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The Influence of PjBL and Self-Efficacy on Critical Thinking in Analytical Separation

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Abstract: *Critical thinking is an essential higher-order thinking skill in chemistry learning, particularly in Basic Distillation within Analytical Separation. However, students often struggle to understand separation concepts and relate theory to practical applications. This study aimed to investigate the effects of the Project Based Learning (PjBL) model, self-efficacy, and their interaction on students' critical thinking skills. A quasi-experimental method with a 2 × 2 factorial design was conducted involving two classes of students from the Chemistry Education Study Program, University of Jambi. The experimental class received PjBL instruction, while the control class received conventional instruction. Data were collected through a self-efficacy questionnaire and a critical thinking essay test and analyzed using two-way ANOVA. The results showed that PjBL significantly affected critical thinking skills (Sig. = 0.001 < 0.05). Self-efficacy also had a significant effect (Sig. = 0.000 < 0.05). However, their interaction was not significant (Sig. = 0.678 > 0.05). These findings indicate that PjBL and self-efficacy independently influence students' critical thinking skills, with PjBL providing better outcomes than conventional learning.*

Keywords: *Project-based learning; self efficacy; critical thingking; distillation*

INTRODUCTION

Critical thinking skills are essential competencies in chemistry learning because students are required to analyze information, evaluate problems, and make decisions based on evidence. These skills enable students to deal with complex problems and apply scientific knowledge in learning contexts (Pradesa et al., 2024; Ilmi & Puspita, 2023). In the Fundamentals of Analytical Separation course, particularly in distillation material, critical thinking is needed because students must understand separation principles and relate them to practical problems. Previous research in chemistry education has also examined critical thinking in relation to learning characteristics and instructional quality (Rihmawati et al., 2024).

However, learning in the Fundamentals of Analytical Separation course still presents challenges for students. Distillation involves concepts related to differences in boiling points, volatility, heating, vaporization, and condensation, which require students to connect theoretical concepts with practical applications (Ikhwanudin et al., 2020). Difficulties in understanding these concepts may affect

students' ability to analyze problems and determine appropriate solutions during the learning process. Therefore, learning strategies that actively engage students in investigating and solving problems are needed.

Project-Based Learning (PjBL) is one learning model that can engage students in investigation, problem-solving, collaboration, and project completion. Previous research has provided empirical evidence of the contribution of Project-Based Learning (PjBL) to the development of students' critical thinking skills. A meta-analysis by Tafakur et al., (2023) examined the effectiveness of PjBL in enhancing critical thinking, while Seftiani et al., (2021), reported a positive overall effect of PjBL on the critical thinking abilities of senior high school students. These findings support the potential of project-based activities to facilitate analytical reasoning, problem-solving, and evidence-based decision-making. Nevertheless, the effectiveness of PjBL should also be examined within specific learning contexts, particularly in higher education courses that require students to connect theoretical principles with practical separation processes.

In chemistry education, research has examined the use of PjBL integrated with Chemo-Entrepreneurship to support students' life skills (Ishak et al., 2021). Other studies have reported the contribution of PjBL to students' conceptual understanding and science process skills, as well as chemistry learning outcomes through project-based activities supported by learning modules (Rose & Prasetya, 2014; Naisution & Panggabean, 2026). Research on Problem-Based Learning has also reported improvements in students' critical thinking skills and learning activities in chemistry learning (Zahro & Lutfianasari, 2024; Marpaungan & Suryanti, 2023). Although Problem-Based Learning and Project-Based Learning are different models, these findings provide related evidence of the potential of active learning approaches to support students' learning and thinking skills. Furthermore, (Rani, 2023) and (Muchtar et al., 2025) have discussed the relevance of PjBL to students' learning and critical thinking development.

In addition to instructional models, students' internal factors may also be associated with learning performance. One such factor is self-efficacy, which refers to students' beliefs about their ability to complete academic tasks. Self-efficacy is associated with students' confidence and persistence when facing learning challenges (Lianto, 2019). Students with different levels of self-efficacy may respond differently to demanding learning activities, including project-based tasks that require planning, problem-solving, and completing a practical project.

