

Integrating Potential Local Coffee into Project Based Science Module to Enhance Students' Critical Thinking Skills

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Abstract: Critical thinking is one of the essential competencies required in 21st century science education. However, the critical thinking skills of junior high school students in Indonesia remain relatively low due to the limited availability of contextual learning resources that actively engage students in authentic problem. This study aimed to develop and evaluate the effectiveness of a project-based science learning module that integrates local coffee resources through the production of coffee aromatherapy candles to enhance seventh-grade students' critical thinking skills. The study employed the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) development model and involved 30 seventh grade students from Class VII C at SMP Negeri 1 Panti, Jember. The developed module was validated by two science teachers and one science education lecturer. The results indicated that the module achieved a validity score of 90.93% (valid category) and a practicality score of 79% (practical category). Its effectiveness was demonstrated by a moderate N-gain score of 0.68, with students' average scores improving from 39.67 on the pretest to 80.80 on the posttest. Furthermore, students showed highly positive responses toward the module, with an average response score of 86.7%. These findings indicate that the project-based science learning module integrating local coffee resources is valid, practical, and effective in fostering junior high school students' critical thinking skills while providing meaningful contextual science learning experiences.

Keywords: project-based learning module, critical thinking skills, coffee aromatherapy candle.

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■ INTRODUCTION

Education continues to evolve in response to the demands of the times (Susanti et al., 2023). The learning process in 21st-century education focuses not only on mastering concepts but also on developing essential competencies such as critical, creative, collaborative, and communicative thinking. Science education, as part of the broader educational system, plays a strategic role in fostering these skills, particularly critical thinking. Critical thinking involves the process of analyzing facts, evaluating information, and drawing conclusions based on relevant evidence (Budianti et al., 2022; Aini et al., 2025). Thus, science learning should provide students

with opportunities to encounter meaningful problems and engage actively in processes that require analysis, reasoning, evaluation, and decision making rather than merely recalling scientific concepts.

Critical thinking is closely related to students' ability to apply scientific knowledge in situations that require interpretation and problem solving (Dewi et al., 2025). In science learning, students are expected to identify relevant information, provide appropriate explanations, evaluate possible solutions, draw conclusions, and determine strategies for addressing problems (Gizaw & Sota, 2023). These skills are reflected in several dimensions of critical thinking,

including basic support, elementary clarification, advanced clarification, inference, and strategies and tactics (Pamungkas et al., 2018). Learning activities that systematically involve these processes can help students move from simply understanding scientific information toward using scientific knowledge to explain phenomena and solve authentic problems. Therefore, the development of critical thinking requires learning environments that encourage students to investigate problems, discuss evidence, construct explanations, and reflect on the solutions they develop.

However, various studies indicate that students' critical thinking skills in Indonesia remain relatively low. Several studies report that the majority of students fall into the moderate to low categories in terms of critical thinking skills (Akwantin et al., 2022; Putri et al., 2024). This issue was also identified through a preliminary study conducted at SMP Negeri 1 Panti, Jember that the students' average critical thinking score was 45.25. Preliminary observations and interviews with the science teacher indicated that students experienced difficulties in analyzing scientific information, providing evidence-based explanations, drawing conclusions, and determining appropriate strategies to solve problems. This situation is influenced by various factors, such as the limited variety of learning resources, suboptimal teaching models, and low student engagement in the learning process (Wulandari et al., 2023). Teacher centered instruction also results in students being less accustomed to developing analytical and problem-solving skills independently. Science learning resources need to be designed not only to present scientific content but also to provide structured learning experiences that actively engage students in thinking and problem-solving processes.

One approach to address these issues is through the development of contextual science learning modules integrated with Project-Based

Learning (PjBL). A learning module can provide systematic guidance for students (Hamzah et al., 2022) by organizing learning objectives, scientific concepts, activities, investigations, and assessments within an integrated learning resource. Combined with PjBL, the module can provide students with a structured pathway for engaging in authentic learning activities while maintaining a clear connection between scientific concepts and project outcomes (Nurussalamah et al., 2025). Previous research has shown that Science learning modules can be systematically designed to help students understand the material while simultaneously fostering critical thinking skills (Yulianti & Herpratiwi, 2024). Furthermore, PjBL promotes authentic learning experiences by engaging students in investigating real-world problems, designing solutions, and producing meaningful products through collaborative inquiry (Indriati et al., 2024).

Project-Based Learning provides a relevant pedagogical framework because it places students in learning situations that involve authentic questions (Gomez-del Rio & Rodriguez, 2022), investigation, planning, implementation, and evaluation of a project (Ramírez de Dampierre et al., 2024; Sánchez-García & Reyes-de-Cózar, 2025). Project activities make students encouraged to investigate problems, discuss possible solutions, make decisions, collaborate with peers, and produce tangible products. These activities give students opportunities to apply scientific concepts in meaningful contexts rather than learning them as isolated information. The process of designing and producing a product also requires students to consider alternatives, predict possible outcomes, evaluate the feasibility of their decisions, and revise their solutions when necessary. These characteristics are closely related to the development of higher-order thinking and critical thinking skills. Previous studies have shown that project-based learning contributes positively to students' higher-order thinking skills (Zhang & Ma, 2023); however,

many existing learning modules focus on general science topics and rarely incorporate local resources as authentic learning contexts.

