

ENHANCING STUDENTS' SCIENTIFIC EXPLANATIONS THROUGH PROJECT-BASED WORKSHEETS ON BIOPESTICIDE PRODUCTION FROM SOURSOP LEAF EXTRACT

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ARTICLE INFO	ABSTRACT
Received : 21 July 2026 Revised : 06 August 2026 Accepted : 07 August 2026 Published: 31 August 2026	Abstract: Vocational high school students' scientific explanation skills remain limited because chemistry instruction tends to emphasize memorization rather than contextual scientific inquiry. This pre-experimental study employed a one-group pretest-posttest design to analyze students' learning activities and improvements in scientific explanation through project-based student worksheets (LKPD) integrated with the production of biopesticides from soursop (<i>Annona muricata</i>) leaf extract. The study involved 35 eleventh-grade Industrial Chemistry students at SMKN 7 Bandung selected using purposive sampling. Learning activities were observed using a structured rubric, while scientific explanation was assessed using a 15-item essay test based on the Claim–Evidence–Reasoning (CER) framework (Aiken's $V > 0.79$; Cohen's $\kappa = 0.85$; Cronbach's $\alpha = 0.82$). Data were analyzed using the Shapiro–Wilk test, paired-samples t-test, and normalized gain (N-gain). PjBL implementation reached 90.6% (very good), and both pretest and posttest data were normally distributed. Students' scores improved significantly, $t(34) = 25.60, p < .001, dz = 4.32$ (95% CI [3.41, 5.25]); the mean score increased from 17.17 to 34.54 (N-gain = 0.61), with the greatest improvement in the Reasoning component (0.74) and the lowest in Claim (0.41). Although limited to a single class without a control group, the findings suggest that project-based worksheets have the potential to improve students' learning activities and scientific explanation skills in contextual chemistry learning at vocational high schools.
Keywords: <i>biopesticide; claim-evidence-reasoning; project-based learning; scientific explanation; soursop leaf; student learning activity</i>	
Kata Kunci: <i>aktivitas belajar siswa; biopestisida; claim-evidence-reasoning; daun sirsak; pembelajaran berbasis proyek; scientific explanation</i>	

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Abstrak: Kemampuan *scientific explanation* siswa SMK masih rendah karena pembelajaran kimia cenderung menekankan hafalan dibandingkan inkuiri ilmiah kontekstual. Penelitian pre-eksperimental dengan desain *one-group pretest-posttest* ini menganalisis aktivitas belajar dan peningkatan kemampuan *scientific explanation* melalui LKPD berbasis proyek yang terintegrasi dengan pembuatan biopestisida dari ekstrak daun sirsak (*Annona muricata*). Penelitian melibatkan 35 siswa kelas XI Teknik Kimia Industri SMKN 7 Bandung yang dipilih menggunakan *purposive sampling*. Aktivitas belajar diamati menggunakan rubrik terstruktur, sedangkan *scientific explanation* diukur menggunakan tes esai 15 butir berbasis *Claim–Evidence–Reasoning* (CER) (Aiken's $V > 0,79$; Cohen's $\kappa = 0,85$; $\alpha = 0,82$). Data dianalisis menggunakan uji Shapiro–Wilk, *paired-samples t-test* dan *normalized gain* (N-Gain). Keterlaksanaan PjBL mencapai 90,6% (sangat baik), dengan data pretest dan posttest berdistribusi normal. Skor meningkat signifikan, $t(34) = 25,60$, $p < 0,001$, $d_z = 4,32$ (95% CI [3,41, 5,25]); rata-rata meningkat dari 17,17 menjadi 34,54 (N-Gain = 0,61), dengan peningkatan tertinggi pada aspek *reasoning* (0,74) dan terendah pada *claim* (0,41). Meskipun terbatas pada satu kelas tanpa kelompok kontrol, hasil penelitian menunjukkan bahwa LKPD berbasis proyek berpotensi meningkatkan aktivitas belajar dan kemampuan *scientific explanation* siswa pada pembelajaran kimia kontekstual di SMK.

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INTRODUCTION

Chemistry learning is not only aimed at understanding chemical concepts, theories, and principles but also at developing students' ability to apply knowledge in explaining everyday phenomena (Raman et al., 2024). However, classroom learning still tends to focus on theoretical content delivery, providing limited opportunities for students to apply concepts in solving real-world problems (Retiyanto et al., 2023). This condition may hinder the development of students' scientific thinking skills, particularly in constructing scientific explanations as one of the essential competencies required in the 21st century.

The ability of scientific explanation refers to the ability to explain phenomena scientifically by connecting claim, evidence, and reasoning to produce logical arguments. Afnan et al. (2023) reported that students still experience difficulties in constructing scientific explanations due to limited

opportunities to analyze data, evaluate evidence, and develop arguments. This condition is associated with low scientific literacy and problem-solving skills, highlighting the need for inquiry-based learning that is connected to real-world contexts (Adawiyah et al., 2026).

