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Research Artikel

ANALYSIS OF THE LOW EFFECTIVENESS OF THE CROCODILE CHEMISTRY LAB-ASSISTED PBL MODEL ON STUDENTS' PROBLEM-SOLVING ABILITIES AND SCIENTIFIC ATTITUDES

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Abstract

This study aims to analyze the effect of the Problem Based Learning (PBL) model assisted by the Crocodile Chemistry Lab (CCL) on students' problem-solving abilities and scientific attitudes in thermochemistry of materials. The research design used is quasi-experimental with a pretest–posttest control group pattern. The research instruments include a problem-solving ability test and a scientific attitude questionnaire that has been expert and empirically validated. The data were analyzed using MANOVA and followed by univariate tests. The research results indicate that the PBL-CCL model has a significant impact on students' problem-solving abilities and scientific attitudes. However, the relatively low partial eta squared values (3.7% and 5.7%) indicate that the model's contribution to the improvement of both variables is still in the small category. Further analysis indicates that the effectiveness of implementation is influenced by students' readiness to learn, variations in motivation, the less-than-optimal implementation of PBL syntax, limitations in equipment facilities, and students' preference for real experiments over digital simulations. This finding confirms that integrating PBL with virtual laboratories has positive potential, but its success is highly influenced by the overall readiness of the learning ecosystem.

***Keywords**: Crocodile chemistry lab, effectiveness, problem-based learning, problem-solving skills, and scientific attitude*

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INTRODUCTION

The increasingly rapid development of technology has become a major driver of change in various aspects of human life, including education (Indarta *et al*., 2022). *The Society 5.0* era , characterized by the use of cutting-edge technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and robotics, requires humans to develop their knowledge and skills creatively and adaptively (Leelavathi & Manjunath, 2024; Saude *et al*., 2022). In the context of education, this era demands strengthening of students' soft and hard skills, such as creativity, collaboration, digital literacy, and social responsibility (Grahito, 2020 ; Putriani & Hudaidah, 2021). Therefore, the learning process must be able to build the ability to think, act, and live adaptively to the development of the times and technology (Rusman *et al*., 2023; Naraidoo *et al*., 2024).

One of the key competencies essential for facing 21st-century challenges is problem-solving ability. This ability not only serves to understand academic concepts but also serves as a foundation for dealing with complex real-world problems (Dori & Lavi, 2023 ; Putra & Suparman, 2020). Government Regulation Number 4 of 2022 emphasizes the importance of developing critical thinking, problem-solving, and creativity as competency standards for education graduates. Therefore, chemistry learning needs to be directed toward developing problem-solving skills and a scientific attitude so that students are able to think systematically, analytically, and evidence-based (Lu & Xie, 2024 ; Ocak *et al*., 2021).

In the context of chemistry learning, the Problem Based Learning (PBL) model is known to be effective in improving problem-solving skills because it actively involves students in analysing and finding solutions to contextual problems (Torp & Sage, 2002; Li & Xu, 2021) . PBL also has the potential to foster scientific attitudes such as curiosity, openness to evidence, and scientific responsibility (Fitriani *et al*., 2020). However, the implementation of PBL in the classroom still faces obstacles, especially in terms of time, student readiness, and the ability of teachers to manage the PBL phases optimally (Ngatijo *et al*., 2019; Kartamiharja *et al* ., 2020; Wayan & Hamid, 2022). To support its effectiveness, the use of technology such as the Crocodile Chemistry Lab is an innovative alternative in modern chemistry learning. This medium allows students to virtually explore chemical concepts, manipulate variables, and analyse simulation results like real experiments (Penn & Ramnarain, 2019; Hayuwardini & Mulyani, 2022).

Thermochemistry is a topic that requires in-depth conceptual understanding and analytical thinking skills. Many students struggle to understand the relationship between energy changes and chemical reactions, distinguish between systems and their surroundings, and interpret energy diagrams (Drysdale, 2016 ; Sri & Suyanta, 2024). Therefore, implementing the PBL model with the help of the Crocodile Chemistry Lab is helpful in improving students' problem-solving skills and scientific attitudes in learning this material.

