

DEVELOPMENT OF STUDENTS WORKSHEET BASED ON PROJECT BASED LEARNING TO TRAIN CRITICAL THINKING SKILLS AT VOCATIONAL HIGH SCHOOL

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ARTICLE INFO	ABSTRACT
<p>Article History: Received 13/07/2025 Revised 22/08/2025 Approved 15/09/2025 Published 27/09/2025</p> <hr/> <p>Keywords: Colligative Properties of Solutions, Critical Thinking Skills, Project Based Learning, Students' Worksheet</p>	<p>Critical thinking is a cognitive skill that helps identify problems and generate solutions, leading to logical decisions or considerations for solving those problems. Students' critical thinking skills can be trained through learning activities to further improve students' critical thinking skills with learning tools. Therefore, this research intends to produce a student worksheet based on project-based learning to train students' critical thinking skills on the colligative properties of solutions. The development research uses the 4D development model from Thiagarajan, limited to the development stage. A limited trial was conducted with 30 students of industrial chemical engineering expertise at Vocational High School 1 Cerme. The findings indicated that the developed student worksheet was declared effective in training students' critical thinking skills. The results of the paired sample t-test obtained a significance value of 0.000 (<0.05), which shows that it indicates an increase in students' critical thinking skills.</p>
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INTRODUCTION

Rapid technological advances and globalization in the 21st century have changed many industries, including education (Malik, 2018; Rahimi & Oh, 2024). Education is vital because competent human resources can advance a nation. 21st-century education faces many challenges, including ensuring that students can compete globally by mastering 21st-century skills, particularly the 4C skills, which have been adapted to technological advances (Kennedy & Sundberg, 2020; Varas et al., 2023). Indarta et al. (2021) argue that students must master diverse knowledge and skills, critical thinking in problem-solving, good communication and collaboration skills, and the 4C skills—critical thinking, communication, collaboration, and creativity. Students in chemistry will gain critical thinking skills through this research. Students, like everyone else, need critical thinking skills to solve difficulties (Isdianti et al., 2021).

The Indonesian curriculum has changed due to the 21st-century learning model, which emphasizes pupils acquiring skills and abilities through technology (Herlinawati et al., 2024). On December 10, 2019, Minister of Education, Culture, Research, and Technology, introduced the independent curriculum to improve the 2013 curriculum (Ibrahim et al., 2024). The government implemented the Merdeka Curriculum to mitigate learning loss after the COVID-19 pandemic. This curriculum emphasizes flexibility and creativity to personalize learning and teach 21st-century skills, encouraging independence, relevance, and adaptability (Anisa, 2022; Fitra, 2023). Active, project-based, and learner-centered learning were included in the Merdeka curriculum during development (Ananta & Sumintono, 2020; Amiruddin et al., 2023). Project-based learning (PjBL) fosters independent curricula and 21st-century skills (Ramadhani et al., 2024). PjBL promotes student inquiry, analysis, innovation, and presentation of concepts from skills learned while developing goods (Yulianto, 2019; Omelianenko & Artyukhova, 2024).



Law 20 of 2003 on national education states that vocational high schools prepare students to work and be productive (Wibowo, 2016). To generate graduates who are competent in their disciplines and able to compete in a challenging and competitive workplace, the government is also aiming to strengthen and develop vocational high school education (Hidayatulloh, et al., 2019). Ministry of Education and Culture Regulation Number 34 of 2018 on National Standards for Vocational High School Education states that vocational high schools/vocational Islamic high schools have nine areas of expertise, including technology and engineering (Teguh, 2019). This study included 30 Grade X industrial chemical engineering students from Vocational High School 1 Cerme.

Learning chemistry is crucial to natural science. Pre-research showed that 94% of pupils found chemistry difficult since teachers' media didn't assist them in learning. Lecture-based lessons bored and confused students. According to Muhan and Nasrudin (2021), 85% of students said chemistry is a complex subject because there are many formulas, confusing material, teachers explain briefly, and there is no learning media. Chemistry is strongly tied to everyday life, but most students think it's about dangerous elements that can harm the environment and others (Febiartaty et al., 2019; Nahlik et al., 2023). Basic industrial chemical engineering students learn basic organic and inorganic chemistry, including standard solution material, chemical reactions, stoichiometry, reaction rates, chemical equilibrium, colligative properties of solutions, redox, and electrochemistry, by the end of phase E. This study will concentrate on colligative qualities of liquids and osmotic pressure. The material on colligative properties of solutions broadly applies principles, particularly in the subtopic of osmotic pressure, which offers a fundamental understanding of chemical industry processes (Herunata et al., 2024). This knowledge is useful for preparing vocational school students to implement practices in industrial chemical engineering.

