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The Development of PBL-Based Local Curriculum Materials on Rice-Field Arthropods to Enhance Pupils' Critical Thinking Skills

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Abstract

This research was motivated by the limited availability of teaching materials that facilitate students' critical thinking skills related to Arthropoda in rice field ecosystems. The study aimed to develop a Problem-Based Learning (PBL)-based student worksheet (LKPD), determine its feasibility, and assess improvements in students' critical thinking skills following its use. The study employed a Research and Development (R&D) method using the 3D model (Define, Design, and Develop). The LKPD was validated by a subject matter expert, a media expert, and a biology teacher and tested on 42 students using a pretest-posttest design. Data were analyzed using N-Gain analysis and the Wilcoxon Signed-Rank Test. The average score increased from 30 to 41, with an N-Gain of 0.79 (high category), while the Wilcoxon Signed-Rank Test showed a significant difference. All six Facione indicators improved following the use of the LKPD.

Keywords: *LKPD, Problem-Based Learning, Arthropods, rice paddy ecosystems, critical thinking*

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INTRODUCTION

The demands of 21st-century education are no longer focused solely on mastering concepts but also on developing higher-order thinking skills (HOTS), one of which is critical thinking. Critical thinking skills are necessary for students to understand information, identify relationships among pieces of information, evaluate evidence and arguments, draw logical conclusions, and reflect on their thinking processes. Facione, 2019 identifies six key indicators of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation. These indicators demonstrate that critical thinking involves not only understanding information but also interpreting information, analyzing relationships among pieces of information, evaluating evidence and arguments, drawing conclusions based on evidence, explaining the reasons underlying decisions, and monitoring and refining one's own thinking processes (Zulfatunnisa & Maknun, 2022). Therefore, biology instruction should be designed not only to convey concepts but also to provide learning experiences that enable students to apply those concepts to analyze and solve real-world problems.

This issue is relevant to biology education, particularly for complex topics that are closely related to real-world phenomena. The topic of biodiversity not only requires students to identify and classify organisms but also to understand the relationships between organisms and their environments and analyze changes that occur within an ecosystem (Nursidin et al., 2022). One context that can be used to illustrate real-world problems is the rice paddy ecosystem. Rice paddy ecosystems are home to various types of arthropods that perform different ecological functions, such as herbivores, predators, and detritivores. The interactions among these organisms play a role in maintaining the ecosystem's balance, so changes in the population of one group of arthropods can affect other groups of organisms (Thei et al., 2020). These characteristics make arthropods in rice paddy ecosystems not only relevant for teaching classification, but also a potential authentic context for developing critical thinking skills through ecological issues that are closely related to students' daily lives.

One learning approach that addresses these needs is Problem-Based Learning (PBL). PBL uses authentic problems as the starting point for learning, encouraging students to understand the problem, organize the necessary information, conduct an investigation, develop alternative solutions, and evaluate the results (Herzon et al., 2018). These characteristics are related to Facione's six indicators of critical thinking skills. The problem-orientation stage can facilitate interpretation through activities that involve understanding phenomena and identifying important information. The learning organization and investigation stage can facilitate analysis through the process of identifying relationships among pieces of information, as well as evaluation through the assessment of the evidence obtained. The process of investigation and solution development can support inference by drawing conclusions based on evidence. The stage of presenting results can facilitate explanation, as students need to articulate their reasoning and defend the results of their analysis, while the evaluation and reflection stages can foster self-regulation through the process of reviewing the results and the thought processes that took place (Facione, 2019).

This relationship indicates that the potential of PBL to develop critical thinking skills depends not only on the use of problems as stimuli but also on how the activities within each PBL syntax are designed to foster specific thinking processes. Therefore, the use of worksheets in PBL is crucial because they translate the learning syntax into structured activities and guide students through a step-by-step thinking process. PBL-based worksheets have been developed in various learning contexts and have demonstrated potential in fostering critical thinking skills

through problem-solving and inquiry activities (Wati & Yuliani, 2020). Previous research has shown that the development of Problem-Based Learning (PBL)-based worksheets has been applied to various subject areas to enhance student engagement and critical thinking skills through problem-solving and inquiry activities (Susana et al., 2025). Nevertheless, the characteristics of the student-based learning worksheets (LKPD) developed in previous studies still show differences in terms of content focus, problem context, and the critical thinking indicators used. Some studies use PBL as a learning framework, while critical thinking indicators are primarily used as outcomes measured after learning. Consequently, the relationship between each stage of PBL and critical thinking indicators has not yet become a primary basis for designing worksheet activities. This situation indicates that the implementation of PBL and the assessment of critical thinking skills are not always accompanied by the design of activities that explicitly guide students to develop each component of critical thinking.

