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Improving Chemical Literacy Ability and Self Efficacy through Context Based Approach with Prediction-Observation-Explanation Strategy

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Abstract: This study addresses the low levels of chemical literacy and student self-efficacy by implementing a context-based learning approach using the Prediction–Observation–Explanation (POE) strategy. The research aimed to assess the differences and effective contributions of chemical literacy and self-efficacy before and after the intervention, and to compare students taught with the POE-based approach versus those using a scientific approach. A quantitative method was used with a quasi-experimental design, including both dependent pre-test and post-test without a control group, and independent pre-test and post-test with a control group. The sample consisted of four randomly selected 11th-grade classes. Instruments included 10 chemical literacy pre-test items, 9 post-test items, and 23 self-efficacy questionnaire items focused on the Thermochemistry unit. Data were analyzed using Paired Sample T-tests and Independent Sample T-tests. Results showed a significant improvement in chemical literacy after implementing the POE strategy, confirming its effectiveness in enhancing conceptual understanding. However, student self-efficacy did not show a statistically significant change, although a slight positive trend was observed. The study concludes that while the POE strategy effectively enhances chemical literacy, it is insufficient for improving self-efficacy, suggesting the need for more sensitive measurement tools and additional strategies to support affective learning outcomes.

Keywords: Chemical Literacy; Context-Based Learning; Predict-Observe-Explain; Scientific Approach; Self Efficacy; Thermochemistry.

Introduction

Education plays a crucial role in shaping high-quality human resources capable of competing in the global era (Zurqoni, Retnawati, Arlinwibowo & Apino, 2018; Alifah, 2021). However, data from the Education Rankings by Country 2021 and UNESCO's Global Education Monitoring (GEM) 2016 indicate that Indonesia's education quality remains relatively low compared to other nations. Disparities in educational facilities and quality, particularly in rural areas, exacerbate this issue (Alifah, 2021). Teachers, as the frontline agents of education, are responsible for enhancing students' understanding and analytical skills (Utami & Vioreza, 2020; Budiariawan, 2019). Unfortunately, learning practices still rely heavily on textbooks and rote memorization (Antara, 2022), despite the Ministry of Education and Culture Regulation No. 22 of 2016 emphasizing the importance of contextual, interactive, and engaging learning experiences (Rianawaty, Suyata, Dwingrum & Yanto, 2021; Marzano

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& Marzano, 2003; Sausan, Saputro & Indriyanti, 2020; Sueb, Hashim, Hashim & Izam, 2020).

One topic that demands deep conceptual understanding is thermochemistry, which is rich in abstract concepts and real-life applications (Subagiyo, 2019; Hidayah, Lutfiana, Kurniawan & Ishma, 2021). However, instructional approaches often lack relevance to everyday contexts (Sausan et al., 2020), leading to high levels of misconception (Sihaloho, Kilo, Kilo & Hadis, 2020). To address this, thermochemistry instruction should be linked to real-world problems to improve conceptual comprehension (Purwanto, Rahmawati, Rahmayanti, Mardiah & Amalia, 2022). Chemical literacy, a primary goal of chemistry education (Muntholib, Ibnu, Rahayu, Fajaroh, Kusairi & Kuswandi, 2020), can be enhanced through context-based learning (Wiyarsi, Pratomo & Priyambodo, 2020), as it encompasses chemical content, contextual understanding, higher-order thinking skills, and affective dimensions (Shwartz, Ben-Zvi & Hofstein, 2006). Nevertheless, students' chemical literacy remains low (Sumarni, Sudarmin, Wiyanto, Rusilowati & Susilaningsih, 2017; Broman & Parchmann, 2014; Nurhayati, Nurhayati, Rahayu & Yahmin, 2017).

Alongside chemical literacy, self-efficacy serves as a crucial element for achieving academic success (Kartikasari & Idayani, 2022; Villafañe, Garcia & Lewis, 2014). Students with high self-efficacy tend to be more persistent and confident in completing tasks. However, self-efficacy is often overlooked in classroom instruction (Heriyani, Widiastuti & Altaf, 2022), even though varied learning experiences can foster active student participation (Hussin, 2018). Therefore, meaningful and contextual learning designs are essential not only for conceptual mastery but also for building students' belief in their own abilities.

