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Enhancing science process skills: problem-based learning in salt hydrolysis for metacognition growth

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ABSTRACT

The demands of today's workforce for knowledge and flexible, cross-disciplinary skills have changed. Through problem-based learning, students can develop the skills necessary for a range of careers. This kind of research employs a pretest-posttest control-group design and is a quasi-experiment. One hundred and twenty-nine students from SMA Negeri 1 South Dampal XI MIPA class made up the study population. Simple random sampling was used to produce the sample. Thirty-two students from class XI MIPA 1 made up the experimental group, while 32 students from class XI MIPA 4 made up the control group. Students using the problem-based learning implementation model exhibited science process abilities with an effect size of 8.92 (M=71.84, SD=7.956), whereas those using the discovery learning model had an effect size of 8.33 (M=72.34, SD=7.872). For both the problem-based learning implementation model (M = 77.03, SD = 3.961) and the discovery learning model (M = 77.62, SD = 2.738), the effect size value of students' metacognitive awareness was 5.56. An independent-samples t-test indicated that the difference between the two groups was not statistically significant (t(62) = 0.67, p > 0.05). As a result of the problem-based learning approach, students' science process skills in the salt hydrolysis material improved significantly. Their metacognitive awareness of the material was affected, and there is a positive correlation between students' science process skills and their metacognitive awareness.

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Introduction

The primary and secondary school curricula for 2013 were intended to adjust to the demands of the increasingly globalised world. The emphasis on student-centred learning highlights the importance of fostering active involvement and overall development. A well-rounded education is important, as evidenced by the integration of emotive, cognitive, and psychomotor elements (Hodza et al., 2021). Learners' critical thinking abilities are greatly influenced by metacognition, as the curriculum emphasises (Mohseni et al., 2020). The importance of metacognition in learning cannot be overstated; it is a critical component in determining students' academic achievement. The term "metacognition awareness" describes a person's conscious knowledge of and management of their cognitive processes (Asy’ari et al., 2019). The curriculum aims to equip pupils with the tools to digest complex material, integrate new information with what they already know, and adapt to changing conditions by encouraging them to reflect on their thinking (Liu et al., 2021). By enhancing metacognitive capacities, learners are better prepared to tackle challenges, find solutions, and develop higher-order cognitive skills. This strategy demonstrates a dedication to fostering higher-order cognitive abilities necessary for success in the contemporary world, alongside procedural and factual knowledge. The curriculum's emphasis on metacognition acknowledges that it can enable pupils to become self-reliant learners who can evaluate, modify, and apply their knowledge throughout their lives (Lamb et al., 2017). The inclusion of metacognition in the curriculum is a forward-thinking approach that equips learners with the skills they need to navigate the challenges of a changing global education landscape.

Academic achievement is consistently higher among those with strong metacognitive skills than among those with weaker metacognition (Abdelrahman, 2020). In this setting, the cultivation of metacognitive awareness is essential, as it helps learners effectively organise, monitor, and regulate their cognitive processes. This significantly enhances the efficacy and efficiency of thinking and learning. Their ability to overcome obstacles, understand difficult ideas, and maximise their general cognitive functioning improves as they get acclimated to these metacognitive processes, all of which support their academic achievement (Alam, 2020; Antonio & Prudente, 2021).

The incorporation of science process skills is imperative for the implementation of the 2013 curriculum, particularly when utilising a scientifically based learning paradigm. The scientific method aims to achieve learning objectives in a variety of domains, such as attitudes, skills, and knowledge, by involving students in scientific thinking and processes (Kyere, 2017). This method encourages pupils to take an active and participatory part in their education, which develops their critical thinking, curiosity, and practical skills. This method represents a modern view of education, recognizing the need for critical thinking and practical skills in preparing them for the demands of the current world (Hyun et al., 2017).

Scientific thinking and metacognitive ability are two significant qualities that contribute to student learning. They aid in the cognitive and skill development of pupils in the context of scientific study. Students' capacity to observe, develop questions, gather data, make predictions, test hypotheses, and draw conclusions based on evidence or information obtained is part of the science thinking process. Students with strong scientific thinking abilities may gain a thorough understanding of scientific topics, discover cause-and-effect relationships, and apply their knowledge across a variety of settings. Students' knowledge and grasp of their own thought processes are examples of metacognitive skills. It entails the ability to plan, monitor, and evaluate one's own learning development. Students with strong metacognitive abilities may organize their learning processes, recognize difficulty in grasping the subject, and take efforts to overcome these obstacles. They can also assess whether or not they have met the learning goals.

Contemporary methods of teaching science, especially in chemistry and, by extension, in other disciplines such as physics and biology, offer unique opportunities for student engagement**.** Chemistry provides a unique opportunity for students to engage in inquiry and develop important skills, including reasoning, thinking, problem-solving, experimentation, observation, data analysis, and scientific reasoning (Stammen et al., 2018). Beyond only imparting theoretical information, the purpose of teaching chemistry in schools is to enable pupils to use the scientific method in practical experiments. This hands-on method develops critical scientific process skills while improving students' comprehension of chemical principles.

In the context of chemistry education, active engagement in practical exercises is essential. Teachers provide an atmosphere that promotes curiosity, discovery, and the development of practical skills by immersing students in experiments and hands-on activities (Papanastasiou et al., 2019). Students improve their comprehension of chemical concepts and acquire critical thinking, problem-solving, and scientific method application skills by practising science process skills via hands-on activities. These abilities help students not just in their future academic endeavors but also in a variety of real-world opportunities and problems (Sutaphan & Yuenyong, 2019; Mulyenı et al., 2019). In conclusion, it is critical to place a strong focus on active participation in real-world activities during the chemical learning process.