Integrating PjBL into science learning is particularly relevant because scientific knowledge is closely connected to phenomena students encounter in daily life. Contextual learning can help students recognize that scientific concepts are not limited to classroom discussions but can be used to explain materials, processes, and problems in their surrounding environment (Kristidhika et al., 2020). A contextual approach may also increase the relevance of learning by connecting scientific concepts with students' experiences and local conditions. Learning resources that utilize local potential can provide authentic contexts in which students investigate familiar materials through scientific perspectives (Purwasih et al., 2025). The integration of local potential is therefore expected to strengthen the meaningfulness of science learning while providing opportunities for students to develop scientific reasoning through direct investigation.

Local potential can serve as an important contextual resource for science education because it connects the learning process with the physical, social, and economic environment surrounding students. Integrating local potential into science learning is expected to enhance students' engagement (Wijayanti et al., 2025) and make scientific concepts more meaningful (Afkarina Izzata Dini & Febri Setiya Rini, 2024) by connecting classroom learning to their surrounding environment. Rather than introducing scientific problems exclusively through abstract examples, teachers can use materials students encounter in daily life as objects of observation and investigation. This approach allows students to connect scientific concepts with real-world phenomena. In project-based learning, local resources can also serve as materials for developing products, creating a direct relationship between scientific concepts, investigation

activities, and project outcomes. Consequently, using local resources can strengthen the contextual dimension of PjBL and provide a meaningful foundation for developing science learning modules.

Panti Village in Jember Regency is well known as one of the coffee-producing areas in East Java, providing abundant local resources that can be utilized in contextual science education. In this study, coffee was employed as the primary material for producing aromatherapy candles, allowing students to explore concepts related to mixtures, changes in matter, heat transfer, and material properties through an authentic project. This contextual approach is expected not only to strengthen students' understanding of scientific concepts but also to stimulate critical thinking through hands-on investigation and problem-solving activities.

The integration of local coffee resources distinguishes the proposed module from learning resources that primarily present science concepts through general or decontextualized examples. Previous studies have examined the development of project-based learning modules and their use to support students' higher-order thinking skills. However, the existing discussion in the present literature base has paid limited attention to learning modules that simultaneously integrate Project-Based Learning, local coffee resources, and critical thinking development in junior high school science education. Using local coffee as the basis for a product-oriented science project therefore provides a contextual dimension that strengthens the relationship between the learning content, students' environment, and project activities.

Based on the foregoing arguments, a project-based science learning module is needed that uses local coffee resources as an authentic learning context and provides structured opportunities for students to develop critical thinking skills. The novelty of this study lies in integrating local coffee resources from Panti, producing coffee aromatherapy candles as a

science project, and explicitly aligning project activities with critical thinking indicators. Therefore, this study aims to develop and evaluate a project-based science learning module using local coffee resources to support the development of junior high school students' critical thinking skills. Specifically, this study addresses the following research questions: (1) How valid is the developed project-based science learning module using local coffee resources? (2) How practical is the developed module when implemented in junior high school science learning? (3) To what extent does the implementation of the developed module improve students' critical thinking skills? Furthermore, (4) How do students respond to the use of the developed project-based science learning module using local coffee resources?

■ METHOD

Types of Research

This study employs a research and development (R&D) approach using the ADDIE model, which consists of five stages: analyze, design, develop, implement, and evaluate. The ADDIE model was chosen because its systematic, structured steps support the development of a learning product, enabling the creation of a valid, practical, and effective module for use in the learning process.

This study aims to develop a science learning module based on a project to make coffee aromatherapy candles in order to improve students' critical thinking skills. In the first stage analysis the researcher identified needs through observation and interviews to determine the learning conditions, student characteristics, and problems faced in the classroom. The design phase involved developing the module's content outline, presentation structure, and learning components.

In the development phase, the designed module was refined by integrating instructional

models and critical thinking competency indicators, then validated by experts to assess feasibility. Once validated, the module is implemented in classroom learning activities to assess its practicality and effectiveness. The evaluation phase is conducted at each stage to assess the overall development process and improve the module based on implementation results.

Research Subjects and Objects

The subjects of this study were seventh-grade students at SMP Negeri 1 Panti, who served as respondents in a pilot test of a project-based science learning module on making coffee aromatherapy candles. The participants were selected using purposive sampling based on predetermined inclusion criteria, which were: (1) students had participated in the science learning activities relevant to the topics addressed in the developed module; (2) students were able to participate in the learning activities and complete the required learning assessments; and (3) students received permission to participate in the study from the relevant parties. Because the participants were junior high school students, the study was conducted in accordance with applicable ethical principles for research involving minors. Before implementing the learning intervention, permission to conduct the study was obtained from the school. Informed consent from the students' parents or legal guardians was also obtained prior to their participation, where required. Students were informed about the purpose and procedures of the study; their participation was voluntary, and the data collected were used solely for research purposes. The students' identities were kept confidential and were not disclosed in the reporting of the research findings. In addition, the study also involved validators consisting of subject matter experts and media experts to assess the suitability of the developed module.

