can give training and consultancy to various parties to increase their understanding and abilities in handling hazardous waste (Calliera et al., 2021). The competence to manage hazardous waste should be included in cross-sector education and training to guarantee that every individual and organization that deals with hazardous waste has a thorough grasp of the hazards and can engage in safe and sustainable practices.

If the authorities or agencies in charge of hazardous waste management are uneducated or ignorant about hazardous waste handling, there can be a variety of negative consequences that can affect the environment, and human health, and perhaps breach legislation. Unsafe or incorrect procedures might result from a lack of understanding or awareness of hazardous waste handling (Fu et al., 2020). Improper management of hazardous trash can pose major health risks. Toxic substances or infections from medical waste can cause a variety of ailments and have long-term health consequences.

Lack of understanding or ignorance of legislation can lead to noncompliance with hazardous waste management laws and regulations. This might result in legal penalties and fines for those who are culpable. Improper hazardous waste disposal can result in the depletion of precious natural resources (Akhtar et al., 2021). Poorly handled hazardous waste can contaminate soil and water, harm ecosystems, and jeopardize nature's sustainability.

In the perspective of the public and clients, irresponsible waste management techniques might create an unfavorable impression (García-Sánchez et al., 2020). A lack of understanding or care to hazardous waste can harm an entity's or individual's reputation. Furthermore, if the negative impact is severe enough, the party involved may face legal consequences.

There are numerous substantial benefits of using Problem-Based Learning (PBL) on hazardous waste management material. PBL is a problem-solving approach to learning that emphasizes contextualized learning experiences. PBL materials are based on real-world events or difficulties associated with hazardous waste disposal (Nagarajan & Overton, 2019). This makes learning more relevant and contextual for students since they may experience how theories and concepts are used in real-world situations firsthand. PBL fosters active student participation in problem-solving. Students' motivation may rise when they perceive a practical aim in mastering and implementing hazardous waste handling ideas. Students believe they have a specific aim to attain.

3. Research Method and Materials

The experimental research approach was employed in the study, utilizing a Pre-Test and Post-Test Control Group Design. This form of experimental research can offer a comprehensive picture of the efficacy of problem-based learning in enhancing the capacity to handle hazardous and toxic waste (B3). Experimental research is an appropriate study method for determining the influence of a certain intervention or therapy on the dependent variable (Gomila, 2021). The intervention investigated in this example is the use of problem-based learning to improve the capacity to handle B3 waste. This form of learning can be used in experimental groups. Students will be exposed to real-world hazardous waste situations, allowing them to gain understanding and practical abilities.

Students are randomly allocated to one of two groups: experimental or control. This study employed one class from the chemical education S-1 study program, class c, which totaled 23 individuals and was then randomly separated into two groups, the experimental group of

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11 people and the control class of 12 people. This helps to reduce prejudice and guarantees that the two groups' starting features are comparable. Before the deployment of problem-based learning, both groups had an initial assessment of their capacity to handle hazardous waste. This assists in determining their baseline or original condition. In the experimental group, problem-based learning is being implemented. In this case, the use of PBL should be intended to increase the ability to handle hazardous waste. After the intervention, re-measure both groups with the post-test. This will demonstrate how much problem-based learning has increased the ability to deal with hazardous waste. The data is analyzed to examine the differences between the experimental and control groups.

N-gain was calculated in this study to determine how much the students' comprehension or competence improved after completing the problem-based learning intervention (Cahyaningsih et al., 2023). The N-gain (Normalized Gain) statistic is used to assess the success of a lesson or intervention in enhancing students' comprehension or abilities. N-gain assessment can offer information on the average change between pre-test and post-test scores (before and after intervention).

$$N - Gain = \frac{\text{Posttest} - \text{Pretest}}{100 - \text{Pretest}}$$

The value of N-gain ranges from -1 to 1, with a positive number indicating an increase, a negative value indicating a decline, and a value of 0 indicating no change. N-gain measurement can offer an overview of how successful problem-based learning is in enhancing students' comprehension or capacity to handle hazardous and toxic waste in the context of your research. The bigger the N-gain value, the better the improvement obtained following the intervention (Pranoto et al., 2021). After measuring N-gain, the analytical procedures that can be taken include employing statistical tests, such as the independent t-test or the Mann-Whitney test, to analyze the difference in N-gain between the experimental and control groups. This aids in determining whether or not the difference between the two groups is statistically significant.