Furthermore, research on arthropods in rice paddy ecosystems has primarily focused on studying biodiversity, roles, and interactions among organisms, whereas the use of these ecological phenomena as contextual problems in PBL-based worksheets still has room for development. Moreover, the integration of the context of Arthropods in rice paddy ecosystems with Facione's six indicators of critical thinking skills has not yet been explicitly incorporated into learning activities. Thus, the limitations of previous research do not lie solely in the failure to use Arthropods or rice paddy ecosystems as learning materials, but rather in the suboptimal integration of authentic ecological contexts, the PBL framework, and Facione's six indicators of critical thinking as the basis for designing worksheet activities.

The results of an interview with a biology teacher at a public high school in Bandung further underscore this need. Instruction on biodiversity still tends to be dominated by the presentation of theoretical concepts and does not yet fully incorporate activities that enable students to analyze problems and develop critical thinking skills (Cahyani et al., 2025). This situation highlights the need for instructional materials that not only present content but also guide students through a thinking process using problems relevant to their environment. The context of arthropods in rice paddy ecosystems provides authentic problems that can be used to connect the concept of biodiversity with ecological functions, interactions among organisms, population changes, and ecosystem balance (Sawitri & Syamsurizal, 2025).

Based on these conditions, this study developed PBL-based student worksheets on the topic of Arthropods in rice field ecosystems by designing and mapping learning activities based on Facione's six indicators of critical thinking skills. The contribution of this study lies in its pedagogical and methodological aspects, namely treating Facione's six indicators not only as constructs to be measured but also as the foundation for designing activities at each stage of PBL. Each stage of PBL is designed to provide students with opportunities to interpret phenomena related to the changes and interactions of arthropods (interpretation), analyze relationships between organisms and environmental factors (analysis), evaluate evidence and alternative solutions (evaluation), draw conclusions based on the results of their investigations (inference), explain the results of their analysis in a reasoned manner (explanation), and reflect on and refine their thinking processes (self-regulation). Thus, the worksheets developed not only use PBL as a learning model but also integrate PBL syntax with critical thinking indicators through explicitly designed and structured activities (Gunawan et al., 2025)

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This study aims to develop Problem-Based Learning (PBL)-based worksheets on the topic of arthropods in rice field ecosystems that facilitate the six indicators of critical thinking skills identified by Facione, as well as to determine the feasibility, practicality, and improvement in students' critical thinking skills after using the developed worksheets. The developed product is expected to serve as an alternative biology teaching material that integrates authentic problems from rice paddy ecosystems with structured problem-solving activities oriented toward the development of critical thinking skills.

METHOD

This study employs a Research and Development (R&D) approach. The development model used in this study adapts the Four-D (4-D) model proposed by Untayana & Harta (2016), which consists of the define, design, develop, and disseminate stages. However, since this study was conducted only up to the develop stage, it utilizes an adapted 4-D model rather than a standalone 3-D model. The limitation to the "develop" stage was imposed because the study focused on the development, validation, revision, and limited testing of the worksheets in a single class, whereas the "disseminate" stage requires the implementation and distribution of the product on a broader scale (Sugiyono, 2023).

The definition phase involves analyzing learning needs, learner characteristics, the curriculum, concepts, and learning objectives through interviews with biology teachers, observations, and literature reviews. This phase aims to identify learning conditions and the need to develop PBL-based worksheets on the topic of arthropods in rice paddy ecosystems. The design phase involves developing the structure and content of the worksheets, creating contextual problems based on the conditions of the rice paddy ecosystem, designing learning activities in accordance with PBL syntax and Facione's critical thinking indicators, and developing validation instruments and critical thinking ability tests (Ayunda et al., 2023). The development phase involved the validation of the worksheets by subject matter experts, instructional media experts, and biology teachers regarding content feasibility, alignment with PBL-based learning, language, presentation, and graphics.

The study was conducted in July 2026 at a public high school in Bandung, involving 10th-grade students in Phase E who were studying arthropods in rice paddy ecosystems. The rice paddy area surrounding the public high school in Bandung (Jl. Cimincrang No. 14, Rancanumpang, Gedebage, Bandung, West Java) served as the site for field data collection, specifically documentation of arthropod diversity, which was used as contextual material in the student worksheets. Identification was conducted through direct observation from the afternoon until the morning using pitfall traps placed at several observation points (Thei et al., 2020). Eight species of arthropods were found (leafhoppers, grasshoppers, crickets, ants, cicadas, spiders, dragonflies, and predatory beetles) and documented as visual data to support the development of the LKPD (researcher's personal documentation). The use of direct observational data from the school's surrounding environment was intended to make the worksheet material more contextual and to help students connect the concept of arthropods with the real-world conditions of the rice paddy ecosystem (Mustika et al., 2019)