Although various studies have shown that the application of the Problem Based Learning (PBL) model has the potential to improve students' critical thinking skills and scientific attitudes, the effectiveness of this model in real-life learning contexts does not always show optimal results. In this study, learning effectiveness is understood operationally as the magnitude of the influence of the Crocodile Chemistry Lab -assisted PBL model on students' problem-solving skills and scientific attitudes. The analysis results show that although there are significant differences between the experimental and control classes, the effect size values obtained are still relatively low, indicating that the learning model's contribution to improving these two abilities is not yet strong. This condition reflects a gap between theoretical expectations regarding the advantages of PBL and the reality of its implementation in the classroom. This phenomenon is important to study further to identify factors that have the potential to cause the low effectiveness of virtual simulation-assisted PBL in chemistry learning, especially in thermochemistry materials that have conceptual characteristics and a high level of abstraction. Therefore, this article aims to critically analyse the factors that influence the low effectiveness of the Crocodile Chemistry Lab -assisted PBL model based on empirical findings and relevant theoretical studies.

METHOD

The research that forms the basis of the analysis in this article used a quasi-experimental pretest–post-test control group design. The study involved two groups: an experimental group that received Problem Based Learning (PBL) instruction assisted by the Crocodile Chemistry Lab simulation and a control group that learned using a scientific approach (5M). The intervention was carried out on thermochemistry material over a one-month learning period.

This research was conducted at SMA Negeri 1 Doro, Pekalongan Regency, in the 2025/2026 academic year. The study population included all eleventh-grade students in public senior high schools throughout Pekalongan Regency. From this population, a sample of eleventh-grade students at SMA Negeri 1 Doro was selected using a simple random sampling technique. The sample consisted of four classes: two experimental classes (XI F1 and XI F5) and two control classes (XI F2 and XI F6), with a total of 144 students.

The instruments used included a descriptive problem-solving ability test and a Likert-scale scientific attitude questionnaire. Both have undergone expert validation and empirical validity testing and demonstrated adequate reliability with a Cronbach's Alpha coefficient > 0.70. The test and questionnaire were administered before and after the learning process to measure students' problem-solving abilities and scientific attitudes. Furthermore, to strengthen the quantitative data, this study also included semi-structured interviews with several students from the experimental class who were selected purposively. The interviews were conducted to confirm the results of the scientific attitude questionnaire and to explore students' learning experiences, level of engagement in problem-based learning, perceptions of the use of the Crocodile Chemistry Lab, and obstacles encountered during the learning process.

Data were analyzed using MANOVA to test for differences between groups, followed by calculating *the effect size* (η^2) to determine the magnitude of the impact of the implementation of PBL assisted by digital simulations. These results serve as the basis for further examining why the effectiveness obtained was relatively low, as well as what factors might influence it in the context of chemistry learning in schools.

The effectiveness of learning in this study was operationalized as the effect size of the application of the PBL model assisted by Crocodile Chemistry Lab on students' problem-solving abilities and scientific attitudes. Effectiveness was measured using the Partial Eta Squared (η^2) value obtained from the results of MANOVA analysis and univariate tests. Low effectiveness in this study refers to the effect size value, which is in the small category, although statistically there is a significant difference between the experimental and control groups.

Information regarding factors influencing the effectiveness of Crocodile Chemistry Lab -assisted PBL implementation is not treated as an independent variable measured quantitatively but rather obtained through reflective analysis and data triangulation. This analysis is based on test and questionnaire results as primary data, and is supported by interview results, observations of the learning process, and teachers' reflective notes. This supporting data is used to provide a contextual understanding of learning conditions that have the potential to limit the optimization of PBL implementation assisted by digital simulations.