4. Results and Discussion

PBL has succeeded in developing a method of concept mastering that is easily grasped by pupils (Hadi et al., 2023). The PBL approach, which stresses problem solving and context-based learning, may have offered a more tangible and contextual learning experience, making it simpler for students to comprehend the principles of hazardous waste disposal. The use of PBL improved the course content structure. With an emphasis on problem-based learning, learning materials may become more organized and closely tied to real-world difficulties in hazardous waste handling. This can help students comprehend the link between concepts and apply them to real-world events. PBL has empowered kids to attain their full potential. This method emphasizes student participation and involvement in problem solving, analysis, and decision-making. As a result, students may maximize the development of their hazardous waste management abilities.

The statement emphasizes the good impact of using PBL in the introductory laboratory, notably on hazardous waste management material. This implies that the PBL technique may be effectively linked with laboratory material and used to give a practical context for learning (Gomez-del Rio & Rodriguez, 2022). PBL appears to contextualize learning and allow pupils to reach optimum competency. This method establishes a learning environment that is analogous to real-world scenarios, allowing students to integrate theoretical concepts with their practical application in hazardous waste disposal. This favorable experience may serve as a solid foundation for continuing to use PBL in the context of hazardous waste handling learning. Furthermore, these findings might be used to inform future development of learning methodologies or curricular changes to increase the quality and efficacy of learning.

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Table 1. Pretest and posttest descriptive analysis results of hazardous waste handling ability

Statistics		Experiment Group Pretest	Control Group Pretest	Experiment Group Posttest	Control Group Posttest
N	Valid	11	12	11	12
	Missing	1	0	1	0
Mean		46.8182	42.9167	88.1818	90
Std. Error of Mean		4.48597	3.91473	2.26362	1.74078
Median		50	40	90	90
Std. Deviation		14.87829	13.56103	7.50757	6.03023
Variance		221.364	183.902	56.364	36.364
Minimum		25	25	80	80
Maximum		70	60	100	100
Sum		515	515	970	1080

According to Table 1, the post-test media scores in the experimental class (taught using PBL) and the control group (taught with conventional learning methods) are about the same, at around 90. The experimental class had a median score of 88.1818, whereas the control class had a score of 90. As a result, the statement demonstrates that there is no substantial difference in score attainment between the two groups. The very identical media and median scores between the two groups might imply that there was no significant difference in achievement between the experimental and control groups based on the final post-test findings. This might imply that both PBL and traditional learning approaches have comparable results in terms of grade attainment. If the post-test findings are similar, it might imply that problem-based learning (PBL) and traditional learning methods are equally beneficial in terms of students' academic progress.

Although the post-test scores are comparable, additional factors that may impact the findings should be considered, such as student happiness, participation in the learning process, and measuring other areas such as practical skills or grasp of particular ideas. When analyzing the results, it is critical to assess the variability of the data and if significant differences may be noticed by looking at the complete range of scores rather than simply the mean or median. The results that can be obtained may have an impact on the purpose of the study and the questions that can be asked. What is the purpose of this study? Is it to determine differences in ability, the efficacy of teaching methods, or something else?

The difference in scores between the two groups is attributable to the fundamental abilities of students in class C who have been provided a foundation in basic chemistry courses. Students who have completed basic chemistry courses may have a firmer foundation of knowledge and comprehension. This may make it easier for them to grasp more complicated ideas connected to hazardous and toxic waste disposal. Previous basic chemistry courses may build a favorable link between basic chemistry concept knowledge and students' capacity to grasp hazardous and toxic waste handling materials. A solid foundation in related subjects can lay the groundwork for grasping advanced topics.

Students who already grasp the fundamentals of chemistry may find it simpler to comprehend more complex concepts linked to hazardous waste disposal (Wang et al., 2021). This may include a grasp of chemical characteristics, chemical interactions, and the fundamental concepts involved in hazardous waste disposal. Students with a solid educational foundation can apply what they've learned to real-world situations more rapidly. As a result, individuals may be able to use their knowledge more successfully in hazardous waste management training scenarios. Integration of relevant courses and learning can help link concepts across courses and provide students with a more comprehensive picture of a certain topic.

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These findings may be used to design the creation of more integrated learning resources that enable incremental knowledge of subjects while leveraging the basics that students have already obtained. Students might be better equipped to study more complicated subjects if they have a solid foundational grasp. This understanding can aid in the improvement of problem-solving abilities, idea analysis, and application in the context of hazardous waste handling.