Previous research in physics education has reported that the effectiveness of instructional models in developing critical thinking skills may differ according to students' levels of self-efficacy. Other studies have also reported positive contributions of Project-Based Learning (PjBL) and self-efficacy to students' critical thinking skills (Ipa & Nggaba, 2023; Rakhmawati & Wahyuni, 2025; Salsabila & Margono, 2020; Yunianti et al., 2016).

Previous studies published in *Jurnal Inovasi Pembelajaran Kimia* have applied factorial designs and two-way analysis of variance to examine the effects of instructional approaches and student characteristics on chemistry learning outcomes. Rizki & Syuhada (2020), reported an interaction between laboratory media and students' initial abilities, whereas Simamora (2022) found no significant interaction between the PjBL model and students' chemical literacy abilities in predicting higher-order thinking skills. Similarly, Sianturi & Panggabean (2019), reported an interaction between laboratory type and students' learning styles. These findings illustrate that the interaction between instructional approaches and learner characteristics may differ across learning contexts. Therefore, examining the main

effects of PjBL and self-efficacy, as well as their interaction, in analytical separation learning is important to provide further empirical evidence.

Although previous studies have examined PjBL, critical thinking, and factors associated with students' learning, further investigation is needed into how PjBL and self-efficacy relate to critical thinking skills when studied together in distillation material within the Fundamentals of Analytical Separation course. In particular, the potential interaction between the learning model and students' self-efficacy requires empirical examination in this context. Addressing this gap can provide evidence regarding the individual effects of the learning model and self-efficacy, as well as whether their combination produces an interaction effect.

Therefore, this study aims to determine the effect of the Project-Based Learning (PjBL) model on students' critical thinking skills, determine the effect of self-efficacy on students' critical thinking skills, and examine the interaction between PjBL and self-efficacy on students' critical thinking skills in distillation material in the Fundamentals of Analytical Separation course.

LITERATURE REVIEW

Project-Based Learning (PjBL)

Project-Based Learning (PjBL) is a student-centered learning model that engages students in completing projects to address real-world problems. Through project activities, students participate in planning, investigation, decision-making, collaboration, and the development of products that can be presented. According to Rani (2023), PjBL emphasizes problem-solving through project activities that encourage students to think creatively and critically while connecting their learning to real-world situations.

In chemistry education, PjBL can provide opportunities for students to apply theoretical knowledge through structured investigations and practical tasks. (Wahyudiati et al., 2021) found that PjBL improved the critical thinking and problem-solving skills of pre-service chemistry teachers. Similarly, research on PjBL-based analytical chemistry learning materials has reported improvements in students' critical thinking skills compared with conventional learning materials (S. A. Sari et al., 2025). These findings suggest that project activities may support higher-order thinking when students are required to analyze information, evaluate results, and communicate conclusions. However, the learning outcomes may depend on the characteristics of the project, the instructional context, and the way learning activities are implemented.

The main characteristics of PjBL include the completion of a project through systematic stages. According to (Dinda & Sukma, 2021), these stages consist of determining the project, planning its completion, preparing a schedule, implementing and monitoring the project, preparing reports and presenting the results, and evaluating the process and final product. These stages provide opportunities for students to take an active role in learning while developing their ability to organize tasks, investigate problems, and communicate findings.

Previous studies in chemistry education have reported several benefits of PjBL. Ishak et al., (2021), examined PjBL integrated with Chemo-Entrepreneurship in relation to students' life skills, while (Anggriani et al., 2019) investigated its contribution to students' conceptual understanding and science process skills. Rose & Prasetya, (2014) also examined the effectiveness of PjBL assisted by learning modules in chemistry learning outcomes. These studies provide supporting evidence for the application of project-based activities in chemistry education. In addition, Muchtar et al. (2025), discussed the benefits of PjBL, including the development of learning motivation, problem-solving, collaboration, and resource-management skills.

Project-Based Learning (PjBL) has been reported to have a significant positive

effect on students' critical thinking skills. Its learning stages encourage students to investigate real-world problems, formulate hypotheses, analyze data, and independently evaluate solutions. Recent studies have emphasized that direct involvement in project development can help students develop higher-order thinking skills and support the achievement of 21st-century learning competencies (Malau, 2024; Murni et al., 2022; Rahmatika et al., 2026; Sularmi et al., 2018).