This study focuses on a project-based science learning module on making coffee aromatherapy candles, developed to enhance students' critical thinking skills. The aspects analyzed include the module's validity, practicality, and effectiveness in the learning process. Furthermore, the study focused on students' critical thinking skills, measured through several indicators: basic support, elementary clarification, advanced clarification, inference, and strategies and tactics.

Data Types and Sources

The data used in this research are primary and secondary. The types of data in this study consist of quantitative and qualitative data. Quantitative data were obtained from expert validation assessments, observations of the implementation of the learning process, and results of students' critical thinking ability tests through pretests and posttests. In addition, quantitative data were also obtained from student questionnaires regarding their responses to the use of the module.

Meanwhile, qualitative data were obtained from validators' suggestions and feedback on the developed module as well as from observations during the learning process. Data sources in this study included students as test subjects, expert validators, and documentation of learning activities.

Data Collection Technique

The data collection techniques used in this study included several methods: validation, testing, observation, and questionnaires. Experts conducted validation to assess the modules'

suitability in terms of content, presentation, language, and graphics. Tests measured students' critical thinking skills through pretests and posttests. The pretest was administered before instruction to determine students' initial abilities, while the posttest was administered after instruction to determine the improvement in students' critical thinking skills. The critical thinking test used in the pretest and posttest consisted of 10 items covering five critical thinking indicators: basic support, elementary clarification, advanced clarification, inference, and strategies and tactics. The researchers developed the test items based on these critical thinking indicators and contextualized them to the science content and learning objectives of the developed module. Before administration, expert validators reviewed the test items to establish content validity. The validators evaluated the relevance, clarity, and suitability of the items with respect to the targeted critical thinking indicators and the learning objectives. Empirical validity and reliability testing were conducted using data from 60 respondents. The validity analysis employed the corrected item-total correlation, with obtained correlation coefficients ranging from 0.463 to 0.750, exceeding the critical value of 0.254 at the 5% significance level. Thus, all 10 test items were considered valid. The reliability analysis using Cronbach's Alpha yielded a coefficient of 0.891, indicating a high level of internal consistency. Observations were conducted to assess the implementation of instruction using the developed module. Additionally, a student response questionnaire was used to gauge students' feedback on the implemented project-based learning module.

Table 1. Results of the critical thinking test item validity analysis

Item	r-count	r-table	Decision
Item 1	0.547	0.254	Valid
Item 2	0.463	0.254	Valid
Item 3	0.638	0.254	Valid
Item 4	0.695	0.254	Valid

Item 5	0.750	0.254	Valid
Item 6	0.713	0.254	Valid
Item 7	0.549	0.254	Valid
Item 8	0.646	0.254	Valid
Item 9	0.615	0.254	Valid
Item 10	0.691	0.254	Valid

Data Analysis Techniques

The collected data were then analyzed using descriptive quantitative and qualitative methods. Validity analysis was conducted by calculating the percentage of scores from the validators' assessments, which were then categorized according to predetermined criteria. Practicality data were analyzed based on observation results of the implementation of learning, calculated as percentages. Meanwhile, effectiveness was analyzed using N-gain calculations to determine improvement in students' critical thinking skills based on pretest and posttest results. The data analysis steps include: (1) collecting and organizing data, (2) processing and calculating quantitative data, (3) interpreting the analysis results, and (4) drawing conclusions based on the data obtained. With this analysis technique, it is hoped that a clear picture of the feasibility and effectiveness of the developed module will be obtained.

■ RESULT AND DISCUSSION

The development of the project-based science learning module followed the ADDIE model, consisting of the Analyze, Design, Develop, Implement, and Evaluate stages. The analysis stage identified the learning conditions, student characteristics, and problems encountered in science learning at SMP Negeri 1 Panti. Data were obtained through classroom observations and interviews with the science teacher. The analysis served as the basis for determining the characteristics and learning needs that needed to be addressed through the developed module.

The preliminary analysis indicated the need for learning resources that could provide students

with more structured opportunities to engage in scientific investigation, discussion, interpretation, and problem-solving. This need was particularly relevant to developing critical thinking skills because the module was designed to involve students in activities requiring basic support, elementary clarification, advanced clarification, inference, and strategies and tactics. The analysis stage therefore established the main requirements for the developed product, namely the integration of science concepts, project-based activities, contextual learning, and critical thinking activities.

The design stage translated the analysis findings into the initial structure of the learning module. At this stage, the researchers developed the content outline, presentation structure, learning activities, and supporting components of the module. The coffee aromatherapy candle project was selected as the central learning activity because it provided a contextual setting for students to explore scientific concepts related to mixtures, changes in matter, heat transfer, and material properties. The module was designed to guide students progressively from introducing the problem and scientific concepts to investigation, project implementation, interpretation of findings, and evaluation of project outcomes.