Table 2. N-gain analysis results

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
N_gain Experiment Class	11	0.5	0.5	1	8.51	0.774	0.15373	0.024
N_gain Control Class	12	0.5	0.5	1	9.8	0.8163	0.13262	0.018
N_gain Persen Experimen Class	11	50	50	100	851.43	77.4026	15.37308	236.332
N_gainPersen Control Class	12	50	50	100	979.52	81.627	13.26235	175.89

The experimental group's N-gain was 0.774, whereas the control group's was 0.8163. Both demonstrated a significant gain in knowledge of the content. The value of $g > 0.7$ in both groups shows a high level of progress, according to the assessment category. The experimental group had an N-gain percentage of 77.4026%, while the control group had an N-gain percentage of 81.627%. Both percentages are greater than 76%, showing a considerable improvement in both groups' grasp of the content. Based on the values of N-gain and N-gain percent, It may be concluded that both the experimental (taught using Problem-Based Learning) and control groups are effective in improving B3 handling abilities in basic laboratory courses. Although there is a slight variation between the two groups, both are highly successful. This demonstrates that both Problem-Based Learning and traditional techniques are effective in teaching pupils about hazardous waste disposal.

Consider the unique context of this learning, such as student characteristics, learning design, and other elements that may influence the outcome. Based on the considerable gain in comprehension of the subject in both groups, it is possible to infer that the learning methodologies used, both PBL and conventional methods, were effective in enhancing the capacity to manage B3 in the introductory laboratory course. This finding paints a favorable image of the efficacy of both learning approaches and demonstrates that they may be employed as useful instruments to increase students' comprehension and hazardous handling abilities.

Various factors can impact the efficiency of employing learning models, both Problem-Based Learning (PBL) and traditional learning models, in the content of handling Hazardous and Toxic Substances (B3) in introductory laboratory courses. The extent to which students can benefit from the applied learning approach depends on their prior understanding of basic chemical principles and hazardous and toxic materials management. Students' desire and interest in the learning topic can also influence their engagement and involvement in the learning process. The lecturer's or facilitator's readiness and command of the content is critical. Lecturers with a strong grasp of hazardous materials can better guide discussions or activities in the PBL paradigm. The capacity of lecturers to supervise student groups Can have an impact on group interaction and learning effectiveness, particularly in the setting of PBL.

The degree to which learning materials are tied to real-world events and students' needs might influence students' interest and involvement. How well-designed the learning framework is, including how information is presented and learning activities are structured.

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The availability of materials and equipment necessary for B3 handling experiments or practicums can have an impact on learning effectiveness, particularly in a laboratory setting. Adequate physical conditions and classroom amenities can help with effective learning implementation. The amount of cooperation and engagement amongst students can have a significant impact on the efficacy of the PBL approach. Student participation in debates, cooperative problem-solving, and idea-sharing can boost learning effectiveness.

How assessment and evaluation are carried out might have an impact on student motivation and learning focus. Assessment approaches suited to the learning paradigm must be explored (Bryson & Andres, 2020). Constructive criticism from instructors or fellow students can help with constant progress and understanding development. Institutional support, such as rules and infrastructure that facilitate the adoption of a certain learning model, can have an impact on its durability and efficacy. Cultural values and conventions in the learning environment can have an impact on how students engage in learning. Links to ethical principles and sustainability can help students comprehend and be motivated by B3 content. Taking these aspects into account, lecturers or learning managers may create and execute appropriate and effective learning models to increase students' comprehension of hazardous materials in basic laboratory courses.

In the control group, the value of employing visual and aural media, such as films and slide-based presentations (PPT), in the context of traditional learning paradigms. The integration of visual and aural media offers students with a multimodal experience, helping them to comprehend hazardous waste handling ideas visually and auditorily (Azzajjad et al., 2020). This method can give a range of sensory cues that can help with comprehension. Some students have distinct learning preferences, and using visual media can aid students who respond better to material provided visually, while using auditory media can benefit students who respond better to information delivered audibly.