One of the contextual issues that can be integrated into chemistry learning is the use of synthetic pesticides in agriculture, which potentially causes environmental pollution, reduces agricultural product quality, and increases pest resistance (Daraban et al., 2023). As an alternative, natural-based biopesticides offer advantages due to their biodegradability and relatively safer residues for the environment (Daraban et al., 2023). Various plants have been investigated as sources of biopesticides, including gliricidia and papaya leaves (Sulianti et al., 2022), soursop leaves (Cindowarni, 2024).

Soursop leaves (*Annona muricata* L.) have potential as a biopesticide source due to their acetogenin content and secondary metabolites, such as alkaloids, flavonoids, tannins, saponins, and polyphenols, which act as natural insecticides by disrupting cellular respiration and insect metabolism (Moghadamtousi et al., 2015; Audina et al., 2024). In addition to their effectiveness as botanical pesticides, the simple extraction process of soursop leaves makes them suitable for integration into laboratory-based chemistry learning (Sahrianti & Mastura, 2023). Several studies have also demonstrated the bioactive potential of soursop leaves as larvicides, botanical fungicides, and natural insecticides against various plant pests (Salsabila & Sukei, 2022).

Real-world problem-based learning can be implemented through project-based student worksheets (LKPD), which promote students' active engagement throughout the project completion process. Hindun et al. (2024) reported that Project-Based Learning (PjBL) enhances scientific thinking, science process skills, and students' ability to construct explanations based on investigative data. In addition, Sholahuddin et al. (2023) found that project-based worksheets increase student participation and support the development of science process skills and learning engagement (Moghadamtousi et al., 2015).

Learning based on real-world problems can be implemented through project-based worksheets that encourage students' active involvement throughout the project completion process. Hindun et al. (2024) demonstrated that Project-Based Learning (PjBL) can enhance students' scientific thinking skills, science process skills, and their ability to construct explanations based on investigation data. In addition, Sholahuddin et al.

(2023) reported that project-based worksheets can improve student participation and support the development of science process skills and learning engagement (Moghadamtousi et al., 2015).

This research gap indicates that studies integrating (1) PjBL as a learning model, (2) the production of soursop leaf extract biopesticides as an authentic context in vocational chemistry learning, and (3) the CER framework as an instrument for assessing students' scientific argumentation skills remain limited. Therefore, this study aims to analyze students' learning activities through the implementation of project-based worksheets and to examine the improvement of students' scientific explanation abilities after participating in a biopesticide production project using soursop leaf extract.

METHOD

Research Design

This study employed a pre-experimental design using a one-group pretest-posttest approach to examine the effectiveness of implementing project-based worksheets on students' scientific explanation skills in the context of producing biopesticides from soursop (*Annona muricata L.*) leaf extract. The design involved a single experimental group that received instruction through Project-Based Learning (PjBL). The participants were administered a pretest prior to the intervention, followed by the implementation of the treatment, and subsequently completed a posttest to measure changes in their scientific explanation skills (Sugiyono, 2023). The research design is presented in Table 1.

Table 1. One-Group Pretest-Posttest Design

Subject	Pretest	Treatment	Posttest
Student	O ₁	X	O ₂

Information:

O₁ = Pretest administered before the implementation of the intervention.

X = Implementation of project-based worksheets in the production of biopesticides from soursop (*Annona muricata L.*) leaf extract.

O₂ = Posttest administered after the implementation of the intervention.

This research design has inherent limitations in establishing causal relationships because it does not involve a control group or comparison

group. Therefore, changes in pretest and posttest scores cannot be fully attributed solely to the implementation of project-based worksheets; other factors, such as participant maturation, testing effects, and concurrent regular classroom learning processes, may also have contributed to these changes. This design was selected due to practical constraints that limited the study to only one available class. Therefore, the findings of this study should be interpreted as preliminary evidence of an association between the implemented intervention and improved learning outcomes, rather than as conclusive evidence of a causal relationship. Future studies are recommended to employ quasi-experimental designs, such as a nonequivalent control group design, or a randomized controlled trial to strengthen the internal validity of the research.

Participants

The participants in this study consisted of 35 eleventh-grade students from the Industrial Chemistry Program at SMKN 7 Bandung during the 2025/2026 academic year, who were enrolled in the Industrial Chemical Processes subject with environmental chemistry topics. The participants were selected from an intact class using a purposive sampling technique based on practical availability, as only one class could be accommodated within the research schedule. This condition limits the generalizability of the findings, which is further discussed in the Discussion and Conclusion sections.

Ethical clearance for this study was obtained from the Research Ethics Committee of UIN Sunan Gunung Djati Bandung. Official permission to conduct the research was granted by the school, and informed consent was obtained from all participating students and their parents or guardians, including consent for the use of research documentation presented in Figure 1 and Figure 2. To protect participants' privacy, all identifiable facial features in Figure 1 and Figure 2 were blurred prior to publication. In addition, the figures will be exported at a minimum resolution of 300 dpi in the final manuscript to be submitted.