Context-based learning is an effective method for connecting abstract concepts to students' real-life experiences (Baydere, 2021; Campbell, Lubben & Dlamini 2000; Gilbert, Bulte & PIlot 2011). It has been shown to increase student interest and understanding (Pilot & Bulte, 2006), although traditional lecture-based methods still dominate classroom practice (Qudsyi, Indriaty, Herawaty, Saifullah & Setiawan, 2011). To strengthen contextual learning, the Predict–Observe–Explain (POE) strategy can be employed, as it reduces misconceptions and enhances learning motivation (Özdemir, Bağ & Bilen, 2011; Fatisa & Galingging, 2021; Çalış & Özkan, 2022). POE encourages students to predict, observe, and explain scientific phenomena based on real-life experiences (Harta, Listyarini, Pamenang, Wijayanti & Lee, 2020; Baydere, 2021; Çalış & Özkan, 2022). Despite its potential, the integration of context-based learning and POE strategy remains underutilized, even though their combination could yield more meaningful and effective learning outcomes.

Given these challenges, this study aims to examine the effectiveness of integrating context-based learning with the POE strategy in improving students' chemical literacy and self-efficacy in thermochemistry. This research is significant due to the limited number of studies that explicitly combine both approaches within a single instructional design, despite their shared potential to create impactful and contextual learning experiences. Previous studies have tended to focus on either chemical literacy improvement through context-based learning or the effectiveness of POE in reducing misconceptions, without exploring their simultaneous contributions to both cognitive and affective domains. Therefore, this study seeks to offer a new perspective in developing instructional models that not only enhance conceptual understanding but also foster students' confidence in navigating chemistry learning challenges.

Method

This research is quantitative research, the type of research used is quasi experiment (pseudo experiment) with nonequivalent groups using two research designs, namely pre-test and post-test without control group design and pre-test and post-test with control group design (Khotari, 2004). Research designs can be shown in Table 1 and Table 2.

Table 1. Research design without control group

Group	Pre-test	Treatment	Post-test
Experiment	LK	CBA-POE	LK
	ED	(OP)	ED

Table 2. Research design with control group

Group	Pre-test	Treatment	Post-test	n-Gain
Experiment	LK	CBA-POE	LK	LK
	ED	(OP)	ED	ED
Control	LK	SA	LK	LK
	ED	(OP)	ED	ED

The school sampling technique is based on convenience sampling and class sampling with random sampling. This study was conducted during the odd semester of the 2023/2024 academic year at SMAN 1 Tempuling, Indragiri Hilir Regency, Riau Province, involving two groups: an experimental group and a control group, each consisting of two classes of 11th-grade students. The experimental group applied a context-based learning approach combined with the Predict–Observe–Explain (POE) strategy, while the control group used the scientific learning approach (5M), which is commonly implemented in schools.

In this study, two independent variables are examined: the Context-Based Approach (CBA) and the Prediction-Observation-Explanation (POE) strategy. The CBA is defined as a learning method that links contexts in a way that builds relationships, integrates new knowledge, and enhances conceptual understanding. It unfolds through four distinct phases: the Contact Phase, where context serves as the starting point for learning; the Curiosity/Planning Phase, in which context is applied to the concept; the Development Phase, where context illustrates the concept; and the Deepening and Connecting Phase, which is devoted to connecting various contexts and concepts. Meanwhile, the POE strategy is characterized as a student-centered learning approach that requires active participant engagement through three key stages: the Prediction Stage, where students make a guess; the Observation Stage, where they observe to validate their prediction; and the Explanation Stage, which involves explaining the connection between the initial guess and the observational outcomes.