One of the most important aspects of scientific education is the training and development of science process skills. Through practical exercises, laboratory work, and inquiry-based learning, teachers want to foster these abilities in their students during the learning process (Ulger, 2021). This method not only improves their comprehension of scientific ideas but also develops their capacity for critical analysis and problem-solving (Akuma & Callaghan, 2019). Measurement of learning in science process skills is largely dependent on assessment and evaluation. Instructors assess students' competency in using these abilities through a variety of assessment techniques, including hands-on experiments, written assignments, and presentations. Both students and teachers need to use this feedback loop to monitor their progress and pinpoint areas for development (Koomson et al., 2024; Sholahuddın et al., 2020).

Given that salt hydrolysis is an analytical process, a problem-based learning (PBL) strategy could be highly effectiv**e.** Learners might be given tasks to solve in real-world circumstances involving salt hydrolysis, which encourages critical thinking and the application of theoretical ideas. Students' comprehension of salt hydrolysis may be enhanced and their viewpoints shared by encouraging inquiry-based learning and collaborative activities (Verawati et al., 2020). Students may also use this as a chance to connect the subject matter to real-world situations. Learning can be improved by using simulations, virtual experiments, or multimedia materials, particularly when learning abstract ideas and doing mathematical computations. Incorporating case studies about salt hydrolysis in various contexts can provide students with a comprehensive understanding of its applications and implications. Teachers can select instructional approaches that support greater comprehension of the subject matter while also accommodating a variety of learning styles by considering the mathematical and practical components of salt hydrolysis (Heliawati & Rubini, 2020). This method supports the objective of helping students become more adept at connecting academic knowledge to practical situations.

The convergence of learning models, past knowledge, metacognitive awareness, and problem-solving abilities within the framework of a problem-based learning strategy for salt hydrolysis content. Understanding how learning models, prior knowledge, metacognitive awareness, and problem-solving abilities converge within the PBL framework for salt hydrolysis content is essential. This recognises that the instructional strategy selected may affect how students reflect on and manage their mental processes, thereby influencing their problem-solving capacity and overall learning outcomes. The relationship identified by Moser et al. (2017) between students' prior knowledge and metacognition underscores the importance of accounting for individual variation when designing a learning process. Optimising the development of metacognition and, consequently, problem-solving abilities requires addressing these disparities.

Notably, the problem-based learning paradigm is beneficial in improving students' science process abilities. This bolsters the theory that the development of practical abilities in science is greatly aided by active involvement, inquiry-based learning, and problem-solving scenarios. Giving readers a clear understanding of the manuscript's goal gives them direction. The research will have a defined direction thanks to your focus on defining how applying a problem-based learning model to salt hydrolysis material affects science process abilities and metacognitive awareness in Class XI MIPA students at SMA Negeri 1 Dampal Selatan.

Problem-Based Learning in Salt Hydrolysis for Metacognition Growth

The 2013 curriculum in Indonesia places a strong emphasis on a learner-centred methodology to support learners' overall development. The curriculum emphasizes moving away from conventional teacher-centred methods toward student-centred ones. This entails motivating critical thinking, fostering autonomous inquiry, and actively involving students in the learning process—the 2013 curriculum centres on the acquisition of competencies, including skills, knowledge, and attitudes. In addition to imparting factual knowledge, the goal is to equip students with useful skills and positive attitudes towards learning (Amolloh et al., 2018).

The integration of a scientific approach across topics is one of the key features of the 2013 curriculum. Students are encouraged to use inquiry-based learning, observation, experimentation, and analysis to think and operate like scientists. Beyond scholastic achievement, the curriculum also prioritizes character education, aiming to instill moral principles, social awareness, and positive values to support students' holistic development into responsible members of society. While these aspects are not directly connected to specific subject content, such as the Periodic Table, they form part of the broader educational objectives outlined in the curriculum. This entails using ICT resources to improve education, advance digital literacy, and prepare pupils for the challenges of the contemporary world (Moreno-Marcos et al., 2020).

To effectively teach and succeed with the Problem-Based Learning (PBL) paradigm, one must comprehend its tenets, how to apply them, and how they could affect student performance (Scott, 2017). Problem-based learning is an educational strategy centred on real-world challenges. Students collaborate to understand the issue, identify relevant ideas, and use their expertise to solve it (Misnasanti et al., 2017). Problem-based learning (PBL) is a student-centred approach that engages learners through active involvement, inquiry, and collaboration. It emphasises applying knowledge to real-world situations while fostering problem-solving and critical thinking skills.