RESULTS AND DISCUSSION

Manova Analysis

MANOVA analysis was conducted to determine the differences in problem-solving ability and scientific attitude simultaneously. The test results showed that the Hotelling's Trace value was p = 0.004 (<0.05), which means there was a significant difference between the experimental and control classes. Another multivariate test. Further univariate analysis showed that both problem-solving ability (F = 5.381; p = 0.022) and scientific attitude (F = 8.538; p = 0.004) were significantly different between the two classes.

Table 1. Multivariate Test Results

No	Types of Multivariate Analysis	*Sig.*	*Partial Eta Squared*
1	*Wilks' Lambda*	0.004	0.076
2	*Hotelling's Trace*	0.004	0.076
3	*Roy's Largest Root*	0.004	0.076

The Partial Eta Squared value showed an effect contribution (effective contribution) of 0.037 for problem-solving ability and 0.057 for scientific attitude, which were included in the low to moderate category.

Table 2. Univariate Test Results

Dependent Variable		Mean Square	F	Sig.	Partial Eta Squared
Ability Solution Problem	Contrast	1743.06	5.38	.022	.037
	Error	323.95			
Attitude Scientific	Contrast	1613.36	8.53	.004	.057
	Error	188.96			

The results of MANOVA analysis and univariate tests indicate that the implementation of the Problem Based Learning (PBL) model assisted by Crocodile Chemistry Lab (CCL) has a significant influence on students' problem-solving abilities and scientific attitudes. However, the relatively low partial eta squared values, namely 0.037 (3.7%) for problem-solving abilities and 0.057 (5.7%) for scientific attitudes, indicate that the model's contribution to improving both variables is still limited. Therefore, further analysis was conducted to examine the factors that influence the level of effectiveness of PBL–CCL implementation. This analysis was conducted in a reflective-interpretive manner by linking quantitative findings (test and questionnaire results) with supporting data in the form of semi-structured interviews with students, observations of the learning process, and teachers' reflective notes during the implementation of learning. The results of the analysis indicate that the low effectiveness of PBL–CCL is mainly influenced by limited learning readiness and student independence, variations in motivation and level of involvement in problem-based discussions, technical constraints and time allocation for using simulations, and some students' preferences for real experiments over virtual simulations.

Independence and readiness to learn as the main determinants of PBL effectiveness

PBL demands self-directed learning skills, including strategic management, decision-making, and independent analysis. However, some students have not yet demonstrated readiness to engage in learning that demands high levels of autonomy. They are more familiar with structured learning patterns that are heavily directed by the teacher, as in the control class. This unpreparedness results in a reliance on exploration and discussion activities, directly impacting the low effectiveness of PBL's core syntax. This condition is consistent with studies by Suyanta *et al*., (2019) and Sundari & Rahmawati (2022), which emphasize that the success of PBL rests on students' cognitive readiness and self-regulation.

Variability of motivation and interest that influences the depth of involvement

Learning motivation is an important variable in problem-based learning. This study shows that students with high motivation can actively participate in problem formulation and solution evaluation, while students with low motivation tend to be passive and simply follow the flow of group discussions. This variability results in heterogeneity in participation levels, which in turn affects overall group performance. These results align with a meta-analysis by Wijnia *et al*., (2024), which showed that the effect of PBL on motivation tends to be small to moderate, so that variations in motivation have the potential to limit learning outcomes.

Implementation of learning that is not fully in accordance with the design

The effectiveness of PBL depends on the successful implementation of the entire syntax, especially the exploration and analysis stages. In the field, learning interventions are not optimally implemented because some time is spent providing tutorials on how to use the Crocodile Chemistry Lab. As a result, the time available to evaluate simulation results is limited. This imbalance in time allocation hinders conceptual deepening, which should be a key strength of PBL–CCL. Chan *et al*., (2021) reported that technical constraints in using virtual laboratories often affect the quality of learning implementation, especially because teachers and students need a considerable amount of adaptation time.

Limited facilities limit the intensity of interaction with simulation media

The use of virtual laboratories requires adequate equipment to ensure all students receive an equal exploration experience. Limited equipment and projectors result in alternating media use, resulting in uneven interaction with the simulation. This situation limits the development of students' analytical skills because they are not fully engaged in the simulation-based exploration process, which should be a key feature of CCL.