Images and visuals may assist depict complicated topics in an easy-to-understand manner, which can aid with knowledge retention. By audibly describing material, auditory media, such as narrator voices in videos, can promote knowledge. Learning may be made more exciting and dynamic by using visual and aural resources. A film depicting the hazardous waste disposal procedure or an engaging lecture might help keep students' attention and participation. The successful use of visual and aural media in the control group may inspire ideas for using comparable media in PBL or other problem-based learning approaches. The usage of media may be tailored to the unique qualities and demands of each learning model.

It is crucial to assess how pupils' comprehension and abilities are affected by media use. To acquire student input on the efficacy of the medium, surveys, questionnaires, or formative assessment assessments might be employed. The usage of visual and aural media in the framework of the curriculum and learning objectives must be appropriately integrated (Azzajjad et al., 2023). The use of media should assist and supplement continuous learning. While visual and aural media can contribute significantly, their success is partly dependent on how they are incorporated into the entire learning experience. Furthermore, the variety of student reactions to media must be acknowledged, and flexibility in the use of learning techniques and media must be maintained to meet the demands of student learning.

Table 3. Pretest Normality Test Results

Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Group	Pretest_Eksperimen_Class	0.176	11	0.200	0.935	11	0.462
Pretest	Pretest_Control_Class	0.252	12	0.034	0.829	12	0.02

Normality test results with a p-value less than the preset threshold value (0.05) indicate that the data is not normally distributed. In this situation, the significance value of 0.02 in the control class is less than the 0.05 criterion, indicating that the data is not normally

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distributed. Non-parametric tests are commonly used when data is not regularly distributed. Non-parametric tests are an option for dealing with non-normality in data. In this case, the Mann-Whitney test may be used to compare the difference between an experimental class and a control class.

Table 4. Posttest Normality Test Results

Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Group	Posttest_Eksperimen_Class	0.232	11	0.1	0.822	11	0.018
Posttest	Posttest_Control_Class	0.333	12	0.001	0.774	12	0.005

Because the normality test results for posttest data in both classes demonstrate that the data is not normally distributed, non-parametric tests may be employed to compare the two groups. The Mann-Whitney Test is a typical non-parametric test in this situation.

Table 5. Mann-Whitney Test Results

Test Statistics[a]

	Group Posttest	Group Pretest
Mann-Whitney U	56	56.5
Wilcoxon W	122	134.5
Z	-0.689	-0.602
Asymp. Sig. (2-tailed)	0.491	0.547
Exact Sig. [2*(1-tailed Sig.)]	.566[b]	.566[b]

If the p-value (Asymp. Sig.) for both the pretest and posttest groups is larger than 0.05, the conclusion is that there is no significant difference between the two groups. This indicates that there is insufficient evidence to reject the null hypothesis that there is no difference in hazardous waste management abilities between the groups that used the PBL learning paradigm and those that did not. Although there is no statistically significant difference, this does not imply that the PBL learning approach has no effect. Change or improvement is conceivable, but it may not be evident due to the sample size utilized or the variability in the data. The exact setting in which the PBL learning model is implemented, the qualities of the learners, and other variables may all have an impact on the results. These considerations must be addressed while interpreting findings.

5. Conclusion

The following conclusions can be drawn from research involving a comparison of the experimental group (using Problem-Based Learning/PBL) and the control group (using conventional learning) in improving the ability to handle Hazardous and Toxic Materials (B3) in the introductory laboratory course: The experimental and control groups both improved significantly in hazardous and toxic materials handling abilities, as evidenced by high N-gain values. This demonstrates the efficiency of both learning approaches in delivering comprehension and increasing students' material-related abilities. High N-gains in both groups, more than 0.7, and N-gain percentages greater than 76% imply that both PBL and traditional approaches help develop understanding and abilities in handling hazardous chemicals. The category's high score shows that both learning modes positively contribute to student learning. Although the Mann-Whitney test findings demonstrate no significant difference between the experimental and control groups, this must be considered in light of the context and other considerations. A p-value of larger than 0.05 suggests that there is no statistically significant difference between the two groups. The findings must be interpreted within the context of the study, which includes student characteristics, learning design, and learning model implementation. These factors may alter the interpretation of the results and give further insights into the learning model's performance. If there is no substantial difference, the research might be used to reflect on and explore adjustments or changes to the PBL learning model's implementation. Additional analysis and feedback

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from students and professors can assist in identifying areas for improvement. Overall, this study revealed that both PBL and traditional learning may be employed effectively in basic laboratory courses to improve B3 handling abilities. These findings might help to build more effective learning approaches in the future.

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