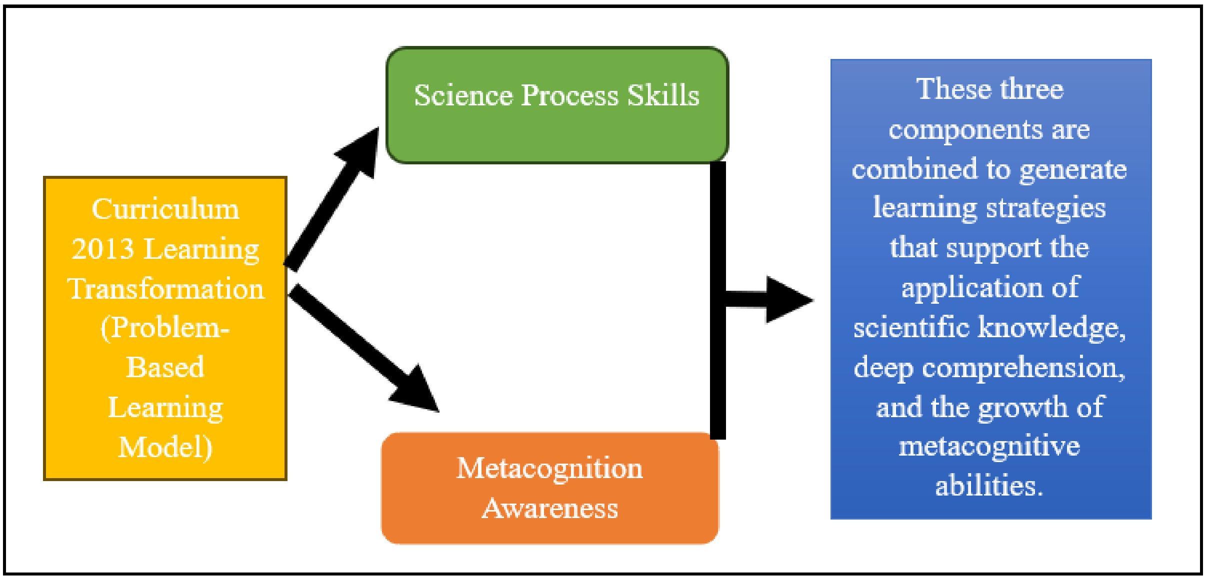
The teacher's role shifts from delivering content to facilitating and guiding students' learning. PBL frequently involves cooperative group projects that foster interpersonal, communication, and collaboration skills (Crespí et al., 2022). PBL helps students develop their critical thinking abilities by having them synthesise, evaluate, and apply knowledge to tackle challenging issues (Ali et al., 2019). Students are naturally motivated and interested in solving real-world challenges, which leads to a deeper understanding of the material. PBL emphasizes applying knowledge in real-world contexts to prepare students for the obstacles they may face. Additional time and material resources may be needed for PBL implementation (Vasiliene et al., 2020). Teachers might need training to guide student inquiry and facilitate PBL sessions. The development of metacognitive skills, which allow students to evaluate their own methods and approaches to learning, is a key component of success (Kasuga et al., 2022). Understanding the tenets, elements, advantages, difficulties, and success metrics of the problem-based learning approach is necessary before delving into it (Smith et al., 2022). PBL implementation requires meticulous planning, facilitation, and evaluation techniques to optimize student engagement, learning, and knowledge application. Interactive demonstrations, simulations, or multimedia materials can effectively illustrate salt hydrolysis processes. Visual aids can enhance understanding and retention.

Students should make concept maps that illustrate the connections between the various elements of salt hydrolysis. This facilitates information organization and understanding of processes. Encourage students to express their knowledge, concerns, and difficulties about salt hydrolysis during class discussions. Promote a cooperative learning atmosphere. In teaching salt hydrolysis, connecting the fundamental concepts to practical applications across various fields and everyday contexts can enhance relevance and student engagement. The use of technology, such as interactive simulations or virtual laboratories, can provide dynamic learning experiences. At the same time, exposure to complex scenarios that require applying salt hydrolysis principles can foster deeper conceptual understanding and strengthen problem-solving abilities (Seskir et al., 2022).

Metacognitive awareness entails reflecting on one's thought processes, including monitoring comprehension, controlling cognitive processes, and being conscious of how one learns. Metacognition enables individuals to actively regulate and enhance their cognitive processes, making it an essential component of learning and problem-solving (Tachie, 2019). being aware of the problem-solving process, keeping an eye on developments, and modifying tactics to overcome roadblocks. transferring information or abilities from one setting to another. Figure 1 shows the linkage of the 2013 Curriculum learning transformation in relation to problem-based learning, science process skills, and metacognition awareness.

Figure 1

Linkage of the 2013 curriculum learning transformation in relation to problem-based learning, science process skills, and metacognition awareness



In the domain of scientific learning, there is a strong relationship between the science thinking process, metacognition, and Problem-Based Learning (PBL) (Kuvac & Koc, 2019). The process of thinking scientifically involves observing events, developing hypotheses, carrying out experiments, analyzing data, and drawing conclusions. To solve issues or provide answers, scientific concepts must be used. Understanding and managing one's cognitive processes is a key component of metacognition (Cho & Linderman, 2019). It entails being aware of the cognitive techniques used, measuring comprehension, and being able to self-regulate to meet learning objectives. PBL is a teaching method in which pupils are presented with real issues and collaborate to find solutions. It promotes the use of information, critical thinking, and metacognition in the development and assessment of problem-solving techniques (Medina et al., 2017). These three components are combined to generate learning strategies that support the application of scientific knowledge, deep comprehension, and the growth of metacognitive abilities.

Methodology

A pretest-posttest control group is part of the quasi-experimental design used in this study's research methodology. While there are some parallels between experimental and quasi-experimental research, full randomisation of individuals to treatment and control groups is absent in the former. This lack of randomisation can introduce potential biases, such as selection bias, which may affect the results (Appelbaum et al., 2018). Based on initial observations, students' academic performance was relatively homogeneous, helping ensure comparable groups at the outset. To further address these limitations, efforts were made to match participants in the experimental and control groups based on key demographic and academic variables to control for potential confounding variables. In this design, the treatment and control groups have their dependent variables measured before and after the intervention.

Table 1

Tabulation of class characteristics data

Classes characteristics	Class XI MIPA 1	Class XI MIPA 4
Class Group	As an experimental class	As a control class
Number of Students	The class comprises 32 students.	Class XI MIPA 4 also consists of 32 students.
Gender Distribution	Within this class, there are 11 boys and 21 girls.	Similar to Class XI MIPA 1, this class includes 11 boys and 21 girls.
Age Range	The students in Class XI MIPA 1 range in age from 16 to 18 years.	The students in Class XI MIPA 4 range in age from 16 to 19 years.