Characteristics and Validity of the Developed Module

The developed product is a project-based science learning module centered on producing coffee aromatherapy candles using local coffee resources. The module combines scientific content, contextual problems, project activities, critical thinking tasks, and evaluation activities.

Using coffee as a local resource provides a direct connection between science concepts and students' surrounding environment, while producing aromatherapy candles offers a tangible project through which students can investigate material properties and changes.

Before implementation in classroom activities, the science learning module on making coffee aromatherapy candles underwent expert validation. The validation test was conducted to

assess the module's suitability across various aspects, including content validity, materials, presentation, language, and graphics. The validation analysis showed that the module achieved an average score of 90.93%, placing it in the "valid" category. This indicates that the developed module meets the suitability criteria and can be used in the learning process after revisions are made in accordance with the suggestions and feedback from the validators.

Table 2. Results of the module validity analysis

No	Evaluation Criteria	Average Percentage (%)	Category
1	Content Validity	90.67	Valid
2	Content Aspects	90.67	Valid
3	Presentation Aspects	92.00	Valid
4	Language Aspects	93.33	Valid
5	Graphic Design Aspects	92.00	Valid
Average Score		90.93	Valid

The language aspect obtained the highest validation percentage, at 93.33%. This result suggests that the instructions, explanations, and wording used in the module were considered clear and appropriate for the target students. The presentation aspect obtained a score of 92.00%, indicating that the organization of the learning material and activities was considered appropriate. The graphic design aspect also obtained 92.00%. Although this score remained within the valid category, it was slightly lower than the language score. This difference may indicate that the visual organization and graphic elements still offered greater opportunities for refinement than the module's wording. The content validity and content aspects each obtained 90.67%. These results indicate that the scientific content and its alignment with the intended learning objectives were considered appropriate.

Practicality of the Developed Module

After validated, the module was then implemented in classroom instruction for seventh-

grade students at SMP Negeri 1 Panti. The instruction took place over four sessions, using the module as the primary learning resource. The instructional activities were designed using a project-based approach, encompassing problem identification, project design, activity implementation, and evaluation of project outcomes.

The learning was conducted using a science learning module based on a developed project to make coffee aromatherapy candles. The learning activities were carried out over four sessions, using the module as the primary learning resource. The implementation of the learning referred to the core activities using the developed learning module, which included stimulation and guidance of module activities, discussion, analysis, interpretation, observation, formulating scientific answers, and evaluation of project results.

A practicality test was conducted through observations of the learning implementation, which three observers evaluated. Based on the analysis results, the module obtained an average

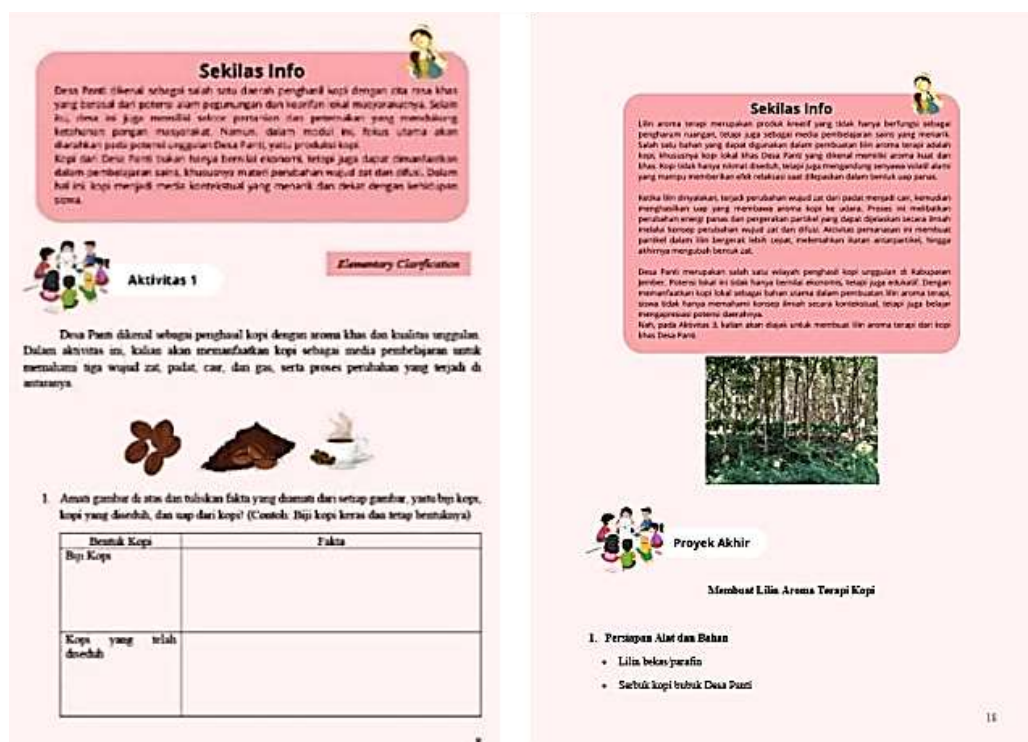


Figure 1 Integrating critical thinking and local potential into the module

implementation score of 79%, falling into the “practical” category. These results indicate that the module can be effectively utilized in the learning process. In each activity, the teacher guided

students in developing indicators of critical thinking skills, such as basic support, elementary clarification, advanced clarification, inference, and strategies and tactics.