The research instruments used were pre and post chemical literacy questions and self-efficacy questionnaires. Several previous studies on chemical literacy skills by Shwartz *et al.*, 2006; Thummathong & Thathong 2016; Sumarni *et al.*, 2017; Wiyarsi, *et al.*, 2020; dan Muntholib *et al.*, 2020 synthesized in this study. Aspects of self-efficacy were also synthesized from several previous studies, namely research Bandura, 1997; Fitriyana, Wiyarsi, Ikhsan, & Sugiyarto, 2020; Solikhin, 2020; Graham, Bohn-Gettler & Raigoza, 2019; dan Handayani & Louise, 2019. The results of the synthesis of chemical literacy and self-efficacy aspects are shown in Table 3.

Table 3. Aspects of chemical literacy and self-efficacy

Dependent Variable	Operational Definition of Variables	Aspect and Operational Definition of Aspects
Chemical Literacy	The ability to analyze thermochemical applications in everyday life phenomena and use their knowledge in connecting and interpreting the scientific information obtained.	Application in context: analyzing the application of thermochemistry in everyday life phenomena
		High Order Learning Skills (HOLS): connecting and interpreting scientific information into thermochemistry material
Self-Efficacy	A person's belief in managing his/her abilities towards motivation, persistence, confidence, task orientation and satisfactory performance results.	Intrinsic motivation: the encouragement that arises within a person to be interested and enthusiastic in learning
		Persistence: sincerity within oneself, consistency and tenacity to empower all existing potential
		Confidence: Confidence to succeed in learning goals, resolve various situations and face various pressures and failures
		Task orientation: ability to complete tasks and responsibilities
		Work results: have demonstrated achievements

Data collection instruments in the form of teaching modules, LKPD, observation sheets, questions and questionnaires. Validity analysis using the Rasch Model with the Exploratory Factor Analysis technique and the Kaiser Meyer Okin value, Reliability is done by looking at the Cronbach's Alpha and Item Rest Correlation values (Hair, Black, Babin, & Anderson, 2014).

Based on the validity and reliability test of the pre-chemical literacy question instrument that can be used in research, there are 10 items while the post-chemical literacy questions that can be used are 9 items. The self-efficacy questionnaire contains positive and negative statements based on aspects and indicators totaling 23 items with a collection technique using the Likert scale guideline, namely a five-point measurement scale (Türel, Özdemir, & Varol, 2017) can be shown in Table 4.

The data analysis technique used was the MANOVA, Before conducting MANOVA analysis, certain prerequisites must be met. However, one prerequisite was not fulfilled—the intercorrelation test among the dependent variables using Pearson Correlation, assessed by the r-value. The obtained r-value of -0.113 falls within the "very weak" category (Jabnabillah & Margina, 2022). This very weak correlation indicates that the MANOVA test cannot proceed; therefore, the appropriate analysis used is the T-test.

Table 4. Likert scale guidelines

Information	Statement Score	
	Positif	Negatif
Strongly agree	5	1
Agree	4	2
Undecided	3	3
Disagree	2	4
Strongly disagree	1	5

Paired Sample T-Test and Independent Sample T-Test (after fulfilling the test prerequisites, namely univariate outliers, univariate normality and univariate homogeneity) and the effective contribution was classified according to Cohen's d in Todorov, Searle-White, & gerber (2020) presented in Table 5.

Table 5. Effective contribution category of T-test

d	Category
0	No effect
0.2	Small
0.5	Medium
0.8	Large

The effective contribution is calculated manually, to calculate the effective contribution of the paired t test (same sample size) using Formula 1.

$$d = \frac{mean}{SD} \quad (1)$$

Based on (Ellis, 2010 dan Cumming, 2012) in the book Cohen, Manion, & Marrison (2018) to calculate the effective contribution of the independent t test with different sample sizes using the following formula:

$$d = \frac{mean\ of\ experimental\ group - mean\ of\ control\ group}{SD\ pooled} \quad (2)$$

Based on Cohen *et al*. (2018) calculation of the total standard deviation value using Formula 3.

$$SD\ pooled = \sqrt{\frac{(N_E-1).SD_E{}^2 + (N_C-1).SD_C{}^2}{N_E + N_C-2}} \quad (3)$$

Information:

N_E = number of experimental group samples
SD_E = standard deviation of experimental group
N_C = number of control group samples
SD_C = standard deviation of control group

Result and Discussion

The effect of the context-based approach with the prediction-observation-explanation strategy on chemical literacy

This study measured chemical literacy to determine the differences before and after the intervention.