Both classes are homogeneous in terms of student type distribution. This supports the internal validity of the research because both groups’ subjective characteristics, such as motivation to learn, interest in science, and preferred learning styles, are similar.

The experimental group received an intervention consisting of implementing HOTS-based LKPD using problem-based learning models. This intervention included a series of structured problem-solving activities designed to enhance critical thinking and science processing skills. The control group, on the other hand, used a discovery learning model with integration of HOTS-based LKPD. Both groups took a pretest to assess their initial knowledge and skills, followed by a posttest after the intervention to measure any changes in their performance. This design enabled a direct comparison of the effectiveness of the HOTS-based LKPD in improving students' critical thinking and science processing skills. Table 2 presents the pretest-posttest control-group design used in the study.

Table 2

Pretest-posttest control group design

Class	Pretest	Treatment	Posttest
Experiment	T	X	T
Control	T	Y	T

The study's population consisted of 129 students from class XI MIPA at SMA Negeri Dampal Selatan. From this population, two classes were randomly selected as samples: class XI MIPA 1 (experimental group, 32 students) and class XI MIPA 4 (control group, 32 students). Simple random sampling was used to minimise selection bias and ensure each student had an equal chance of being selected, thereby supporting the external validity of the study.

Instruments

The instruments used in this study included: (1) a test of science process skills consisting of six open-ended questions, and (2) a metacognitive awareness inventory.

The science process skills test measured students' abilities in observing, classifying, predicting, measuring, concluding, and communicating (Nurhayati et al., 2021). Each skill was assessed using specific open-ended questions designed to elicit responses that demonstrate students' proficiency in that area. For example, observing was evaluated by asking students to describe phenomena they witnessed during experiments, while predicting required them to hypothesize outcomes based on given scenarios.

The metacognitive awareness inventory assessed students' awareness and regulation of their own learning processes, providing insight into how they plan, monitor, and evaluate their learning strategies.

The Metacognitive Awareness Inventory (MAI) is the measure used by the metacognitive awareness tool. Fifty-two statements, comprising metacognitive knowledge (knowledge about cognition) and control of cognition with eight indications of metacognitive awareness, make up this inventory or questionnaire, which is used to assess students' metacognitive awareness. Declarative knowledge, procedural knowledge, and conditional knowledge are the three indicators that make up metacognition knowledge, or understanding of cognition. Planning, information management strategy, comprehension monitoring, strategic debugging, and assessment methods are the five indicators that make up the regulation of cognition. The MAI has been widely used in previous studies to assess metacognitive awareness, demonstrating good reliability and validity. For instance, studies by Schraw and Dennison (1994) reported high internal consistency with a Cronbach's alpha of 0.90, indicating strong reliability. Furthermore, the validity of the MAI has been supported by factor analysis, which confirms the inventory's ability to measure distinct aspects of metacognitive awareness.

Experts' construction validity tests were employed as the validity test in this study. From a technical standpoint, an instrument grid, also known as an instrument development matrix, can help in construction validity testing. Indicators serve as benchmarks in this grid, and question item numbers are derived from them. This instrument grid makes validity testing simple and methodical. An expert validator who certified that the science process skills test instrument and the metacognition awareness questionnaire were suitable for data collection provided validity evidence for this instrument (Snyman & Kruger, 2019).

Validity

The validity of the science process skills test instrument and the metacognitive awareness questionnaire was confirmed by an expert validator, who certified that both instruments were appropriate for data collection (Snyman & Kruger, 2019).

Data Analysis

Data were analysed using both descriptive and inferential statistics. Descriptive statistics (mean, standard deviation) were used to summarise the data for each variable. Independent samples t-tests were conducted to determine whether there were significant differences between the experimental and control groups in science process skills and metacognitive awareness. Effect size (Cohen's d) was also calculated to assess the magnitude of these differences. All analyses were performed using SPSS version XX, with a significance level set at $p < 0.05$.

Findings/Results

The students' classical science process abilities in the experimental and control classes may be noticed in the pretest scores provided at the start of the session and the posttest scores collected at the end of the course. Table 3 shows the statistics on the experimental and control class students' science process skills.