Despite these benefits, PjBL also presents challenges. Project completion may require considerable time, adequate facilities, and sufficient resources. Teachers and students must also be able to manage group work and coordinate project activities effectively. Therefore, the implementation of PjBL requires careful planning and monitoring to ensure that project activities remain aligned with the intended learning objectives.

In the present study, PjBL is implemented in distillation learning through project activities that require students to plan, investigate, carry out procedures, analyze results, and present their findings. These activities are expected to provide opportunities for students to practice critical thinking by analyzing problems, evaluating information, and drawing conclusions based on evidence.

Self-Effecacy

Self-efficacy refers to an individual's confidence in their ability to plan and carry out the actions required to attain a specific goal or desired outcome Lianto (2019). Self-efficacy plays a crucial role in determining a student's willingness to try, persist, and complete tasks or problems. Students with high self-efficacy tend to be more confident in setting learning goals, managing learning strategies, and demonstrating greater effort to achieve optimal learning outcomes.

According to Lianto (2019), self-efficacy also relates to an individual's belief in their motivational abilities, cognitive abilities, and the actions necessary to deal with various situational demands. A person's level of self-efficacy can influence learning behavior, persistence, and success in acquiring new skills.

Self-efficacy is relevant to learning because students' beliefs about their capabilities may be associated with their persistence, effort regulation, and academic performance. In a systematic review of university students, reported a moderate relationship between academic self-efficacy and academic performance, while also identifying cognitive and motivational factors that may influence this relationship. More directly, Febriani et al., (2024), investigated the association between university students' self-efficacy and critical thinking skills, with self-regulation and academic motivation serving as mediating variables. These findings suggest that self-efficacy should be considered alongside the learning environment when examining students' critical thinking, rather than being treated only as a personal characteristic.

Evidence from chemistry education also indicates that self-efficacy is a relevant variable in learning. I. A. Sari et al., (2022), investigated the application of the Think-Talk-Write model and self-efficacy in relation to students' critical thinking abilities in reaction-rate material. Setiawan et al., (2023) also examined the effect of a Scientific Critical Thinking model supported by Exelearning on students' self-efficacy in learning basic chemical laws. Although these studies used instructional approaches and chemistry topics different from those of the present study, they provide a contextual basis for examining students' confidence in their capabilities when learning chemistry. The present study extends this discussion by examining self-efficacy together with PjBL in distillation learning.

Lianto (2019) Self-efficacy was conceptualized as comprising three dimensions: magnitude, strength, and generality. Magnitude refers to the degree of task difficulty that an individual believes they

are capable of overcoming.Strength refers to the strength of an individual's belief in their ability to achieve goals despite obstacles. Meanwhile, generality indicates the breadth of an individual's belief in their abilities across different activities and situations.

Critical Thinking

Critical thinking is a higher-order thinking skill (HOTS) that is important to develop in the educational process. It enables students to analyze information, evaluate alternatives, and make logical and reflective decisions (Ilmi & Puspita, 2023). Critical thinking involves cognitive processes such as analysis, synthesis, evaluation, and problem-solving based on evidence and logical reasoning. According to (Rahardhian, 2022), critical thinking is a rational and reflective process of determining what to believe or do. This ability helps students organize their thoughts, communicate ideas systematically, and improve the quality of their learning.

In Bloom's revised taxonomy, critical thinking is associated particularly with analyzing (C4) and evaluating (C5), while creating (C6) involves developing new ideas or solutions based on the knowledge and evaluation undertaken (Elfitriyah et al., 2025). These cognitive processes are relevant to chemistry learning because students need to interpret information, examine evidence, identify problems, and determine appropriate solutions. In distillation learning, for example, students may be required to analyze separation problems, evaluate experimental results, and propose solutions based on the principles of separation.

The development of critical thinking requires learning activities that encourage students to engage actively in analyzing problems and evaluating information. Rahayu et al. (2026) Identified five indicators of critical thinking: providing simple explanations, developing basic skills, drawing conclusions, offering further explanations, and determining appropriate strategies and tactics. Research in chemistry education has also examined critical thinking in relation to students' learning characteristics and instructional approaches. Rihmahwati et al. (2024), examined the associations among learning interest, achievement motivation, learning quality, and students' critical thinking skills in the context of reaction-rate material. Meanwhile, Zahro & Lutfianasari (2024), examined the implementation of Problem-Based Learning in relation to students' critical thinking skills and learning activities in salt hydrolysis material. Although these studies address different learning contexts and, in the latter case, a different learning model, they provide relevant context for examining how chemistry learning may support critical-thinking development.