Intervention Procedures

The intervention was conducted over two meetings (each lasting 5 × 45 minutes), following the six stages of Project-Based Learning (PjBL). Students were divided into six heterogeneous groups, consisting of five groups with six students and one group with five students. The groups were

formed by the teacher based on students' previous academic achievement to ensure a balanced group composition.

In each session, the researcher acted as a facilitator by introducing the learning objectives, supervising laboratory safety procedures, and guiding students through stimulating questions without providing direct answers. The first meeting focused on analyzing the problem of synthetic pesticide use and the potential utilization of soursop leaf waste as a biopesticide raw material, followed by project planning, including the preparation of testing procedures. The activities were then continued through laboratory investigations involving organoleptic testing, solubility testing, phytochemical screening, final biopesticide formulation, and analysis of the provided pest mortality data.

The second meeting focused on the final evaluation of the products developed by students and the presentation of project outcomes through posters and oral presentations by each group. After the presentations, students disseminated their posters through social media as a form of project dissemination and public education regarding the use of soursop leaf extract-based biopesticides as an environmentally friendly alternative for pest control.

Research Instruments

The research instruments consisted of: (1) a lesson plan; (2) a structured student observation sheet based on a 1–5 rating scale rubric with operational definitions for each stage of Project-Based Learning (PjBL); (3) project-based Student Worksheets (LKPD) designed to guide students through the six stages of PjBL, accompanied by an assessment rubric; (4) a scientific explanation test administered as a pretest and posttest; and (5) presentation, product, and poster assessment sheets used to evaluate the biopesticide produced during the project stages, including organoleptic testing, solubility testing, phytochemical screening, final formulation, and analysis of pest mortality data.

The scientific explanation test consisted of 15 essay items evenly distributed across the three Claim–Evidence–Reasoning (CER) components, with five items assigned to each component: five items for Claim, five items for Evidence, and five items for Reasoning. Each item was scored using different scales, with the Claim component assessed on a 0–2 scale, while the Evidence and Reasoning components were assessed on a 0–3 scale, resulting in a maximum possible score of 40. For example, one of the Reasoning items required students to explain the mechanism of acetogenin

compounds in soursop leaf extract in inhibiting cellular respiration and causing pest mortality. This item required students to connect chemical concepts with evidence obtained from experimental results.

All research instruments were reviewed by three expert validators, consisting of two Chemistry Education lecturers and one chemistry teacher from SMKN 7 Bandung, using a 0–3 rating scale covering content, construct, and language aspects. Content validity was subsequently quantified using Aiken's V coefficient, with results of $V > 0.79$ ($p < 0.05$) for all instrument items, indicating adequate content validity. Inter-rater reliability was analyzed using Cohen's kappa coefficient based on independent assessments by two raters on 20% of the sample ($n = 7$), yielding $\kappa = 0.85$, which indicates an almost perfect level of agreement. Meanwhile, the internal consistency of the instruments was analyzed using Cronbach's alpha coefficient, resulting in $\alpha = 0.82$, indicating good reliability. Revisions based on the validation results included converting the pretest and posttest items into essay questions, improving the concept map and concept analysis, aligning the scientific explanation indicators with the lesson plan, and refining the design of the Student Worksheets (LKPD).

Observation of learning activities was conducted by six Chemistry Education students who served as observers. Prior to the observation, all observers received training on the use of the assessment rubric and the operational definitions of each indicator to ensure a shared understanding of the assessment process. During the observation, each observer used the same instrument and assessed the assigned groups. Inter-rater agreement was achieved through calibration and consensus-based assessment without calculating a formal reliability coefficient.

Data Analysis

Descriptive statistical analysis was used to summarize the results of the Project-Based Learning (PjBL) implementation observations in the experimental class. Across the six PjBL stages, the overall mean score was 91.8, with a standard deviation of 6.61 and a maximum score of 98.95. The lowest mean score was obtained in the Problem Analysis stage, with a score of 83.3 ($SD = 11.53$), while the highest mean score was achieved in the Conducting the Investigation stage, with a score of 100.0 ($SD = 0.00$). Based on the predetermined assessment criteria, the implementation of all six PjBL stages was categorized as Very Good.

The normality of the pretest and posttest data was examined using the Shapiro–Wilk test, which is appropriate for the sample size of this study (n

= 35 < 50). Subsequently, differences in students' scientific explanation scores between the pretest and posttest were analyzed using a paired-samples t-test at a significance level of $\alpha = 0.05$. This analysis was only applied to compare pretest and posttest scores, not to compare the six stages of Project-Based Learning (PjBL). The magnitude of the difference was determined using the effect size (Cohen's d_z) for paired data, which was calculated using the formula $d_z = \frac{t}{\sqrt{n}}$. Values of approximately 0.20, 0.50, and 0.80 were interpreted as representing small, medium, and large effects, respectively. In addition, a 95% confidence interval was also calculated. The improvement in students' scientific explanation ability was further analyzed using the normalized gain (N-gain) proposed by Hake (1999), which was calculated using the following formula $g = \frac{\text{post-pre}}{\text{maksimum-pre}}$. A value of $g > 0.70$ was categorized as high, $0.30 \leq g \leq 0.70$ as medium, and $g < 0.30$ as low. The N-gain calculation was performed for both the overall score and each individual Claim-Evidence-Reasoning (CER) component, with a maximum score of 10 for the Claim component (5 items $\times$ maximum score of 2), and 15 for both the Evidence and Reasoning components (5 items $\times$ maximum score of 3 each).