Table 3

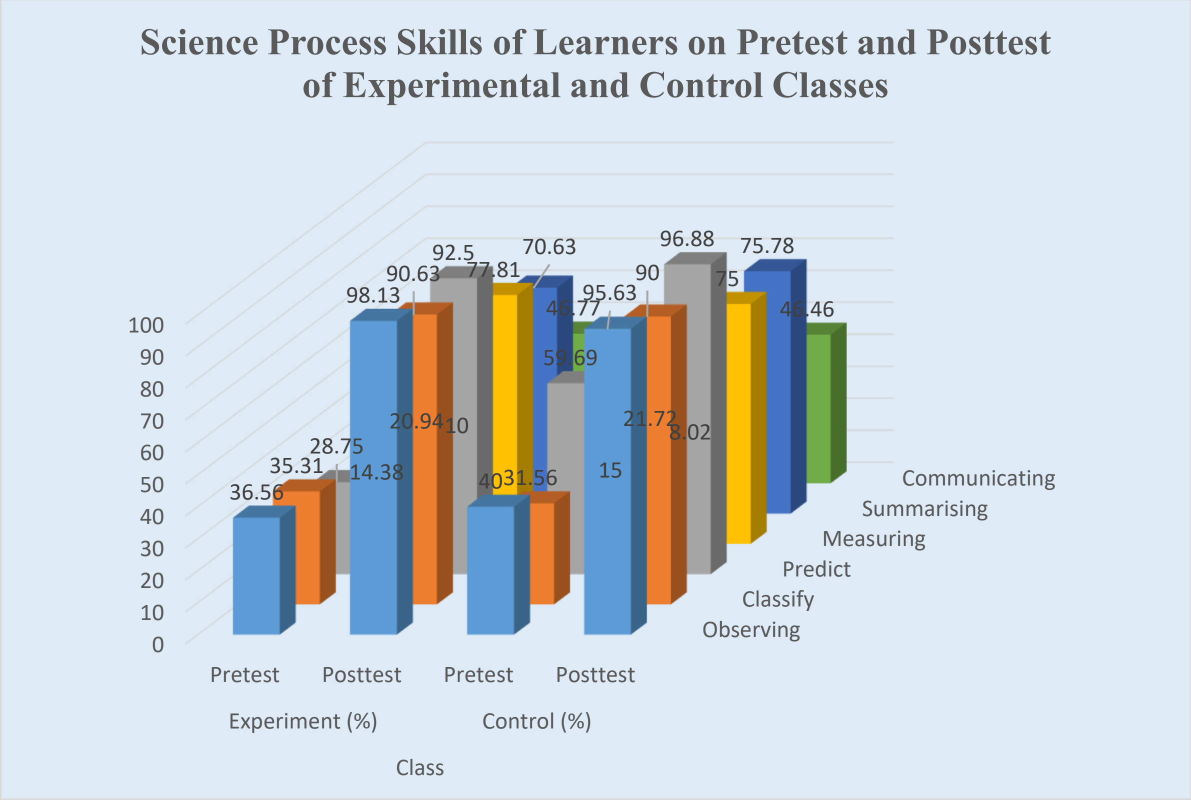
The value of the results of the pretest and posttest of the classical science process skills

Experiment Class			Control Class		
Description	Pre-Test	Post Test	Description	Pre-Test	Post Test
Sample	32	32	Sample	32	32
Lowest Score	16	58	Lowest Score	17	56
Highest Score	25	96	Highest Score	30	90
Average Score	20.13	71.84	Average Score	22.88	72.34
Standard Deviation	1.99	7.95	Standard Deviation	2.91	7.87

The increase in posttest scores for both research classes, particularly the experimental class's average score, is a strong signal that the intervention or learning approach used may have a favorable effect on students' capacity for science thinking. This finding is confirmed by statistical test results, specifically a *t*-test, which demonstrates considerable progress (p-value < 0.05) and indicates that the intervention was successful in enhancing students' capacity to think scientifically. The increase in posttest scores in both courses demonstrates that students in both the experimental and control classes improved after the intervention. The rise in scores following treatment in both classrooms demonstrates that both discovery learning (control class) and problem-based learning (experimental class) have a favorable effect on average student scores. Despite the increase in both groups, the control class's mean score (72.34) was greater than the experimental class's (71.84). This might imply that, in this unique situation, discovery learning outperformed problem-based learning in improving students' test results. This nuanced finding prompts a deeper analysis of why discovery learning might unexpectedly outperform PBL in certain metrics, which could be explored further in subsequent research.

Figure 2

Science process skills measurement results



The findings revealed that using problem-based learning (experimental class) and discovery learning (control class) models improved students' science process abilities in the context of studying salt hydrolysis.

This suggests that using problem-based learning to improve students' understanding and abilities in the context of salt hydrolysis may be more beneficial (QomariYah, 2019). The improvement in each criterion demonstrates that the applied learning approach was successful in enhancing students' science process abilities (Simamora et al., 2018). However, further research may be undertaken to understand better the precise components that contribute to the effectiveness of each learning model and the amount to which such variances may alter learning outcomes.

Table 4

Effect size of science process skills indicators for experimental and control class learners

	Experiment Class		Control Class	
Science Process Skills Indicators	Effect Size	Category	Effect Size	Category
Observing	7.00	Very large	5.56	Very large
Classifying	4.65	Very large	5.22	Very large
Predicting	7.01	Very large	2.82	Very large
Measuring	6.22	Very large	4.53	Very large
Concluding	5.40	Very large	5.35	Very large
Communicating	2.66	Very large	3.25	Very large

The findings revealed that using learning models in both experimental (problem-based learning) and control (discovery learning) classrooms had a significant impact on all markers of science process abilities. Further analysis found an intriguing contrast between the two groups, revealing the influence of each learning model as assessed by the effect size for each indicator. Both problem-based learning and discovery learning have a considerable positive influence on learners' science process abilities. The effect sizes observed in this study were consistently classified as very large, indicating meaningful practical significance in the classroom. For example, the very large effect size for observing suggests that students improved substantially in making detailed observations, a skill essential for conducting scientific investigations and experiments. Such improvements are likely to enhance students' overall scientific reasoning and problem-solving abilities in real-world contexts.

Table 5

The value of the results of the pretest and posttest of the classical science process skills

Parameters	Class	
	Experiment	Control
M Pretest	20,13	22,88
M Posttest	71,84	72,34
Std. Deviation Pretest	1,996	2,915
Std. Deviation Posttest	7,956	7,872
Effect Size (d)	8,92	8,33
Criteria	Very large	Very large

The traditional data analysis indicates that the effect of using a problem-based learning strategy to increase students' science process abilities in salt hydrolysis material is extremely substantial. The same thing happened in the control class, which used the discovery learning approach and had a significant impact on strengthening students' science process abilities on salt hydrolysis. Traditionally, the discovery learning approach has been used to encourage active participation, conceptual understanding, and inquiry-based exploration in science subjects, including chemistry. However, the experimental class had a larger effect size than the control class, suggesting that, compared to the discovery learning model, the problem-based learning approach is more effective at enhancing students' science process abilities for the salt hydrolysis material.