In this study, students' critical thinking abilities were evaluated based on their capacity to identify irrelevant information, recognize and correct conceptual errors, make decisions grounded in available evidence, and formulate innovative solutions to problems. These abilities were examined in the context of distillation learning through Project-Based Learning (PjBL). The assessment focused on students' analysis, evaluation, and evidence-based reasoning when addressing problems related to the distillation process.

Distillation

Distillation is a separation method used to separate mixtures based on differences in the boiling points and volatilities of their components. This process aims to obtain a purer liquid through evaporation and condensation without involving chemical reactions (Ikhwanudin et al., 2020). According to Putri et al., (2021), distillation or distillation processing is a chemical and physical separation method used to obtain essential oils. In this study, distillation was selected as the separation technique for lemongrass essential oil because its basic operating principles are expected to help students carry out the separation process effectively. During distillation, the mixture is heated to vaporize the components with lower boiling points first, after which the vapor is cooled and condensed into a liquid known as

the distillate. The main equipment used in the distillation process includes a heating vessel (boiler), a condenser, and a distillate container.

Lemongrass essential oil has various benefits and is widely used as a raw material in the production of perfumes, medicines, cosmetics, preservatives, and other industrial products. Amarullah et al., (2023), also reported the potential antibacterial activity of lemongrass essential oil against *Propionibacterium acnes* and *Staphylococcus aureus*, which are associated with acne. The various applications of lemongrass essential oil demonstrate its potential as a valuable product and provide a relevant real-world context for students to understand the practical application of distillation in separating natural compounds.

According to their underlying principles and applications, distillation can be classified into several types, including simple distillation, fractional distillation, vacuum distillation, steam distillation, azeotropic distillation, and extractive distillation (Setiawan, 2018). Simple distillation is used to purify substances with a large difference in boiling points, while fractional distillation is used to separate mixtures with close boiling points through a fractionation column. Vacuum distillation is carried out at low pressure to lower the boiling point of the substance, while steam distillation is used to separate compounds that are sensitive to high temperatures. Meanwhile, azeotropic distillation and extractive distillation are used to separate mixtures that are difficult to separate by ordinary distillation by adding certain substances.

In chemistry learning, distillation requires not only a conceptual understanding of the principles of separating mixtures, but also the ability to analyze the process, evaluate factors that influence separation results, and determine the appropriate distillation method based on the mixture's characteristics. Therefore, distillation has the potential to be used to train students' critical thinking skills through investigative activities, problem-solving, and the application of concepts in real-world situations.

METHODS

This study adopted a quantitative approach using a quasi-experimental method with a 2 × 2 factorial design. This design was chosen to examine the main effects of the Project-Based Learning (PjBL) model and self-efficacy on students' critical thinking skills, as well as the interaction between these variables. Specifically, the study aimed to determine whether the influence of PjBL on students' critical thinking skills varied according to their levels of self-efficacy, categorized as high or low (Hasnan et al., 2020; Watoni et al., 2025; Wulandari et al., 2026). The study employed a Non-Equivalent Control Group Design, involving an experimental group and a control group without full random assignment of participants. In this study, the PjBL model served as the independent variable, students' critical thinking skills as the dependent variable, and self-efficacy as the moderator variable. The research design used is a Non-Equivalent Control Group Design, which is a quasi-experimental design involving an experimental class and a control class without full subject randomization. In this study, the Project-Based Learning (PjBL) model was examined as an independent variable to determine its effect on students' critical thinking skills, with self-efficacy serving as a moderating variable.

The study was conducted in the Chemistry Education Study Program at Jambi University during the even semester of the 2025/2026 academic year, focusing on distillation in the Fundamentals of Analytical Separation (DDPA) course. The study population comprised all fourth-semester students enrolled in the Chemistry Education Study Program at Jambi University who were taking the course. A total sampling technique was applied at the class level, including both parallel classes available for the course. This sampling technique was selected because only two parallel classes were available for the subject under investigation, allowing both

classes to be included in the study. According to (Lilis et al., 2020), total sampling is a sampling technique in which the number of samples equals the population. The sample consisted of two classes, namely the experimental class given the PjBL model treatment and the control class using conventional learning.