Table 6. Paired Sample T-test Results on Chemical Literacy

Paired Sample Test				
Chemical Literacy	Equal Variance Assumed	t	df	Sig (2-Tailed)
		-11.194	41	.000

Based on Table 6, the paired sample t-test results show a significance value of 0.000, which is less than 0.05. Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted, indicating a significant difference between the pre-test and post-test results. This demonstrates that the use of the context-based approach combined with the POE strategy has a significant impact on chemical literacy. Moreover, the success of this learning approach is further evidenced by the higher mean scores observed post-intervention compared to pre-intervention.

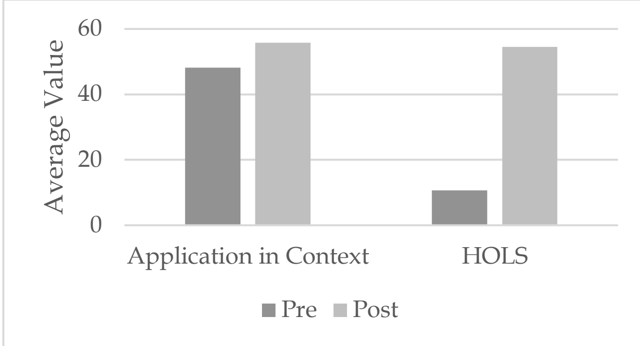

Figure 1. Graph of Average Scores by Aspect of Chemical Literacy

Based on Figure 1, the average scores obtained before and after the instruction were 25.655 and 55.095, respectively. As an active learning approach, the context-based method emphasizes that students construct their own concepts and helps them retain the acquired knowledge in the long term (Wiyarsi et al., 2020). Additionally, the average scores for each aspect of chemical literacy in the post-test are higher compared to the pre-test. The "application in context" aspect experienced an increase, albeit not a very large one, indicating that students were able to analyze the application of thermochemistry in everyday life through relevant contexts (Baydere, 2021). Meanwhile, the significant increase in the "High Order Learning Skills (HOLS)" aspect demonstrates that students can connect and interpret scientific information through discussions based on real-life experiences (Cigdemoglu & Geban, 2015).

The effective contribution of the instructional approach and strategy to chemical literacy is determined by dividing the mean score by the standard deviation, with the result interpreted into categories according to Cohen's guidelines.

Table 7. Results of the Effective Contribution Test on Chemical Literacy

Mean	Std Deviation	Effect Size
29.4381	17.0434	1.727

Based on Table 7 the effective contribution of the context-based approach combined with the prediction-observation-explanation strategy toward chemical literacy is 1.727, which is categorized as a large contribution. This indicates that the use of the approach and strategy has a positive impact on chemical literacy skills. The context-based learning method, coupled with the POE strategy, facilitates everyday phenomena as representations of relevant thermochemistry contexts, thereby stimulating students to develop chemical literacy through activities that involve predicting, observing, and explaining results in group discussions. According to Sumarni et al. (2017), a student's acquisition of knowledge depends on their thinking and the learning experiences related to their previously established conceptual understanding.

The Impact of a Context-Based Approach with the Prediction-Observation-Explanation Strategy on Self-Efficacy

This study assessed self-efficacy to determine differences before and after the intervention.

Table 8. Presents the results of the paired-samples t-test for self-efficacy.

Paired Sample Test				
Self Efficacy	Equal Variance	t	df	Sig (2-Tailed)
	Assumed	-.501	40	.619

Based on Table 8, the paired sample t-test yielded a significance value of 0.619, which exceeds the threshold of 0.05. Consequently, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_a) is rejected. This indicates that the implementation of a context-based approach integrated with the prediction-observation-explanation strategy does not exert a positive effect on self-efficacy.