Table 6

Dimensions of metacognition awareness level of experimental and control classes

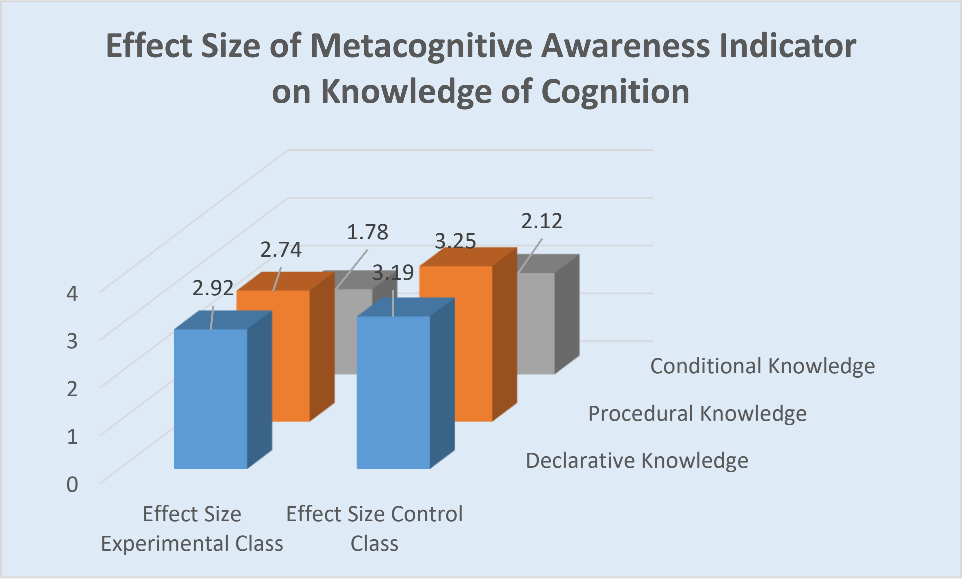
Metacognitive Awareness Indicator	Experiment Class				Control Class			
	Pretest		Posttest		Pretest		Posttest	
	Score (%)	Category	Score (%)	Category	Score (%)	Category	Score (%)	Category
Knowledge of Cognition								
Declarative Knowledge	55.18	Sufficient	79.69	High	56,93	Sufficient	79,20	High
Procedural Knowledge	56.35	Sufficient	77.93	High	56,25	Sufficient	78,71	High
Conditional Knowledge	52.81	Low	72.03	High	55,47	Sufficient	74,84	High

Average	54.78	Low	76.55	High	56,22	Sufficient	77,58	High
Regulation of Cognition								
Planning	52,79	Low	72,66	High	53,01	Low	74,11	High
Information management strategies	54,06	Low	80,70	Very High	54,69	Low	80,08	Very High
Stabilisation of understanding	52,23	Low	76,00	High	53,79	Low	76,00	High
Improvement strategy	48,28	Low	80,47	Very High	50,00	Low	77,19	High
Evaluation	53,52	Low	77,31	High	54,82	Low	80,86	Very High
Average	52,18	Low	77,02	High	53,26	Low	77,65	High
Average Metacognitive Awareness	53,48	Low	76,79	High	54,74	Low	77,62	High

To see the effect size of students' metacognition awareness, calculate the effect size for each indicator. The effect size for metacognition awareness for each indicator is shown in Figure 2.

Figure 4

Effect size of indicators of metacognition awareness of experimental class and control class learners on cognition regulation



The findings revealed that using the learning model in both the experimental (problem-based learning) and the control (discovery learning) classes had a significant impact on all indices of metacognitive awareness. The problem-based learning approach has a significant impact on metacognition awareness, particularly the component of knowing about cognitive processes. The declarative knowledge indicator has the maximum impact size value of 2.92 in the dimension of knowledge about cognition. The indicator of stability of understanding had the maximum impact size value of 4.78 in the dimension of control of cognition. The discovery learning approach has a significant impact on all aspects and measures of metacognition awareness. The indicator of procedural knowledge has the maximum impact size value of 3.25 in the dimension of knowledge about cognition. The indicator of repair method has the largest impact size in the cognitive control dimension, at 5.83. On the metacognition awareness indicator, the control class showed a larger effect size than the experimental class. Discovery learning appears to have a greater influence on metacognition awareness than problem-based learning in this scenario.

Table 7

Hypothesis testing results of the relationship between science process skills and metacognition awareness

Variables	N	Sig (2-tailed)	Pearson Correlation
Science Process Skills	32	0,003	0,505
Metacognitive Awareness	32	0,004	0,506

The correlation analysis findings show a significance value of $p = 0.003$, which is below the 0.05 threshold, indicating a statistically significant relationship between science process abilities and metacognition awareness. The correlation coefficient ($r = 0.50$) explains approximately 25% of the variance shared between the two variables, suggesting that other factors account for the remaining variation. This association does not imply any direction of causality, but rather that students with higher levels of one tend also to have higher levels of the other.