The study involved three variables: the independent variable, which was the Project-Based Learning (PjBL) model; the dependent variable, which was students' critical thinking skills; and the moderating variable, which was students' self-efficacy. Self-efficacy is used to group students into high and low categories based on the results of filling out the questionnaire.

The experimental class followed the Project-Based Learning (PjBL) model, which involved several stages: formulating essential questions, designing the project, developing an activity schedule, carrying out and monitoring the project, presenting and assessing the results, and evaluating and reflecting on the learning process. In the initial stage, students were given contextual problems related to distillation material, then continued with project design and implementation activities in groups until they produced learning products. The lecturer acted as a facilitator who monitored the process throughout.

The research instruments consisted of an essay test designed to assess students' critical thinking skills and a questionnaire used to measure their self-efficacy. The essay test was administered as both a pretest and a posttest and was developed based on critical thinking indicators at the C4 (analysis), C5 (evaluation), and C6 (creation) cognitive levels, using distillation as the subject matter. Meanwhile, the self-efficacy questionnaire was structured using a Likert scale based on Bandura's three dimensions of self-efficacy: magnitude, strength, and generality.

Data collection techniques included pretests and posttests to measure improvements in critical thinking skills, self-efficacy questionnaires to categorize students' confidence levels, and observation sheets to monitor learning implementation. The data obtained were analyzed using a percentage formula to determine critical thinking skill scores, then categorized according to research criteria.

Before conducting hypothesis testing, prerequisite tests were performed using SPSS, including a normality test with the Kolmogorov–Smirnov method and a homogeneity test using Levene's test. Data were declared eligible if the significance value was greater than 0.05. Subsequently, hypothesis testing was performed using a two-way analysis of variance (ANOVA) to examine the effects of the PjBL model and self-efficacy on students' critical thinking skills, as well as the interaction between these two variables. This analysis was in accordance with the 2 × 2 factorial design used in the study.

The use of two-way ANOVA is consistent with previous research in chemistry education. Sinuhaji & Sutiani, (2025) employed two-way ANOVA alongside other statistical procedures to analyze learning outcomes in acid-base chemistry. Similarly, Lestari et al., (2020), used a 2 × 2 factorial design to examine the effects of a learning approach and self-efficacy, including their interaction. These studies provide methodological support for applying two-way ANOVA to examine the main effects of instructional models and learner characteristics, as well as the interaction between the two factors.

RESULT AND DISCUSSION

By comparing the average scores of the experimental and control classes, we can observe the impact of project-based learning and self-efficacy on critical thinking. The results of the experimental and control groups differed on average between the pre- and post-tests, indicating that the two groups learned different things. Figure 1 illustrates this.

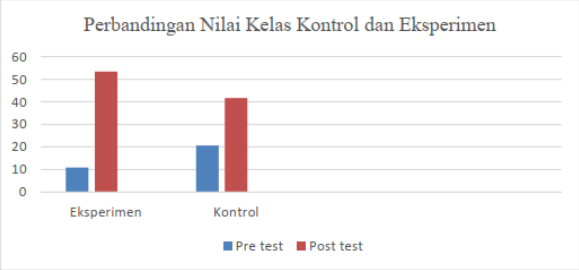


Figure 1. Comparison diagram of control and experimental class values

The average post-test score for the control group was 41.67, while the experimental group's score was 53.33 (Figure 1). On average, the experimental class performed better than the control class, according to these statistics. Both the experimental and control groups were tested for normality of pre- and post-test scores. You can see the results of the normality test for both datasets in Table 1.

Table 1. Normality Test Results

Kelas	Aspek	Nilai sig.	ket
kontrol	Pretest	0.620	Normal
	Posttest	0.133	Normal
Eksperiment	Pretest	0.237	Normal
	Posttest	0.508	Normal

In Table 1, the normality test results indicate that the students' scientific literacy scores in both the control and experimental classes have significance values greater than 0.05. Since the data in both groups follow a normal distribution, we accept H0. The pre- and post-test significance scores for both the experimental and control groups are higher than 0.05, according to the results of the homogeneity test. This indicates that the variances of the two groups are not significantly different. The mean critical thinking scores of the students are presented in Table 2 below.