Preference for real experiments influences students' perceptions of digital simulations.

Research findings also indicate that some students prefer real-world experiments over simulations. The perception that hands-on experiments are more "real," "textural," and "concrete" influences students' enthusiasm levels during CCL-based activities. As one student expressed,

"I can't visualize the chemical reactions through simulations. It's much easier to practice directly in the lab" (SW/07/30/2025).

This preference suggests that CCL is positioned as an alternative medium, rather than a primary medium, thus suboptimal student engagement. This perception can limit the effectiveness of simulations, especially on materials considered more “experiment centric.”

Overall, the findings of this study confirm that the implementation of PBL–CCL has a positive and significant impact on students' problem-solving abilities and scientific attitudes, although the magnitude of the contribution is still relatively low. This indicates that innovative learning models such as PBL combined with digital simulations have pedagogical potential, but their performance is strongly influenced by students' internal readiness. Unpoetically developed learning independence, variations in motivation, and uneven self-regulation skills result in students being unable to maximize the exploration, analysis, and evaluation stages that are the core of PBL. These conditions demonstrate that the success of PBL rests not only on innovative learning designs, but also on students' cognitive and affective readiness to engage actively and independently.

In addition to internal factors, the effectiveness of PBL–CCL is also influenced by technical and structural aspects during implementation. Adapting to the use of the Crocodile Chemistry Lab virtual laboratory requires sufficient time and guidance, resulting in some learning time being absorbed by the technical process rather than deepening the concepts. Limited equipment and projection facilities make student interaction with the simulation uneven, resulting in only a portion of students gaining in-depth exploration experiences. This unevenness has the potential to reduce the effectiveness of the use of simulation media, particularly in thermochemistry materials that require a strong conceptual understanding and opportunities for independent experimentation through digital visualization.

Beyond technical factors, students' preference for real-world experiments is also an important consideration in integrating digital simulations into chemistry learning. Some students still view hands-on experiments as a more concrete and credible method than simulations, resulting in a lack of optimal enthusiasm for digital media. This suggests that technology acceptance in chemistry learning is determined not only by media quality but also by prior perceptions and learning experiences. Therefore, adaptive strategies are needed to integrate PBL–CCL, such as providing a more systematic orientation, improving facility support, and fostering the habit of using simulations so that students can develop positive perceptions of digital media. These efforts are expected to strengthen the impact of PBL–CCL on future learning outcomes.

CONCLUSION

The results of the study indicate that the application of the Problem Based Learning (PBL) model assisted by the Crocodile Chemistry Lab (CCL) provides a statistically significant difference in students' problem-solving abilities and scientific attitudes compared to conventional learning. In this study, learning effectiveness is defined as the magnitude of the learning model's contribution to improving problem-solving abilities and scientific attitudes, which is measured through the effect size value (partial eta squared).

Partial eta squared values of 0.037 for problem-solving ability and 0.057 for scientific attitude indicate that there was indeed an improvement, but the model's contribution to this improvement was still relatively small. Thus, PBL assisted by Crocodile Chemistry Lab can be declared statistically effective, but not yet practically effective in providing a strong impact on improving these two abilities.

Further analysis shows that this low effectiveness is influenced by several factors. Internal student factors, such as learning independence and varying motivations, limit optimal engagement in PBL syntax. Furthermore, implementation constraints, particularly uneven time allocation and the need to adapt to the use of the Crocodile Chemistry Lab, also hinder conceptual depth. Limited school facilities and students' preference for real-world experiments also weaken the role of digital simulations in facilitating the learning process.

Overall, these findings indicate that while the integration of PBL and Crocodile Chemistry Lab has the potential to support thermochemistry learning, its effectiveness is not yet strong due to the influence of pedagogical, technical, and student characteristics. PBL assisted by digital simulations requires more mature implementation conditions to function as a truly optimal learning approach in improving students' problem-solving abilities and scientific attitudes.

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