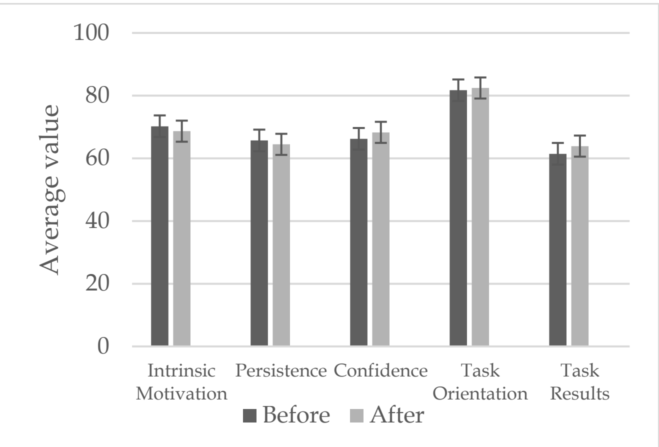

Figure 2. Graph of Mean Scores per Self-Efficacy Aspect

According to Figure 2, the mean scores for each self-efficacy aspect show a very slight difference between pre-test and post-test values. However, the aspects of confidence, task orientation, and performance outcomes experienced an increase after the intervention. The indicators under the confidence aspect include self-assurance in achieving learning objectives, confidence in solving various learning problems, and the ability to overcome pressure and failure. This finding is consistent with Anam, Ningrum & Setiawan (2024), which suggests that the POE emphasizes the active engagement of students in exploring and generating new ideas, while simultaneously providing ample opportunities for the development of independent thinking skills. When students discover their understanding independently, they tend to develop greater self-confidence in their ability to accept and complete tasks responsibly—an indicator of task orientation—as well as in their performance outcomes. Furthermore, these results align with Tutal (2023), who found that context-based learning can foster a more meaningful and engaging educational experience, thereby enhancing students' attitudes and motivation.

Table 9. Presents the results of the effective contribution test of self-efficacy (Paired Sample T-test).

Mean	Std Deviation	Effect Size
0.3537	4.5207	0.078

Based on Table 9, self-efficacy shows a very small effective contribution, with a value of 0.078. This is primarily due to the measurement relying solely on questionnaires, causing respondents to answer somewhat randomly. During the pretest, the use of Google Forms encountered various issues—such as forgotten passwords, insufficient internet data, or not having an account or phone. Consequently, some participants filled out the questionnaire at home while others did so in the classroom, making it difficult to verify the validity of the responses. For the posttest, the questionnaire was printed and administered over 90 minutes to avoid similar issues. Additionally, the limited time available for completing both the chemical literacy questions and the questionnaire likely hindered the participants' self-reflection, resulting in an imperfect measurement of self-efficacy.

Differences Between the Context-Based Approach with the Prediction-Observation-Explanation Strategy and the Scientific Approach Concerning Chemical Literacy

Regarding the difference between the context-based approach with the POE strategy and the scientific approach on chemical literacy, the study measured chemical literacy to identify treatment differences between the experimental and control groups on the topic of thermochemistry. This was done by administering open-ended questions—10 items before the intervention and 9 items after.

Table 10. Presents the results of the Independent Sample T-test for chemical literacy.

Independent Sample Test				
Chemical Literacy	Equal Variance Assumed	t	df	Sig (2-Tailed)
		.212	84	.832

Based on Table 10, the significance value is 0.832, which is greater than 0.05. This indicates that there is no statistically significant difference between the two groups.

Table 11. Presents the results of the effective contribution test for chemical literacy.

Group	*Mean*	*N*	*SD*	*Effect Size*
Experiment	0.5171	44	0.16595	0.046
Control	0.5081	42	0.22265	

Based on Table 11, the average normalized gain (n gain) for the experimental group (0.5171) was slightly higher compared to the control group (0.5081). The context-based approach with the Prediction-Observation-Explanation (POE) strategy provided a meaningful experience in predicting, observing, and explaining thermochemistry phenomena; however, the improvement in chemical literacy was not significant because this skill needs to be practiced repeatedly in order to achieve optimal results (Wiyarsi et al., 2020; Mustofa, Kuswanti & Hidayati, 2017).