Facione (2011) says this research teaches critical thinking. Critical thinking is the cognitive process of identifying a problem and making logical decisions to solve it (Khoiriyah, 2018; Jaelani et al., 2023; Altun & Yildirim, 2023). Learning is a great way to develop pupils' critical thinking skills. Interpretation, analysis, appraisal, inference, explanation, and self-regulation are critical thinking signs. Only strong critical thinkers perform six indicators; thus, this study only evaluates interpretation, analysis, evaluation, inference, and explanation (Facione, 2011). When the five indicators of critical thinking skills are linked to the colligative qualities of the solutions subtopic on osmotic pressure, students can create questions from an occurrence or phenomenon in the reading material (Anggraeni et al., 2023). Students can assess project outcomes to answer osmotic pressure subtopic questions. Students practice inference by completing their projects. Students also learn to explain by presenting project results with relevant arguments based on project data. These five markers of critical thinking skills are related to the learning model and better at increasing students' critical thinking (Aini et al., 2022).

34 of 36 Grade X industrial chemical engineering students at vocational high school 1 Cerme considered chemistry challenging, according to pre-research questionnaires distributed on April 23, 2024. In addition, 92.4% of students said it was difficult to learn the material on colligative properties of solutions because it contained many theories and formulas for calculations. The pre-research showed that students' critical thinking skills were still low, as the interpretation indicator was 15%, analysis 21.48%, inference 6.11%, and explanation 2.96%. Thus, learning activities can develop students' critical thinking skills. During research implementation, critical thinking skills indicators differed from pre-research. After reviewing the learning model for measuring student critical thinking skills, assessment was found to be an additional indicator.

Teaching resources make chemistry learning more effective and relevant. Teaching materials encourage effective learning (Nalarita & Listiawan, 2018; Hadisaputra et al., 2020). According to prior research, vocational high school students have low critical thinking abilities due to limited student involvement, poor learning quality, and insufficient learning support like inadequate instructional materials (Haryani et al., 2022). This research will create a worksheet based on the project-based learning approach, which teaches critical thinking. The PjBL learning model encourages students to solve problems and organize projects, which improves their critical thinking (Sasson et al., 2018). Project planning requires multifaceted thinking, implementation is limited by a timeframe, and teamwork trains students' critical thinking skills as they generate ideas to complete a project in a limited timeframe.

PjBL integrates cross-disciplinary knowledge and abilities into application-based projects to impart students' in-depth expertise (Andini & Rusmini, 2022). Students explore challenges, devise solutions, and create genuine goods, making learning more intriguing and meaningful (Jamal et al., 2023). PjBL is a novel way to teach critical thinking. Fatikasari et al. (2023) found that PjBL-based Electronic Student Worksheets with virtual labs effectively train students' critical thinking skills on reaction rate factors, with a practicality percentage of $\geq 90\%$, an effectiveness review based on pretest-posttest results, and an n-gain score of 0.72, meeting high criteria. The main aim of PjBL is student learning. Students' projects will teach them to argue, explore, evaluate, develop, and draw unique findings (Pan et al., 2021; Muis & Dewi, 2021). Building upon what has been said, this research aims to describe the validity, practicality, and effectiveness of the student worksheet-based PjBL on Colligative Properties of Solutions to Develop Critical Thinking Skills of Grade X Students in Industrial Chemistry Engineering Expertise. Benefits from this research are expected: (1) making it easier for students to understand

colligative properties of solutions and train critical thinking skills; (2) for teachers, the developed student worksheet can be used as an alternative learning medium, especially for the topic of colligative properties of solutions; (3) for schools, the developed student worksheet can be used as supporting media for the learning process in schools to improve learning quality.

METHOD

This type of research is research and development (R&D). This research refers to the 4-D (Four-D) development model from Thiagarajan, which consists of four stages of development, namely define, design, develop, and disseminate (Fauziah, 2025). However, this research is limited to the development stage, involving a limited trial with industrial chemistry engineering expertise students at Vocation High School 1 Cerme to assess the practicality and effectiveness. In the first stage, the define stage, the researcher established and defined the requirements for learning, also known as the needs analysis stage, which consisted of conducting a front-end analysis of students, task analysis, concept analysis, and learning objective analysis. The first stage was carried out by conducting preliminary research through interviews with vocational high school chemistry teachers and observations of students, as well as tests to measure students' knowledge and critical thinking skills.