Table 3. Results of the analysis of implementation observations

Activity	Observer Score	Average (%)	Category
The teacher provides stimulation and guidance for Activity 1 in the module	4	80	Practical
The teacher guides students in a discussion to determine the states of matter (basic support)	4	80	Practical
The teacher guides students in analyzing the properties of the objects shown in the images in the module (elementary clarification)	3	67	Practical
The teacher guides students in interpreting the properties of each state of matter (advanced clarification)	4	73	Practical
The teacher directs students to observe the images and answer the mini case study in Activity 2 (inference)	4	80	Practical
The teacher directs students to develop scientific tactics and strategies to solve the presented problems (strategies and tactics)	5	93	Very Practical
The teacher explains the final project of making coffee aromatherapy candles to the students	4	80	Practical
Average		79	Practical

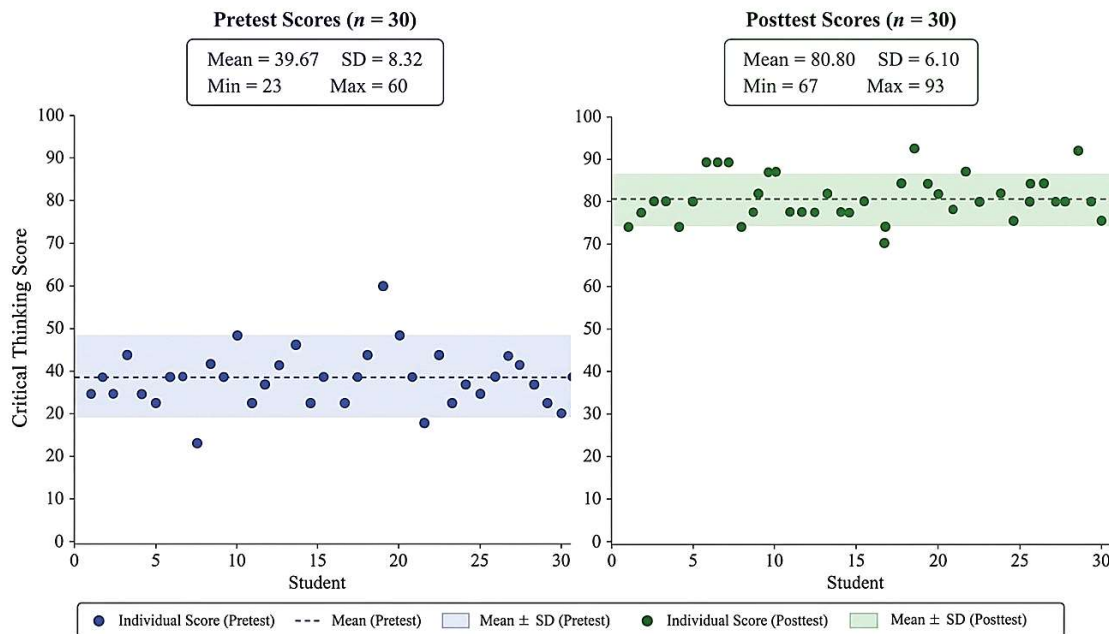
Figure 2. Scatter plot of pretest and posttest scores

The results indicate that the developed learning modules can be effectively used in the learning process and can optimally facilitate student activities. The improvement in implementation during each session suggests that students and teachers are becoming increasingly accustomed to using project-based modules. In addition, students appeared to be more active

and engaged in learning activities, particularly in collaborating, discussing, and completing assigned projects. Nevertheless, several challenges were still encountered during implementation.

Effectiveness on Learning Outcomes

Students' critical thinking skills were assessed through pretests and posttests

**Figure 2.** Scatter plot of pretest and posttest scores

administered after implementing a science learning module based on a project to make coffee aromatherapy candles. The results showed significant improvement, with the average pretest score rising from 39.67 to 80.80 on the posttest. This improvement indicates that the implemented learning approach brought about positive changes in students' critical thinking skills.

To determine the level of improvement more precisely, the data were analyzed using the N-gain calculation, yielding a value of 0.68, which falls into the moderate category. These results indicate that the developed learning module is quite effective in improving students' critical thinking skills.

Further analysis of each critical thinking indicator shows that the indicators for basic support, elementary clarification, and advanced clarification fall into the moderate category. This indicates that students can understand problems, provide simple explanations, and develop reasoning step by step. Meanwhile, the indicators for inference and strategies and tactics fall into the high category, indicating that students have shown greater improvement in their ability to draw conclusions and determine problem-solving strategies. The effectiveness of the developed project-based science learning module was evaluated by comparing students' critical thinking scores before and after the learning intervention.