Discussion

The problem-based learning (PBL) methodology is particularly appropriate for salt hydrolysis content because it encourages learners to become adept at addressing real-world situations (Zinsli, 2021). The PBL paradigm, for example, allows learners to actively engage in problem solving and grasp ideas in detail by answering questions such as "How do I know the nature of salt?" or "Why can salt lower the pH of the soil?" The PBL model is appropriate for salt hydrolysis material because it emphasizes solving real-world issues, such as investigating the effects of using fertilizers as a source of plant nutrients and the effects of salt decomposition on soil pH. This provides learners with a relevant context and makes learning more engaging (Kizilcec et al., 2017). Following the introduction of the PBL paradigm, observations revealed that learners' activities and interactions increased. This strategy allows for conversation, cooperation, and concept development, enhancing learners' interest in learning. The teacher's role is diminished in PBL, as students are encouraged to solve their own problems (Phungsuk et al., 2017). The instructor serves as a facilitator, directing and supporting the learning process. This allows students to improve their independence and problem-solving abilities (Robinson & Persky, 2020). PBL enables students to identify and solve issues on their own or in groups. This technique can help them connect theory to practical applications, such as salt hydrolysis. The relationship between PBL and students' increased engagement and understanding of salt hydrolysis material highlights the importance of problem-based learning approaches in science education. By guiding students to actively engage in solving real-world problems, PBL not only enhances conceptual understanding but also prepares students to apply their knowledge in real-life situations. This aligns with constructivist theory, where students build their understanding through interaction with the real world and through hands-on experiences.

The use of problem-based learning (PBL) in teaching salt hydrolysis has several notable benefits. The PBL paradigm begins with learners being introduced to the provided challenge. In this setting, the teacher poses a pertinent problem and encourages students to consider the nature of the salt produced by the neutralisation reaction. This technique gives learners a meaningful context and a clear aim (Roach et al., 2018). Learners may observe, identify required resources, and design problem-solving solutions.

Problem orientation is the first stage in adopting the problem-based learning (PBL) approach to salt hydrolysis material. This stage includes numerous critical goals, including assessing learners' understanding of required content and establishing challenging scenarios that might entice and inspire them to engage in investigative activities. The problem-orientation stage allows the instructor to assess learners' mastery of key preparatory information. This helps determine their initial level of comprehension before engaging with the salt hydrolysis content. The instructor creates a troublesome scenario by presenting an issue related to the nature of the salt produced by the neutralisation process. This boosts learners' attention and motivation. The challenge provides a real-world setting that can serve as a focus for study and problem-solving. Learners are encouraged to participate actively in observation. They can learn about the nature of salt solutions formed when acids and bases are combined by seeing them. The initial stage in acquiring and improving science process abilities is observation. Observation skills are not only important for understanding the nature of salt solutions, but they also serve as a springboard for the development of future science process skills.

Learners can improve analytical skills, data interpretation, and scientific judgment by witnessing events or experiments. As a result, the issue orientation step of PBL lays the groundwork for deep learning. It not only gives an early review of learners' learning, but it also increases their interest and motivation by presenting difficult problems from everyday life. Furthermore, learners' participation in observation allows for the development of critical scientific process abilities. The significant correlation between metacognitive awareness and science process skills in the experimental class suggests that PBL not only enhances conceptual understanding but also promotes metacognitive development. Metacognitive awareness enables students to plan, monitor, and evaluate their learning processes, thereby strengthening their abilities in scientific processes such as observation, data interpretation, and decision-making. The important implication of this finding is that integrating metacognitive exercises into the science curriculum can further enhance students' science process skills, which are crucial for their success in scientific fields.

Observation is an important part of problem-based learning (PBL). Learners are expected to engage in assessing what they know and recognizing their needs from the start to progress to the next stage of learning. In this case, observation is accomplished by asking questions about instances of salt compounds encountered in ordinary life. Learners are invited to think about and respond to questions concerning real-life examples of salt compounds. Learners' initial understanding of salt compounds is reflected in their responses, which include noting table salt ($NaCl$), NH_4Cl, and CH_3COONa. The instructor then randomly divides the class into groups. This group divide can encourage learners to collaborate, improve their learning through cooperation, and spark different viewpoints that can be used in issue-solving. A Learner Worksheet (LKPD) is distributed to each group, which acts as a problem or job to be completed during problem-based learning. The LKPD becomes the focal point of group activity to study further and address the difficulties presented. For learners to build problem-solving techniques, LKPD serves as a guide or starting point. Learners are required to plan the following steps, beginning with more observations and experiments and ending with the creation of solutions, by comprehending the issues specified in the LKPD. Learners actively participate in the observation and inquiry stages by responding to the questions and focusing on the LKPD. This offers a learner-centered environment where learners can build their own knowledge and problem-solving skills. Learners can also supplement one another's knowledge and expertise by working in groups.

In the second level of the problem-based learning (PBL) approach, learners are organized to learn actively and cooperatively. This stage aims to encourage students to seek information from diverse sources regarding the difficulties identified in the first phase. Learners are tasked with locating information about the highlighted problem. Textbooks, scientific journals, internet sources, and related experiments can all be used to get information. Learners are encouraged to take an active role in researching a wide range of relevant sources of knowledge. Although PBL has proven effective in enhancing understanding and science process skills, this study's methodology has certain limitations. For instance, the non-randomisation of groups in this study may introduce selection bias, potentially affecting the internal validity of the results. Additionally, external variables such as differences in teacher quality or student motivation, which were not controlled, may influence the outcomes. A critical reflection on these limitations is important for informing the interpretation of the results and the design of future studies.

Conducting individual or group investigations is the third phase in the problem-based learning (PBL) methodology. At this step, learners are tasked with planning and conducting an inquiry to test a previously formulated hypothesis. The use of the PBL approach helps students to identify solutions to challenges on their own. Teachers may monitor learners' capacity to identify, test, and record the outcomes of experiments in this setting, which are signs of success in scientific inquiry (Orhan Göksün & Gürsoy, 2019). Based on these findings, it is possible to infer that using the PBL paradigm effectively inspires learners to actively participate in the study while also developing their scientific and analytical skills.