In the second stage, known as design, the focus is on creating the learning media, which will be developed and reviewed according to the results of observations made during the pre-research phase. This process ensures that the media is tailored to meet students' needs based on information gathered in the define stage. A decision is made to develop learning media in the form of printed student worksheets. After review by the supervising lecturer and expert assessment by three validators—two chemistry education lecturers and one vocational high school chemistry teacher—the final product will be a worksheet-based PjBL for students. The validators must review and validate the researcher's student worksheet, module, response questionnaire instrument, student activity observation instrument, and critical thinking skills test sheet. Reviewers will provide feedback to improve the student worksheet before expert assessment. Expert assessment will be utilized to evaluate the student worksheet's validity. According to Lutfi (2021), validity data is ordinal data that cannot be operated mathematically; hence, data analysis is done by establishing the mode. Table 1 uses the Likert scale to compute validation percentages.

Table 1. Likert Scale Score

Score	Assessment Criteria
1	Very Poor
2	Unfavorable
3	Good
4	Very Good

Riduwan (2022) defines a valid student worksheet as achieving a mean score of ≥ 3 with good and very good assessment requirements. The validator's comments for the student worksheet must be implemented before a limited trial can be conducted. The restricted trial deployment will be used to evaluate student worksheet practicality and efficacy. Practicality will be assessed using student answer questionnaires and student activity observations. The Guttman scale is used to analyze the student response questionnaire's positive and negative statements. If the student answers "Yes," then they get a score of 1; if they answer "No," then they get a score of 0. Table 2 will show student questionnaire responses and activity percentages. To be considered practical, a student worksheet must meet $\geq 61\%$ practicality criteria based on questionnaire responses and relevant student activities (Riduwan, 2022).

Table 2. Interpretation Categories of Students Worksheet Practicality Aspect Scores

Percentage (%)	Categories
0,01 – 20,99	Very Impractical
21,00 – 40,99	Less Practical
41,00 – 60,99	Quite Practical
61,00 – 80,99	Practical
81,00 – 100,00	Very Practical

Students' critical thinking skills will be tested pre- and post-test to assess effectiveness. Calculate the difference in average pretest and posttest scores (N-Gain Score) to examine pretest and posttest outcomes. Additionally, Table 3

categories will be used to explain n-gain score values. With SPSS, the pretest and posttest data will be checked for normalcy using the Kolmogorov-Smirnov test and the n-gain score. H1 is approved if the normality test reveals that the data is regularly distributed with a significance value > 0.05 . This shows that the produced kids worksheet improves critical thinking. If the data is not normally distributed (significance level < 0.05), use the Wilcoxon signed-rank test for nonparametric statistical analysis.

Table 3. N-Gain Score Categories

Value	Category
$g \geq 0,7$	High
$0,3 \leq g < 0,7$	Medium
$g < 0,3$	Low

RESULTS AND DISCUSSION

Results

After development, the research outcome will be a worksheet-based PjBL on colligative features of solutions to train grade X students with industrial chemical engineering competence in critical thinking. The data used to establish the feasibility of the student worksheet was reviewed for validity, practicality, and efficacy. The validation results, response questionnaire results, student activity observations, and pretest and posttest KBK results determine the validity, practicality, and effectiveness of the developed student worksheet. The design stage for the students' worksheets includes several steps: preparing critical thinking skills tests, selecting media, choosing formats, and producing Draft I, which will consist of a student worksheet design featuring three types of projects.

Figure 1. Cover Draft I for Students

Figure 2. Cover Draft I Teacher Handbook



Figure 3. Cover Proyek 1



Figure 4. Cover Proyek 2



Figure 5. Cover Proyek 3

Validity of Students Worksheet

This part should offer Validity evaluates the pupil's worksheet's feasibility before a limited student trial. The worksheet-based PjBL was validated by two chemistry lecturers and one vocational school chemistry instructor. A valid student worksheet is defined as having a modal score of ≥ 3 from three validators with adequate assessment criteria (Riduwan, 2015). Content and construct validity are defined in this study. Validators scored six primary content validity components with a mode score of 3 with satisfactory criteria. For construct validity, graphics, presentation, and language scored 4 with very good criteria. According to Lutfi (2021), the students' worksheet is legitimate, as it had a mode score of ≥ 3 with adequate and very satisfactory requirements for content and construct validity.