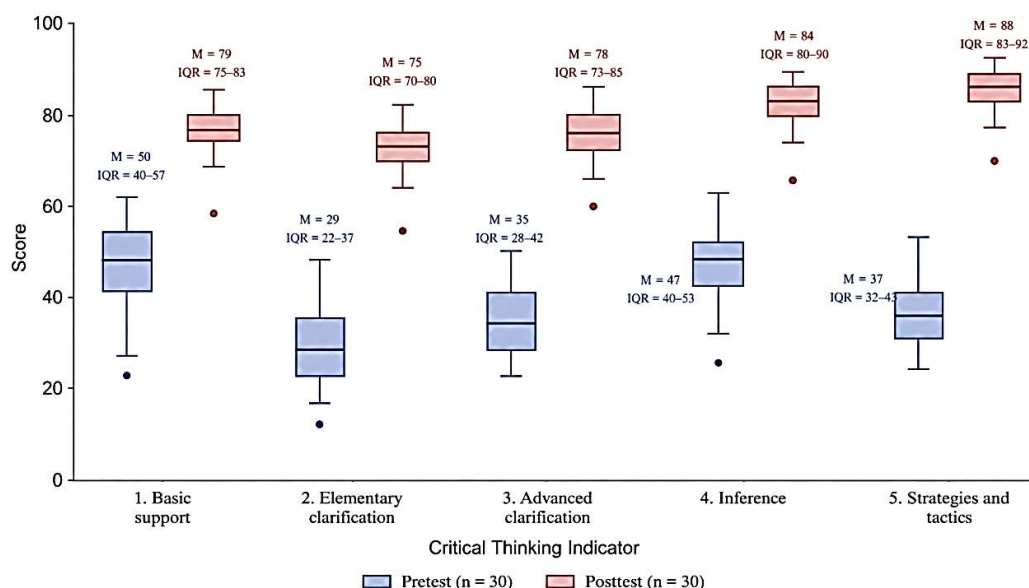


Figure 3. N-Gain analysis of critical thinking skills indicators

A paired-samples t-test was conducted because the pretest and posttest scores were obtained from the same group of students. The normality test of the difference scores showed that the data were normally distributed (Shapiro–Wilk = 0.946,

$p = 0.130$), indicating that the assumption for the paired-samples t-test was satisfied.

The descriptive analysis showed that the mean pretest score was 39.67 (SD = 8.23), whereas the mean posttest score increased to

Table 5. Paired sample t-test results

Pair	Mean Difference	SD	95% CI Lower	95% CI Upper	t	df	p
Posttest – Pretest	41.13	7.96	38.33	44.27	28.427	29	<0.001

80.80 (SD = 5.87). Thus, the mean score increased by 41.13 points after implementing the developed module. The paired-samples t-test revealed a statistically significant difference between the pretest and posttest scores, $t(29) = 28.427$, $p < 0.001$, with a 95% confidence interval for the mean difference ranging from 38.33 to 44.27. The effect size was also very large (Cohen's $d_z = 5.19$), indicating a substantial within-group change in students' critical thinking performance. These results demonstrate that students' critical thinking scores were significantly higher after participating in the learning activities using the developed module. The findings provide statistical evidence of improved critical thinking

performance following the implementation of the project-based science learning module using local coffee resources. However, because the study employed a one-group pretest-posttest design without a comparison group, the results should be interpreted as evidence of significant within-group improvement rather than definitive evidence of a causal effect of the developed module.

Student Responses of Developed Module

Student responses to the science learning module, based on a project to make coffee aromatherapy candles, were measured through a questionnaire administered to 30 seventh-grade students after the learning activity was completed.

This questionnaire covered three main indicators: interest, content, and language. The analysis results showed that the average percentage of

student responses reached 86.7%, falling into the “very good” category. In detail, interest received 85.9%, content 87.7%, and language 86.4%.