RESULT AND DISCUSSION

Analysis of Students' Learning Activities

Student activities during the implementation of the project-based worksheets were assessed using a structured observation sheet across six learning groups based on the six stages of PjBL, namely problem analysis, project design, investigation, prototype development, product evaluation and refinement, and product presentation. The assessments for Stages 1, 2, 3, and 6 were based on the achievement of completing activities in the worksheets, while Stages 4 and 5 were evaluated based on the quality of students' responses to scientific explanation questions using the CER framework. The results of student activity assessments for each group are presented in Table 2.

The overall mean score for each group reached 90.6%, while descriptive analysis based on the six PjBL stages (Table 3) resulted in an average score of 91.8. This difference was due to variations in the units of analysis used for each calculation (see the reconciliation explanation below). Group 2 achieved the highest overall score (94.1%), followed by Group 4 (94.0%) and Group 6 (93.5%), whereas Group 5 obtained the lowest average score (81.8%), although it was still categorized as Very

Good. The lower performance of Group 5 was mainly attributed to its relatively low achievement in the problem analysis stage (68%).

Table 2. Results of the Student Activity Observation Sheet (%)

No	Project-Based Learning (PjBL) Stages	Student Learning Groups						Average (%)
		1	2	3	4	5	6	
1	Problem Analysis	88	80	80	96	68	96	84,6
2	Project Design	80	90	100	100	90	80	90
3	Conducting the Investigation	80	100	80	93,3	93,3	100	91,1
4	Developing the Draft/Prototype	90	100	100	90	80	90	91,6
5	Measuring, Evaluating, and Refining the Product	100	100	100	100	80	100	96,6
6	Finalization and Product Presentation	95	95	90	85	80	95	90
Average		88,8	94,1	91,6	94	81,8	93,5	90,6
Interpretation		Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good

Based on the analysis of each PjBL stage, the highest percentage was obtained in the measuring, evaluating, and refining the product stage, reaching 96.6%, with five out of six groups achieving the maximum score. This finding supports Adawiyah et al. (2026), who stated that students' direct involvement in product testing and improvement can enhance procedural understanding through hands-on learning experiences. In contrast, the problem analysis stage showed the lowest achievement (84.6%) with the greatest score variation (68–96), indicating differences among groups in identifying and formulating problems related to the utilization of soursop leaf waste. This condition is consistent with the characteristics of the initial stage of PjBL, which requires students'

analytical thinking abilities before obtaining experimental data as a basis for constructing scientific explanations (Retiyanto et al., 2023).

In addition to the group-level results presented in Table 2, students' performance was also analyzed descriptively at the individual level to provide a more comprehensive overview of learning performance, as presented in Table 3.

Table 3. Descriptive Statistics of LKPD Assessment at Each PjBL Stage in the Experimental Class

No	Stage	Mean	SD	Max	%	Category
1	Problem Analysis	83,3	11,53	93,3	83,3	Very Good
2	Project Design	95,3	4,56	100	95,3	Very Good
3	Conducting the Investigation	100	0	100	100	Very Good
4	Developing the Draft/Prototype	93,9	9,12	100	93,9	Very Good
5	Measuring, Evaluating, and Refining the Product	93,0	6,08	100	93,0	Very Good
6	Finalization and Product Presentation	85,2	10,41	94,4	85,2	Very Good
Overall average		91,8	6,61	98,95	91,8	Very Good

The highest score was obtained in the conducting the investigation stage, with a mean value (M) of 100.0 and a standard deviation (SD) of 0.00. This finding is consistent with Sholahuddin et al. (2023), who reported that students' direct involvement in hands-on experimental activities can enhance learning engagement and conceptual understanding. In the prototype development stage (M = 93.9; SD = 9.12) and the product evaluation/refinement stage (M = 93.0; SD = 6.08), assessment was based on students' ability to answer scientific explanation questions using the Claim–Evidence–Reasoning (CER) framework (McNeill & Krajcik, 2008). The very good achievement in both stages indicates that students were able to construct scientific arguments based on the investigation data they obtained. Meanwhile, the problem analysis stage showed the lowest score (M = 83.3; SD = 11.53), indicating that students still experienced challenges in identifying and analyzing problems during the initial stage of PjBL before obtaining experimental evidence to construct their scientific explanations (Retiyanto et al., 2023).