Validators found that content validity did not meet the maximum mode. Since the evaluation feature related to the applicability of students' worksheet activities or research projects received a mode of 3 with a good criterion, innovation is needed. The PjBL model's stages and indicators should also be considered for student activities.

Practicality of Students Worksheet

The response questionnaire and student actions throughout learning demonstrate the worksheet's applicability. Students submit feedback on project-based learning worksheets utilizing student response sheets. Three key learning media objectives were identified using 25 student response questionnaire statements. Table 4 shows students answer questionnaire data.

Table 4. Percentage of Participant Response Questionnaire Results

No	Objective	Percentage	Category
1.	To determine students' responses regarding the language, design, and font of the Students Worksheet project-based learning developed so that it is easy to understand.	98,8%	Very Practical
2.	To determine students' responses to learning using Students Worksheet developed with the project-based learning model	95,2%	Very Practical
3	To determine students' responses to project-based learning Students Worksheet to train students' critical thinking skills	94,4	Very Practical
Overall Average		96,1%	Very Practical

Table 4 shows that student responses in all aspects were $> 61\%$, with an average practicality of 96.1% for worksheet-based PjBL, indicating high practicality. In addition to the student response form, three observers observed student actions throughout learning to assess practicality. These observations were used to assess student active engagement in worksheet-based PjBL learning activities. These observations assessed whether student activities followed the project-based learning model's phases. Effective student activity data supports the usefulness of the worksheet when relevant activities outnumber irrelevant ones ($\geq 61\%$, Riduwan, 2022). Table 5 shows data from student learning observations.

Table 5. Results of Student Activity Observation Sheet

Relevant Student Activities		Irrelevant Student Activities	
Meeting 1	Meeting 2	Meeting 1	Meeting 2
95,2%	97,5%	4,8%	2,5%

Table 5 shows that 95.2% and 97.5% of relevant student activities during trial implementation in the first and second meetings were very practical. The first and second meetings included 4.8% and 2.5% unrelated activity. Tables 5 (student answer questionnaire and student activity observation sheet) show that the overall proportion for each aspect was $\geq 61\%$. Thus, the researcher's worksheet-based PjBL is useful for learning. Siswanto et al. (2019) agree that a learning tool is practical if it fosters student-teacher interactions, aligns with learning objectives, and is student-centered. Based on the practicality aspect in the student response questionnaire results and the observation results of student activities, which obtained a percentage greater than or equal to 95%, the students' worksheet-based PjBL was reviewed. It was found to positively impact student activity in learning and train students' critical thinking skills. The inconsistency between student responses on the questionnaire and their unrelated activities during learning affects the practicality percentage. Thus, the teacher must reduce relevant student activities. The second meeting primarily concentrated on project implementation results and presentations, leading to a decrease in irrelevant student activities.

Effectiveness of Student Worksheet

Students' worksheet-based PjBL was evaluated by their critical thinking skill growth between pretest and posttest. This study used descriptive pretest-posttest questions with 3 interpretation indicator questions, 2 analysis questions, 2 evaluation questions, 1 inference question, and 3 explanation questions. The pretest was given before learning utilizing the student worksheet, and the posttest was given after learning at the second meeting. Figure 6 depicts students' pretest-posttest outcomes.

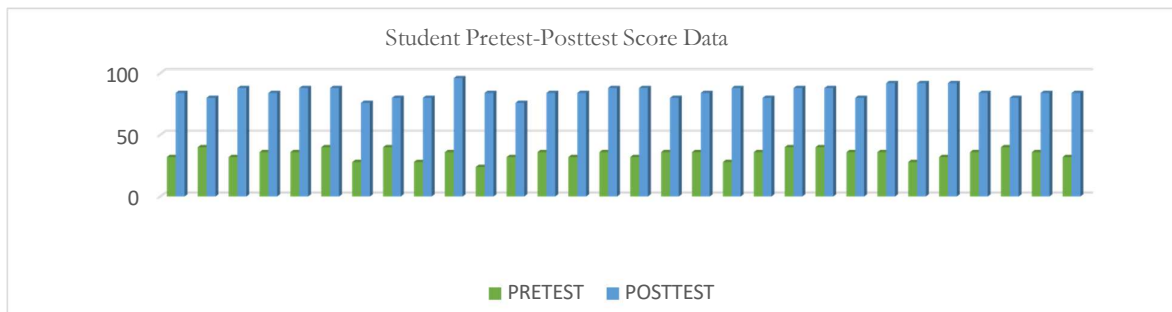


Figure 6. Student Pretest-Posttest Score Data

Figure 6 shows that pupils had low pretest scores (≤ 40), indicating poor critical thinking skills. Meanwhile, students' posttest results rose significantly. This shows that students' critical thinking on solution colligative qualities improved following worksheet learning. The pretest and posttest critical thinking scores were used to construct an n-gain value to assess student improvement. Table 6 shows the pretest-posttest percentages for each critical thinking skill indicator.