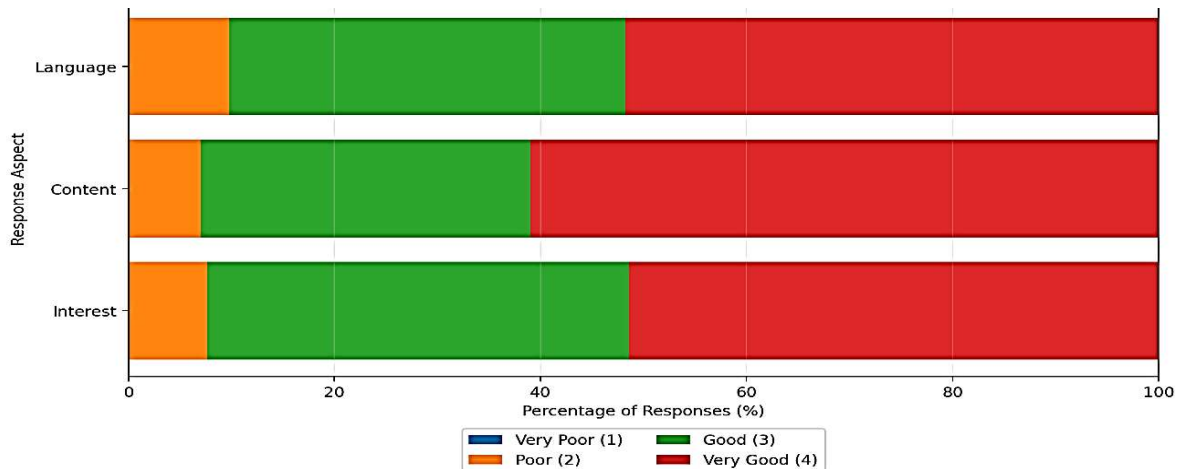


Figure 4. Results of the student response questionnaire analysis

The results show that students responded very positively to the learning module. The high percentages for each indicator suggest that the module is not only engaging and easy to understand but also relevant to students' learning needs. The project-based learning module on making coffee aromatherapy candles fosters more active and meaningful learning and supports the development of students' critical thinking skills. The research results show that the developed project-based learning module for making coffee aromatherapy candles meets the criteria of being valid, practical, and effective for use in learning. The validation stage is an important initial step in ensuring product quality before classroom implementation. This process not only assesses the module's feasibility but also identifies shortcomings and refines the product based on expert feedback (Sari, 2020). The validation results indicate that the module falls into the valid category in terms of both content and construct aspects, which include material, presentation, language, and graphics. This indicates that the module was systematically designed in accordance with learning outcomes and aligned with the critical thinking ability indicators intended

to be developed (An Nabil et al., 2022; Asri & Dwiningsih, 2022). The produced module is not only feasible for use but also has a strong theoretical and pedagogical foundation.

The implementation stage shows that the module is highly practical, with learning feasibility falling into the practical to very practical category for each activity indicator. This indicates that the module is easy for both teachers and students to use and can facilitate the learning process in a more directed manner. Project-based learning implemented through the module provides an active and meaningful learning experience, where students are directly involved in observation, analysis, and product creation activities. This gradual, systematic process allows students to develop critical thinking skills in stages, from understanding problems to formulating solutions (Sutarto et al., 2023). In addition, the use of real-world context in the form of coffee as a local potential further strengthens the connection between the learning material and the students' daily lives, thereby increasing the relevance and appeal of the learning experience.

In terms of effectiveness, the research results show a significant improvement in students'

critical thinking skills after using the module. The significant difference between pretest and posttest scores, along with the moderate N-gain value, indicates that the module positively impacts learning outcomes. The mean critical thinking score increased from 39.67 (SD = 8.23) on the pretest to 80.80 (SD = 5.87) on the posttest, representing a mean increase of 41.30 points. The paired-samples t-test confirmed that the difference between the pretest and posttest scores was statistically significant, $t(29) = 28.427$, $p < 0.001$, with a 95% confidence interval of the mean difference ranging from 38.33 to 44.27. Using pretests and posttests as measurement instruments provides a clear picture of changes in students' abilities before and after learning (Rojikin et al., 2022). This aligns with the view that a learning product is effective if it produces a significant improvement in learning outcomes (Yusuf et al., 2023). The developed module not only serves as teaching material but also as a means to enhance the overall quality of learning.

The magnitude of improvement found in this study is comparable to that reported in previous empirical studies implementing Project-Based Learning (PjBL). Herlita et al (2023) reported an N-gain of 0.417 using a PjBL-STEM model for science learning, which was categorized as moderate. Similarly, Putri et al (2019) found an average N-gain of 0.47 in the PjBL group when learning involved projects for recycling used cooking oil. These findings indicate that moderate gains in critical thinking are consistently observed when PjBL is implemented through authentic and problem-oriented learning activities. Other studies have reported higher levels of improvement. Andini & Rusmini (2022) reported N-gain values of 0.70 following the implementation of PjBL in colloid learning. Therefore, compared with previous PjBL studies, the improvement achieved in the present study falls within the range of gains reported in the literature. The comparison also suggests that the effectiveness of PjBL may vary

depending on the learning content, student characteristics, instructional design, learning duration, and assessment instruments used. The present study demonstrates a substantial absolute increase of 41.30 points between the pretest and posttest scores. This increase is accompanied by a statistically significant difference and a moderate N-gain, providing evidence that the developed module contributed positively to students' critical thinking development. Although direct comparisons of N-gain values should be made cautiously because of differences in research contexts and measurement instruments, the findings are consistent with previous empirical evidence showing that PjBL can facilitate the development of critical thinking skills. The project-oriented activities provide students with opportunities to identify problems, gather and evaluate information, formulate solutions, make inferences, and apply their knowledge to authentic tasks.