The overall percentage of Project-Based Learning (PjBL) implementation reported in Table 2 (90.6%) differs numerically from the overall mean reported in Table 3 (91.8%). Similar differences are also observed in several stages, such as the problem analysis stage (84.6% in Table 2 compared with 83.3 in Table 3) and the product evaluation and refinement stage (96.6% in Table 2 compared with 93.0 in Table 3). These differences are attributed to the different units of analysis used in each table. Table 2 uses the group-level unit of analysis ($n = 6$ groups), where each cell represents the average score of one learning group at a specific stage, while the overall percentage is calculated from the combined average of all groups and all stages.

In contrast, Table 3 uses an individual-level unit of analysis ($n = 35$ students), where descriptive statistics were directly calculated based on each student's scores at each stage. Although numerical differences were observed between the two tables, both consistently indicate that the problem analysis stage was the most challenging stage, whereas the conducting the investigation and product evaluation stages showed the highest achievements. This finding demonstrates that the observed pattern remains consistent and robust across both levels of analysis.

The biopesticide production project involved laboratory practical activities, particularly organoleptic testing and solubility testing (Figure 1), which were conducted according to standard procedures for evaluating the organoleptic properties and solubility of plant extracts as described by Octavia et al. (2023).



Figure 1. Students Conducting Organoleptic and Solubility Tests During The Biopesticide Production Project.

Following these two tests, the students proceeded with phytochemical analysis and biopesticide formulation to identify the secondary metabolites present in the extract and to prepare the final biopesticide concentration according to the research design, as presented in Figure 2.



Figure 2. Students Conducting Phytochemical Analysis and Preparing the Final Biopesticide Formulation Using Soursop (*Annona muricata* L.) Leaf Extract in the Laboratory.

Improvement in Students' Scientific Explanation Skills Following the Implementation of Project-Based Worksheets

Before hypothesis testing was conducted, the pretest and posttest data on students' scientific explanation skills were first examined for normality using the Shapiro–Wilk normality test. The results of the normality test are presented in Table 4.

Table 4. Normality Test Results for Pretest and Posttest Items

Average	Shapiro-Wilk			
	Statistic W	df	Sig	Information
Pretest	0,950	35	0,116	Normal distribution
Posttest	0,968	35	0,377	Normal distribution

The Shapiro–Wilk normality test indicated that both the pretest ($p = 0.116$) and posttest ($p = 0.377$) data were normally distributed ($p > 0.05$), allowing the use of parametric analysis. Although the posttest scores tended to be higher, their distribution (29–40 out of a maximum score of 40) was not concentrated at the maximum value (ceiling effect), indicating that the assumption of normality was still satisfied.

The paired-sample t-test revealed a significant difference between pretest and posttest scores, $t(34) = 25.595$, $p < 0.001$. The mean difference between scores was 17.37 points ($SD = 4.02$). The effect size was calculated using Cohen's d_z :

$$d_z = \frac{\overline{X}_{\text{diff}}}{SD_{\text{diff}}} = \frac{17.37}{4.02} \approx 4.32$$

The Cohen's d_z value of 4.32 indicates a very large difference between the pretest and posttest scores following the implementation of the project-based worksheets. The 95% confidence interval for the mean score difference ranged from 15.99 to 18.75, indicating that the increase in mean scores occurred consistently among the research participants.

Based on Table 6, the mean pretest score was 17.17 (SD = 3.97; range 6–24), which increased to 34.54 (SD = 2.97; range 29–40) in the posttest, with an overall N-Gain of 0.61 (moderate category). The decrease in standard deviation from the pretest (3.97) to the posttest (2.97) indicates that students' scores became more homogeneous after the intervention. This finding aligns with the view that structured project-based learning provides more equitable opportunities for all students to develop understanding through direct learning experiences.

Table 5. Paired-Sample T-test (Pretest-Posttest)

Variable	N	Mean	SD Difference	SE Mean	t	df	Sig. (2- tailed)	Informat ion
Posttest– Pretest	35	17,37	4,02	0,679	25,595	34	< 0,001	Significant

The results of the Paired Sample t-Test indicated a significant difference between students' pretest and posttest scores following the implementation of the Project-Based Learning (PjBL) model. As presented in Table 5, the calculated t-value was 25.595 with 34 degrees of freedom ($df = 34$), and the significance value was $p < 0.001$ (Sig. 2-tailed). Since the significance value was lower than 0.05, the null hypothesis was rejected and the alternative hypothesis was accepted. The mean difference between the posttest and pretest scores was 17.37, with a standard deviation of 4.02. These findings indicate that students' scientific explanation skills improved after participating in learning activities using the Project-Based Learning (PjBL) model.

The significant improvement suggests that the implementation of Project-Based Learning (PjBL) was associated with improved scientific explanation skills. Through the stages of PjBL, students were engaged in analyzing problems, designing experiments, and communicating their findings, thereby promoting the development of higher-order thinking skills and conceptual understanding. These findings are consistent with previous studies reporting that project-based learning provides students with contextual and meaningful learning experiences. herefore, the

implementation of the PjBL model can serve as an alternative instructional strategy for improving students' scientific explanation skills.