Table 6. Pretest and Posttest Results Data

KBK Indicator	Pretest (%)	Posttest (%)	N-Gain Score	Category
Interpretation	45,33	88,33	0,78653	High
Analysis	35	82,5	0,73076	High
Evaluation	32,66	85,33	0,78215	High
Inference	35	88,33	0,82041	High
Explanation	21,42	81,42	0,76355	High

Table 6 shows that each critical thinking skill indicator increased between pretest and posttest. The n-gain score for each critical thinking skill indicator was > 0.7 , indicating high. The explanation and analysis indicators had lower posttest critical thinking skill scores than the others. Besides the n-gain test, normality and paired sample t-tests were performed.

Normality Test

The normality test used in this study was the Kolmogorov-Smirnov normality test to determine whether the pretest and posttest data were normally distributed or not using SPSS. The data obtained based on the Kolmogorov-Smirnov normality test using SPSS showed the following test results.

Table 7. Recapitulation of the Results of the Normality Test of the Pretest and Posttest

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		30
Normal Parameters ^{a,b}	Mean	.0000000
	Std. Deviation	4.85912895
Most Extreme Differences	Absolute	.155
	Positive	.155
	Negative	-.140
Test Statistic		.155
Asymp. Sig. (2-tailed)		.063 ^c

Table 7 shows the normality test data significance value was 0.063. The study's data is regularly distributed because the normality test significance value is > 0.05 . A nonparametric statistical study employing a paired sample t-test will

evaluate if pretest and posttest data change significantly since the data is normally distributed.

Paired Sample T-Test

Because the data used in the research is normal, a paired sample t-test was performed on the pretest and posttest data to determine if students' critical thinking skills improved significantly after learning about colligative properties of solutions using worksheet-based PjBL. The paired sample t-test was run in SPSS. If the estimated $t > t$ table, the study data is significantly different, and vice versa. This study's paired sample t-test results:

Table 8. Summary of Paired Sample T-test Results

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 <i>pretest - posttest</i>	-50.400	6.441	1.176	-52.805	-47.995	-42.857	29	.000

Table 8 shows a t-value of -42.857, a t-table value of 0.05, and a df of 29 of 1,699. H_0 is rejected and H_1 approved since the calculated t-value is bigger than the t-table value. This shows a considerable pretest-posttest difference. The pretest and posttest significance values are 0.000. These test findings suggest rejecting H_0 and accepting H_1 . An enhancement in students' critical thinking skills after utilizing the prepared worksheet is indicated by a significance value < 0.05 .

Students' pretest-posttest scores usually increase significantly, indicating effectiveness. A paired sample t-test reveals a significant impact on students' critical thinking skills after project-based learning, with a significant value of < 0.05 and a calculated t value greater than the t table.

CONCLUSION

Considering the research findings and discussions presented, it can be concluded that the student worksheet, grounded in project-based learning for the topic of colligative properties of solutions, is appropriate for instructional use. This conclusion is supported by its validity, which achieved a validation score of ≥ 3 ; its practicality, indicated by questionnaire responses and relevant student activities yielding a percentage of $\geq 61\%$; and its effectiveness, evidenced by the increase in pretest and posttest scores as assessed through the n-gain score and paired sample t-test, which revealed a significance value of 0.000, denoting a significant difference in the data analyzed in the study. Future research on assessing or enhancing students' critical thinking skills should incorporate all indicators, including those of self-regulation, and broaden the scope to encompass the complete subject of colligative properties of solutions, as the current study was confined to the subtopic of osmotic pressure.

AUTHOR CONTRIBUTIONS

All authors participated in the conceptualization, design, data collection, analysis, interpretation, writing, and revision of the article. All authors approved the finalized manuscript.

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CONFLICT OF INTEREST STATEMENT

The author asserts no conflicts of interest exist in publishing this paper. This research and results were not influenced by financial, personal, or other affiliations, and supervisors performed their professional duties. We did our best to perform and deliver the research with integrity and transparency.

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