Table 2. Homogeneity Test Results

Aspek	Nilai sig.	Keterangan
Berfikir Kritis	0.669	Homogen

In Table 2, the homogeneity test results show that the significance value for students' critical thinking scores on the pretest and posttest is greater than 0.05. Since the results of the study show a consistent distribution of variance, we can conclude that H1 is true and reject H0. Table 3 below displays the results of the test for differences in the average critical thinking scores of the two students after the analysis was carried out using SPSS version 27.0.

Table 3. Presents the results of the two-way ANOVA.

Source	Type III Sum of Squeres	df	Mean Squere	F	Sig.
Corrected Model	3518,854[a]	3	1172,951	11,521	,000
Intercept	61246,274	1	61246,274	601,554	,000
Kelas	1450,750	1	1450,750	14,249	,001
SE	2029,557	1	2092,557	20,553	,000
Kelas *SE	17,794	1	17,794	,175	,678
Error	3767,098	37	101,813		
Total	99460,000	41			
Corrected Total	7285,951	40			

The results obtained to see the influence of the PjBL model on critical thinking skills can be seen from the sig value of 0.001 < 0.05, which means that there is a positive influence on the PjBL model on students' critical thinking skills. Furthermore, the effect of self-efficacy on critical thinking skills was indicated by a significance value of 0.000 <0.05, demonstrating a statistically significant effect. Meanwhile, the interaction between the PjBL model and self-efficacy yielded a significance value of 0.678, which exceeds 0.05, indicating that there was no statistically significant interaction between the PjBL model and self-efficacy in influencing students' critical thinking skills. Although previous studies have examined the relationship between project-based learning, self-efficacy, and students' learning outcomes, the interaction between instructional models and individual learner characteristics may vary across learning contexts. Pujianto et al., (2024), investigated project-based learning and self-efficacy in

relation to students' critical thinking skills, while Siregar et al., (2025), found no statistically significant interaction between the instructional model and self-efficacy in relation to students' science problem-solving skills. In the present study, the interaction between PjBL and self-efficacy was also not statistically significant ($p = 0.676$). This finding indicates that the current data do not provide sufficient evidence that the effect of PjBL on critical thinking differs between students with high and low self-efficacy. Further research is therefore needed to examine this interaction across different chemistry courses and student populations.

The results of this study are consistent with previous research examining the implementation of project-based learning in chemistry and chemical engineering education. Fregolente et al., (2018), demonstrated the application of project-based learning in undergraduate distillation and absorption education. Dulanlebit et al., (2024), reported the use of project-based chemistry practicum to develop critical thinking and conceptual understanding. Pratiwi et al., (2023) also investigated the integration of Project-Based Learning (PjBL), STEM, and field studies in the teaching and learning of elemental chemistry. In addition, research on cross-curricular project-based laboratory learning has highlighted the value of interdisciplinary and practical learning experiences for chemical engineering students. Collectively, these studies support the relevance of project-based and practice-oriented learning in chemistry education. The present study extends this evidence by examining the effect of PjBL on critical thinking skills in undergraduate distillation learning while also considering students' self-efficacy.

CONCLUSION

The findings of this study demonstrate that the Project-Based Learning (PjBL) model had a significant effect on students' critical thinking skills in the Distillation topic within the Fundamentals of Analytical Separation course. Students who participated in PjBL-based instruction exhibited stronger critical thinking skills than those who received conventional instruction. Additionally, self-efficacy had a significant effect on students' critical thinking skills, with those exhibiting higher self-efficacy performing better than those with lower self-efficacy. However, no statistically significant interaction was found between the PjBL model and self-efficacy in relation to students' critical thinking skills.

The findings suggest that implementing PjBL integrated with digital technology, can serve as an effective alternative instructional approach for enhancing students' critical thinking skills. These findings also support the development of chemistry instruction focused on higher-order thinking skills (HOTS) and provide a valuable reference for designing innovative learning models for other chemistry topics in the digital era.

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