Descriptive statistics and N-Gain were used to analyze changes in students' scientific explanation skills before and after the implementation of Project-Based Learning (PjBL). The analysis was based on the pretest and posttest scores for each assessed aspect, while the improvement in students' skills was evaluated using the N-Gain score. The results of the analyses are presented in Tables 6 and 7.

Table 6. Descriptive Statistics of Pretest and Posttest

	N	Mean	SD	Min	Max
Pretest	35	17,17	3,97	6	24
Posttest	35	34,54	2,97	29	40
Gain	35	17,37	4,02	8	26

Table 7. N-Gain Scores for Each Scientific Explanation Aspect
(max = 15 per aspect)

Scientific Explanation Aspect	Pretest Mean	Posttest Mean	N-Gain	Interpretation
Claim	6.80	10,16	0,41	Moderate
Evidence	5.30	11,99	0,69	Moderate
Reasoning	5.07	12,42	0,74	High
Average	17,17	43,54	0,61	Moderate

*Total score across all three aspects (max = 40). N-gain was calculated as $g = \frac{\text{post-pre}}{\text{maksimum-pre}}$, with a maximum score of 15 points per aspect.

Based on Table 6, the mean pretest score was 17.17 (SD = 3.97; range 6–24), while the mean posttest score increased to 34.54 (SD = 2.97; range 29–40), representing an improvement of 17.37 points. The lower standard deviation in the posttest compared with the pretest indicates that students' score distribution became more homogeneous after the intervention. This finding is consistent with the study by Hindun et al. (2024), which reported that structured project-based learning provides students with opportunities to develop understanding through direct learning experiences.

Based on Table 7, the Reasoning component obtained the highest N-gain value of 0.74 (high category), indicating the greatest improvement in students' ability to connect evidence with claims using relevant scientific principles. This finding is consistent with the characteristics of Project-Based Learning (PjBL), which intensively trains students to explain the mechanisms of active compounds in soursop leaves, such as acetogenins, alkaloids, and flavonoids, in relation to pest mortality.

The improvement was particularly evident during the prototype development and product evaluation stages, in which students were required to explain cause-and-effect relationships based on experimental data using the Claim–Evidence–Reasoning (CER) framework (McNeill & Krajcik, 2008). The Reasoning aspect is one of the most demanding components of CER because it requires students to connect previously learned chemistry concepts with the results obtained from project activities. Therefore, the high N-gain value in this aspect indicates that direct learning experiences through projects contribute to the development of students' scientific reasoning abilities in a more profound manner.

The Evidence aspect obtained an N-gain value of 0.69 (moderate category and approaching the high category threshold), indicating that students' ability to use relevant and sufficient data to support a claim developed quite well. This was reflected in the utilization of phytochemical test results and pest mortality data at various extract concentrations as the basis for constructing scientific arguments.

The pest mortality data used by students as evidence in constructing scientific explanations were obtained from a bioassay conducted by the researcher, rather than from direct testing performed by the students. This was because mortality testing requires controlled conditions with an exposure period of approximately 72 hours, including the regulation of temperature, humidity, and feed availability, making it impossible to conduct within the duration of classroom learning activities. Therefore, students were provided with raw mortality data at several extract concentrations (0%, 25%, 50%, and 75%) to be analyzed based on the dose–response relationship pattern, which was then used as the basis for constructing scientific explanations using the Claim–Evidence–Reasoning (CER) framework.

This procedural decision aimed to ensure the reliability of the mortality data used in the learning process; however, on the other hand, it reduced students' direct involvement (ownership) in the inquiry process because they did not design or conduct the bioassay independently. Therefore, this aspect needs to be considered when interpreting the Evidence score, considering that students' main task at this stage focused more on their ability to interpret experimental data rather than to generate experimental data directly.

The Claim aspect obtained the lowest N-gain value, which was 0.41 (moderate category), indicating that students still experienced difficulties in formulating appropriate and concise statements or conclusions according

to the research problem. This finding is consistent with the LKPD results in the Problem Analysis stage, which also obtained the lowest score (83.3) compared with all other PjBL stages. These results further indicate that students' abilities in formulating problems and developing initial conclusions remain challenging. This condition is consistent with the opinion of Retiyanto et al. (2023), who stated that chemistry learning that is overly oriented toward theory limits students' abilities to construct valid and scientifically testable claims.

The overall N-gain value of 0.61 (moderate category) obtained in this study is comparable to the results reported by Sholahuddin et al. (2023) on the implementation of project-based learning combined with a flipped classroom approach to improve scientific literacy. These findings indicate that structured project-based Student Worksheets (LKPD) tend to produce improvements in abilities within the moderate to high categories across various learning contexts.