The fourth phase of the problem-based learning (PBL) methodology is to create and showcase learners' work. At this step, students collaborate in groups to present their research findings and solutions. Data interpretation and communication skills are two parts of the science process abilities that are gained at this level. By the end of this level, learners have mastered not only data interpretation and communication skills but also the process of generating scientific findings and presenting information effectively. During this stage, the PBL approach assists learners in connecting their newly acquired knowledge and abilities to real-world situations by linking theoretical concepts with practical applications through tangible presentations (Ballesteros et al., 2019). Given the findings that discovery learning has shown superiority in certain aspects over PBL, future research could focus on the specific conditions under which each teaching method excels. For instance, comparative studies investigating how learning context, student characteristics, or the type of learning content influence the effectiveness of PBL and discovery learning could provide educators with further insights for selecting appropriate teaching strategies for specific situations.

The fifth phase in the problem-based learning (PBL) paradigm includes learners analysing and assessing their problem-solving process. At this step, learners provide feedback on other groups' work to determine each group's strengths and weaknesses. After receiving feedback and development ideas from the teacher and other groups, learners determine the best problem-solving strategy to use. Communication abilities are among the science process skills gained at this level. This level promotes interpersonal communication skills, the capacity to provide and receive constructive criticism, and the ability to think critically about ideas and solutions presented by other groups by integrating learners in peer review (Vong & Kaewurai, 2017). It also promotes a reflective mindset, which can help learners consistently improve their quality. The practical implications of these findings are significant for educators seeking to implement PBL in science teaching. Teachers can apply PBL to enhance student engagement and develop their science process skills by providing relevant contexts and encouraging active exploration. Challenges that may arise include the need for additional teacher training to adopt the role of facilitator, as well as the need to design PBL tasks that genuinely reflect real-world problems. However, the benefits of deep learning and the development of critical thinking and problem-solving skills make PBL a valuable approach in science education.

The findings of the experimental class's pretest and posttest, which showed an improvement in average score from 20.13 (pretest) to 71.84 (posttest), demonstrated the usefulness of the problem-based learning (PBL) learning model in boosting students' comprehension and knowledge. Some of the contributing variables highlighted in the description are: The adoption of the PBL model through defined stages lays the groundwork for learners to be actively involved in the learning process. PBL encourages learners to engage in exploration and problem-solving rather than simply receiving knowledge passively (Y. Liu & Pásztor, 2022).

The teacher's straightforward presentation of the idea of salt hydrolysis, supplemented by instructional resources in the form of LKPD and modules, provides students with clear direction and a solid framework for understanding. Teachers employ LKPD and modules built on the PBL paradigm, which provide practical, meaningful contexts for salt hydrolysis. The first meeting's observation and problem-solving exercises on the nature of salt provide an introduction to the notion of acid-base solutions as necessary material. This helps learners connect known concepts to the new content they are learning. The instructor employs a contextual learning strategy by connecting the information to real-life circumstances. However, further research might focus on the longitudinal effects of PBL on students' learning outcomes. It would be beneficial to investigate how sustained use of PBL impacts students' ability to apply scientific concepts over time, particularly in different learning environments or across diverse student populations.

According to the results of the study in Table 7, there was a high link between science process abilities and students' metacognition awareness in the experimental class that used the problem-based learning paradigm. That is, there is a strong positive association between the experimental class's level of metacognition awareness and science process abilities. This suggests that learners with a high level of metacognitive awareness also have stronger science process abilities. In other words, excellent metacognitive awareness can aid in the development of scientific process abilities. Meanwhile, the Pearson correlation coefficient was 0.505 in the control class using the discovery learning model. According to the correlation test criteria in Table 7, this result indicates a strong association between science process abilities and students’ metacognition awareness in the control class. Although not as strong as in the experimental class, the control class shows a substantial positive relationship between metacognition awareness and students' science process abilities. As a result, it is possible to conclude that there is a favourable relationship between metacognitive awareness and students' science process abilities in both experimental and control classrooms. However, the experimental class showed a stronger correlation than the control class, suggesting that the problem-based learning paradigm has the potential to strengthen the link between the two variables. The findings suggest that educators might consider integrating more metacognitive strategies into their PBL approaches to enhance students' science process skills further. This could include activities that promote self-reflection, goal-setting, and self-assessment, helping students become more aware of their own learning processes and develop stronger scientific inquiry skills.

Conclusion

Several significant themes may be drawn from the study and discussion outcomes. The use of the problem-based learning (PBL) paradigm improves students' science process skills in the context of salt hydrolysis. This is evident in the extremely large effect sizes for both the experimental (8.92) and control (8.33) classes. This suggests that PBL can significantly improve students' abilities in the scientific process. The use of a problem-based learning strategy improves students' metacognition awareness of salt hydrolysis information. The experimental class had an effect size of 5.56 (very big), whereas the control class had an effect size of 6.46 (extremely large). This demonstrates that using PBL may dramatically increase students' metacognition awareness. On salt hydrolysis material, there is a positive association between science process abilities and students' metacognition awareness. The Pearson correlation coefficient of 0.772 in the experimental class indicates a substantial relationship between the two variables. In the control class, the Pearson correlation coefficient of 0.505 indicates a moderate relationship, accounting for approximately 25% of the shared variance, with the remainder attributable to other factors. This suggests that pupils with strong science process abilities have more metacognition awareness, and vice versa. Thus, the findings revealed that using a problem-based learning approach not only had a good influence on students' science process abilities and metacognition awareness, but also demonstrated a positive association between the two variables.

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