Descriptive results for each aspect of chemical literacy showed that the recommended POE strategy in constructivist teaching (Karamustafaoğlu & Mamlok-Naaman, 2015) was implemented by beginning with an initial appraisal and stimulating questions, followed by dividing the students into six groups and using worksheets (LKPD). The first stage (prediction) used thermochemistry-related phenomena to evoke responses; the second stage (observation) required students to collect information through readings—even though, ideally, this should have been accomplished through direct experimentation in line with POE principles—and the third stage (explanation) involved presentations and discussions to summarize the findings, as suggested by White and Gunstone (1995).

On the other hand, the control group employed scientific learning that started with an initial appraisal and an in-depth explanation by the teacher, after which students were divided into groups and given worksheets to observe the phenomena, followed by stages of questioning, experimenting, reasoning, and group discussion presentations. The effective contribution to chemical literacy was recorded as very small (0.046 based on Cohen's d), indicating that the increase in chemical literacy in the experimental group did not yield a significantly positive effect compared to the control group. Contributing factors include suboptimal implementation of the learning process—such as delays or reduced time due to other school activities—which led to ineffective group discussions, thereby necessitating adjustments in the learning activities to achieve the intended objectives and requiring teachers to be flexible (Zendrato, 2016).

Differences Between the Context-Based Approach with the Prediction-Observation-Explanation Strategy and the Scientific Approach on Self-Efficacy

This study measured self-efficacy to examine the differences between the experimental and control groups in the context of thermochemistry. Self-efficacy was assessed using a 23-item questionnaire comprising both positive and negative statements, administered both before and after the instructional period.

Table 12. presents the results of the Independent Sample T-Test for self-efficacy.

Independent Sample Test				
Self Efficacy	Equal Variance	t	df	Sig (2-Tailed)
	Assumed	-.263	59	.794

Based on Table 12, the significance value is 0.794, which is greater than 0.05, indicating that there is no statistically significant difference between the two groups. The average normalized gain for self-efficacy was 0.2967 for the experimental group and 0.3091 for the control group, demonstrating that the experimental treatment does not outperform the conventional learning method. Overall, there is no significant difference in the self-efficacy aspects between the groups. However, in the areas of task orientation (items 21 and 22) and performance outcomes (item 23), participants in the experimental group performed better; this supports the view that self-confidence positively influences learning outcomes (Anggraeni, Ismail, & Damayanti, 2020).

Table 13. Presents the results of the effective contribution test for self-efficacy.

Group	Mean	N	SD	Effect Size
Experiment	0.2967	31	0.17457	0.067
Control	0.3091	30	0.19256	

Based on Table 13, the effective contribution of self-efficacy is small (0.067), indicating that the treatment did not yield positive feedback. This minimal impact may be attributed to internal factors such as personality and intelligence, as well as external factors like the social environment (family and classmates) (Nauvalia, 2021). Additionally, the generic design of the questionnaire might have contributed to the issue, suggesting that the development of the instrument should be tailored to the specific characteristics of the respondents (Nabila & Ashshiddiqi, 2023).

Conclusion

The context-based learning approach (CBA) combined with the Predict–Observe–Explain (POE) strategy has proven effective in enhancing students' chemical literacy, with a substantial contribution after the intervention measured at 1.727. However, this approach did not result in a significant improvement in students' self-efficacy, either before or after the intervention, with an effective contribution of only 0.078, categorized as very small. When compared to the scientific approach, the effective contributions of CBA-POE to chemical literacy and self-efficacy were also very small, at 0.046 and 0.067 respectively. These findings indicate that while the POE strategy within the CBA framework significantly strengthens students' cognitive aspects, its impact on affective aspects remains limited. Therefore, it is necessary to develop additional instructional strategies that more effectively support the enhancement of self-efficacy in the chemistry learning process.

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Author Contributions
Conceptualization, S.D.J. and H.S.; methodology, S.D.J. and H.S.; software, S.D.J.; validation, S.D.J. and H.S.; formal analysis, S.D.J. and H.S.; investigation, S.D.J.; resources, S.D.J.; data curation, S.D.J.; writing—original draft preparation, S.D.J.; writing—review and editing, H.S.; visualization, S.D.J.; supervision, H.S.; project administration, S.D.J.; funding acquisition, H.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
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