However, the very large effect size value obtained in this study $d_z = 4.33$ and the high N-gain value in the Reasoning aspect (0.74) need to be interpreted with caution. Posttest scores tended to be concentrated within a high score range (with a minimum score of 29 out of a maximum score of 40), indicating the possibility of a ceiling effect. In addition, because the Claim–Evidence–Reasoning (CER)-based assessment rubric was able to clearly reveal students' low initial abilities during the pretest, the improvement that occurred after the learning process may appear relatively large when expressed in the form of N-gain, even though the absolute increase in scores was not substantial.

In addition, because this study did not use a control group, other factors that may have contributed to the improvement in learning outcomes cannot be completely ruled out, such as the testing effect resulting from the use of instruments with similar structures in the pretest and posttest, student maturation during the three-week intervention period, statistical regression toward the mean among students with very low pretest scores, and the possibility of influences from regular learning activities occurring simultaneously.

Therefore, the improvement in abilities obtained in this study should be interpreted as being associated with the implementation of project-based LKPD, rather than as evidence of a causal relationship that is entirely attributed to the implementation of the project-based LKPD itself.

Specifically, within the context of chemistry education in vocational high schools (SMK), this pattern of findings indicates that SMK students

tend to demonstrate good abilities in procedural aspects and practical activities within Project-Based Learning (PjBL), as reflected by the very high achievement in the experimental stage. However, they still require scaffolding or more explicit instructional support to develop scientific argumentation skills, particularly in formulating claims.

Chemistry teachers in vocational high schools (SMK) are recommended to systematically integrate Claim–Evidence–Reasoning (CER)-based activities into project-based LKPD by providing greater support during the initial stages of problem identification and formulation. This strategy can help develop students' scientific reasoning abilities from the practical skills they already possess. However, because this study only involved one class with a limited sample size ($n = 35$), these findings are still preliminary; therefore, further research with broader sample coverage and more diverse locations is needed to strengthen their applicability.

CONCLUSION

This study analyzed the learning activities and scientific explanation abilities of 11th-grade students at SMKN 7 Bandung ($n = 35$) through the implementation of project-based Student Worksheets (LKPD) for the production of biopesticides from soursop leaf extract. Students' activities across all six stages of Project-Based Learning (PjBL) were categorized as Very Good, with an overall mean score of 91.8 ($SD = 6.61$). The highest achievement was obtained in the experimental stage ($M = 100$), while the lowest achievement was found in the problem analysis stage ($M = 83.3$). These findings indicate that students experienced greater difficulties in formulating problems during the initial stage of the project compared with the later implementation stages, which were more practical in nature.

Regarding students' scientific explanation abilities, the Shapiro–Wilk test results showed that the pretest ($p = 0.116$) and posttest ($p = 0.377$) data were normally distributed. Furthermore, the paired-samples t-test results indicated a significant difference between the pretest and posttest scores, $t(34) = 25.595$, $p < 0.001$ (Cohen's $d_z = 4.32$; 95% confidence interval $[3.41; 5.25]$). The mean score increased from 17.17 ($SD = 3.97$) to 34.54 ($SD = 2.97$), with an improvement of 17.37 points and an overall N-gain value of 0.61 (moderate category). The highest improvement occurred in the Reasoning aspect (0.74; high category), followed by Evidence (0.69; moderate category), while the Claim aspect showed the lowest improvement (0.41; moderate category). These findings are

consistent with the low achievement of students in the problem analysis stage during the implementation of project-based learning.

Overall, the implementation of project-based LKPD demonstrated a positive relationship with the improvement of students' learning activities and scientific explanation abilities. However, the limitations of the pre-experimental one-group pretest-posttest design without a control group, as well as the limited sample size from a single class ($n = 35$), indicate that these findings are still preliminary and cannot yet be widely generalized. Future studies are recommended to employ a quasi-experimental design with a comparison group, involve a larger sample size from multiple vocational high schools, and place greater emphasis on developing students' problem identification and scientific claim construction abilities.

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REFERENCES

- Adawiyah, R., Naswir, M., Ekaputra, F., Afrida, A., & Kriswantoro, K. (2026). Pengembangan LKPD Berbasis Problem Based Learning pada Materi Kimia Hijau Berorientasi Literasi Sains dan Hasil Belajar. *JURNAL PENDIDIKAN MIPA*, 16(2), 266–274. <https://doi.org/10.37630/jpm.v16i2.4142>
- Afnan, R., Munasir, M., Budiyanto, M., & Aulia, M. I. R. (2023). The Role of Scientific Literacy Instruments For Measuring Science Problem Solving Ability. *IJORER : International Journal of Recent Educational Research*, 4(1), 45–58. <https://doi.org/10.46245/ijorer.v4i1.271>
- Audina, M., Lukiyono, Y. T., Wulandari, D. D., & Romdloni, M. A. (2024). The effect of giving soursop leaves extract (*Annona muricata* L.) on *Aedes aegypti* instar iii larvae. *Environmental and Toxicology Management*, 3(2), 31–37. <https://doi.org/10.33086/etm.v3i2.6399>
- Cindowarni, O., & Setyawati, A. I. (2025). Bioactivity of Theobrom Cacao Leaf and Shell Extract of Biopesticide *Nezara viridula*. *Jurnal Agrotek Tropika*, 13(2), 482. <https://doi.org/10.23960/jat.v13i2.10081>