The indicators of inference and strategies and tactics fall into the high category, while the other indicators fall into the moderate category. The relatively greater improvement in inference may be related to the investigative sequence embedded in the coffee aromatherapy candle project. During the project, students were not only instructed to follow a predetermined procedure but also observed materials and their characteristics, interpreted changes that occurred during the activity, and formulated scientific explanations. These findings indicate that project-based learning is more effective in training higher-order thinking skills related to decision-making and problem-solving. Project activities that require students to produce tangible products encourage students to think more applicatively and reflectively (Omelianenko & Artyukhova, 2024). Meanwhile, basic skills such as analysis and clarification still require more intensive practice and habituation. Therefore, the teacher's role in providing scaffolding is crucial to help students

develop critical thinking skills more effectively (Amala et al., 2020). The answer to question number 3 in this module consists of two distinct responses: one response illustrating a student's

answer that has not yet demonstrated critical thinking skills, and another response illustrating a student's answer that has demonstrated critical thinking skills.

3. Taktik Ilmiah: Mendesain Strategi Aroma Tahan Lama

Susunlah taktik atau strategi ilmiah untuk menjawab pertanyaan berikut!

Bagaimana agar aroma dari lilin kopi lebih lama menyebar di ruangan? Tentukan variabel yang bisa diubah (misalnya ventilasi, suhu ruangan, bentuk wadah lilin, posisi peletakan lilin).

aroma lilin kopi lebih lama dengan cara jika ditaruh di tengah ruangan dan semua pintu ditutup agar aromanya tidak keluar ruangan. Hal yang diubah adalah ~~per~~ posisi dan ventilasi ruangan

(a)

3. Taktik Ilmiah: Mendesain Strategi Aroma Tahan Lama

Strategies & Tactics

Susunlah taktik atau strategi ilmiah untuk menjawab pertanyaan berikut!

Bagaimana agar aroma dari lilin kopi lebih lama menyebar di ruangan? Tentukan variabel yang bisa diubah (misalnya ventilasi, suhu ruangan, bentuk wadah lilin, posisi peletakan lilin).

Agar aroma lilin kopi lebih lama menyebar di ruangan, saya akan mengubah beberapa hal, yaitu ventilasi, suhu ruangan, dan posisi lilin. Ventilasi saya buka sedikit agar udara tetap bersirkulasi sehingga aroma menyebar ke seluruh ruangan, tapi tidak terlalu cepat keluar. Suhu ruangan saya jaga 25-27°C dan tidak membiarkan terlalu lembab agar suhu stabil, lilin saya letakkan di tengah sehingga aromanya dapat menyebar ke berbagai arah. Saya akan mencoba beberapa kondisi tersebut satu per satu dan membandingkan hasilnya untuk mengetahui strategi yang membuat aroma bertahan paling lama.

(b)

Figure 5. (a) student's answer reflecting low critical thinking; (b) student's answer reflecting high critical thinking

Students' responses to the module also showed very good results, as reflected in the high percentage of positive responses regarding interest, content, and language. This indicates that the module captures students' attention, facilitates understanding of the material, and creates an enjoyable learning atmosphere. This positive response indicates that the learning is not only cognitively effective but also capable of enhancing student motivation and engagement in the learning process. This aligns with the view that a high student response is an indicator of successful learning (Nabillah et al., 2024; Wahyuni et al., 2022).

Based on observations during the learning process, several challenges were identified in using project-based modules. The first challenge is that students still struggle to analyze problems related to the module's content. This indicates that students' critical thinking skills, particularly at the analysis stage, still need improvement. To address this, the teacher provided guidance through scaffolding questions to help students better focus on understanding and analyzing the problems. The second challenge is that not all students are active in group work; some tend to be passive and merely follow their peers. This

situation can hinder the effectiveness of project-based learning, which emphasizes active engagement. Therefore, the teacher assigns tasks more systematically so every student has responsibilities and plays an active role in group activities. With these solutions in place, the challenges can be minimized, allowing learning to proceed more effectively and in a conducive environment.

■ CONCLUSION

This research shows that the developed project-based learning module for making coffee aromatherapy candles meets the criteria of being valid, practical, and effective for use in learning. The validity test results showed an average of 90.93% in the valid category, indicating that the module is suitable for implementation. The implementation stage, or practicality test, obtained an average of 79% in the practical category, indicating that the module is easy to use and can support optimal learning execution.

The module's effectiveness is shown by an increase in students' critical thinking skills. The increase in the average score from the pretest of 39.67 to 80.80 on the posttest, as well as an N-gain value of 0.68 in the moderate category. In

addition, the student response questionnaire results of 86.7% indicate that students gave very positive feedback on the module. This confirms that project-based modules can create meaningful learning and support the development of critical thinking skills. However, this study still has limitations, particularly in the scope of the material focused on a single topic and the limited number of meetings. Therefore, future research should develop and implement similar modules in other science subjects with a broader scope and longer learning time. Thus, the results obtained can provide a more comprehensive picture regarding the effectiveness of project-based learning in enhancing students' critical thinking skills.

■ **DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS**

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) solely to assist with language editing, sentence refinement, and improving the manuscript's clarity and coherence. The authors developed and verified all scientific content, analysis, interpretations, and conclusions. After using the tool, the authors reviewed and revised the content as necessary and accept full responsibility for the final content of the article.

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