- Daraban, G. M., Hlihor, R. M., & Suteu, D. (2023). Pesticides vs. Biopesticides: From Pest Management to Toxicity and Impacts on the Environment and Human Health. In *Toxics* (Vol. 11, Number 12). Multidisciplinary Digital Publishing Institute (MDPI). <https://doi.org/10.3390/toxics11120983>
- Hindun, I., Nurwidodo, N., Wahyuni, S., & Fauziah, N. (2024). Effectiveness of project-based learning in improving science literacy and collaborative skills of Muhammadiyah middle school students. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(1), 58–69. <https://doi.org/10.22219/jpbi.v10i1.31628>
- Moghadamtousi, S. Z., Fadaeinasab, M., Nikzad, S., Mohan, G., Ali, H. M., & Kadir, H. A. (2015). *Annona muricata* (Annonaceae): A review of its traditional uses, isolated acetogenins and biological activities. In *International Journal of Molecular Sciences* (Vol. 16, Number 7, pp. 15625–15658). MDPI AG. <https://doi.org/10.3390/ijms160715625>
- Raman, Y., Surif, J., & Ibrahim, N. H. (2024). The Effect of Problem Based Learning Approach in Enhancing Problem Solving Skills in Chemistry Education: A Systematic Review. *International Journal of Interactive Mobile Technologies*, 18(5), 91–111. <https://doi.org/10.3991/ijim.v18i05.47929>
- Retiyanto, H. F., Putri, S. E., As-Shidiq, M. H., & Suyanta, S. (2023). Systematic Literature Review: Analysis of Student's Critical Thinking Skills towards Chemistry Learning. *Jurnal Penelitian Pendidikan IPA*, 9(SpecialIssue), 113–121. <https://doi.org/10.29303/jppipa.v9ispecialissue.6436>
- Sahrianti, N., Asnawiah Mastura, A., Farmasi, J., Wallacea, U., & Sulawesi Barat, P. (n.d.). Skrining Fitokimia Senyawa Metabolit Sekunder Daun Sirsak (*Annona muricata* L.) di Kabupaten Majene, Mamuju dan Mamuju Tengah. *Jurnal Ilmiah Farmasi Simplisia*, Desember, 2023(2), 2023.
- Salsabila, A. N., & Sukesu, T. Y. (2022). Efektivitas Larvasida Infusa Daun Sirsak (*Annona muricata* L.) terhadap Mortalitas Larva *Ae. aegypti*. *Jurnal Vektor Penyakit*, 16(1), 1–10. <https://doi.org/10.22435/vektor.v16i1.5646>
- Sholahuddin, S., Fadhillah, R., & Kurniasih, D. (2023). Efektivitas Model Pembelajaran Berbasis Proyek terhadap Pemahaman Konsep pada Materi Larutan Asam Basa. *Hydrogen: Jurnal Kependidikan Kimia*, 11(5), 666. <https://doi.org/10.33394/hjkk.v11i5.8675>

- Simanjuntak, M. P., Simatupang, H., Hardinata, A., Manurung, G. A., & Octavia, S. C. (2023). Literasi Sains Dengan Pembelajaran Ipa Berbasis Proyek Terintegrasi STEM. *Jurnal Pendidikan Fisika*, 12(1), 35. <https://doi.org/10.24114/jpf.v12i1.45733>
- Sugiyono. (2023). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (Edisi ke-2). Alfabeta.
- Sulianti, N. W. S., Alpin, A. Z., Ashari, M., Amalia, D. R., Alfionita, U., Sari, F. W., Aryatresna, I. G. A. E., Jamila, Z., Aprilia, D. C., Fitria, L., Kirana, A. D. C., Oktoria, A. P., & Pratiassandi, G. (2022). Pelatihan Pembuatan Pestisida Nabati Berbahan Dasar Daun Gamal dan Daun Pepaya Sebagai Inovasi Berkelanjutan dan Ramah Lingkungan Terhadap Pengendalian Hama Tanaman Budidaya. *Jurnal Gema Ngabdi*, 4(3), 273–278. <https://doi.org/10.29303/jgn.v4i3.273>
- Weni Mandasari, Yulizar Prawiranti, Sofi Siti Shofiyah, Muftiah Yasi Dwi Wahyuni, Fitriyan Kurnia, Atika Wulandari Putri, Dodi, Yudith Evametha Vitranilla, & Wenry Ramadhania. (2025). Inovasi Produk Kimia Ramah Lingkungan: Sabun Herbal dari Limbah Kulit Nanas sebagai Media Edukasi Siswa MAN 2 Pontianak. *JURPIKAT (Jurnal Pengabdian Kepada Masyarakat)*, 6(3), 1478–1487. <https://doi.org/10.37339/jurpikat.v6i3.2450>