The test subjects were 42 students in Class X-8, and all of them participated in the entire process—from the pretest, through the learning process using the worksheets, to the posttest—with no students failing to complete any of the stages. The class was selected using purposive sampling, which involves selecting subjects based on specific criteria aligned with the research objectives (Etikan et al., 2016). The criteria used in selecting the experimental class included:

(1) the class was currently studying the topic of Arthropoda within the biodiversity curriculum for the current semester, making it appropriate for the scope of the developed product; (2) the class was recommended by the biology teacher based on students' learning achievements and characteristics that did not differ significantly from those of other parallel classes at the same grade level; and (3) the class had not previously used PBL-based worksheets on the Arthropoda topic, ensuring that changes in scores were not influenced by prior exposure to the product. Because this technique is non-probability-based, the pilot test results are not intended to be generalized to a broader student population but rather to illustrate changes in critical thinking skills among the subjects who participated in the pilot test (Creswell, 2018).

In addition to the students, the study involved three participants as product validators: one subject matter expert, one instructional media expert, and one biology teacher, each of whom was selected based on their competencies and the alignment of their areas of expertise with the aspects being validated.

In accordance with the quality criteria for educational development products, the suitability of the worksheets is assessed through three tests that are analyzed and reported separately, rather than treated as a single unit (Hasmawaty et al., 2020):

1. Validity testing, which assesses whether the design, content, and construction of the worksheets align with theoretical studies and learning needs as determined by subject matter experts and media experts, as indicated by validation questionnaire scores (Nur Khoiri, 2011).
2. Practicality testing, which assesses the ease of use and readability of the worksheets from the perspectives of teachers and students during the pilot test (Sugiyono, 2023)
3. Effectiveness testing involves examining changes in students' critical thinking scores before and after using the worksheets, within the specified interpretation guidelines (Winarno, 2017).

Data on the product's effectiveness were obtained through a critical thinking test consisting of 11 essay questions designed based on six indicators of critical thinking—namely, interpretation, analysis, evaluation, inference, explanation, and self-regulation—which were administered to students as pretests and posttests (Facione, 2019). Each indicator has an operational definition that serves as a reference for writing test items, establishing answer criteria, and developing scoring rubrics, as summarized in Table 1. The columns for test item numbers, answer criteria, and scoring rubrics in the table were organized according to the instrument outline developed during the design phase and supplemented with research data.

The critical thinking assessment instrument was reviewed by the supervising lecturer to ensure that the test items were consistent with the subject matter, the indicators of critical thinking, and linguistic aspects. The results of the review were used as the basis for revising the instrument before it was used in the pilot study. Construct validity was assessed based on the alignment of each test item with Facione's six indicators of critical thinking, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation. Furthermore, the reliability of the instrument was analysed using Cronbach's Alpha coefficient (Maryono & Pamela, 2022) The questionnaire for validating the suitability of the worksheets used a Likert scale and was completed by subject matter experts, learning media experts, and biology teachers, with a checklist covering aspects of content suitability, PBL content, language, presentation, and graphics.

A limited trial utilised a one-group pre-test–post-test design in a single class: pupils were given a pre-test before the lesson, took part in the lesson using the worksheets, and were then

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given a post-test (Gusvita et al., 2023). This design does not involve a control or comparison group and is therefore susceptible to threats to internal validity, including the testing effect, learner maturation, the influence of regular learning outside the treatment, and teacher factors that may contribute to changes in scores apart from the use of the worksheets (Bierer et al., 2025).

Data were collected through interviews, observations, literature reviews, questionnaires and tests (Creswell, 2018). Interviews and observations yielded supporting qualitative data during the 'define' stage. The validation questionnaire data were analysed by converting the Likert scores into percentages, which were then interpreted into validity categories ranging from invalid to highly valid, serving as the basis for decisions regarding product revisions (Cahyo & Marsono, 2024).

The pre-test and post-test data were analysed using the Shapiro–Wilk test on the difference in scores. The test results indicated that the data were non-normally distributed; therefore, the differences in scores were analysed using the Wilcoxon Signed-Rank test to determine the significance of changes in scores among the same pupils (Frost et al., 2023). Furthermore, relative improvement was calculated using N-Gain with the aid of IBM SPSS Statistics 27 and Microsoft Excel and categorised as low, moderate or high. N-Gain was used to describe the magnitude of the improvement. As the study employed a one-group pre-test–post-test design without a comparison group, the results were interpreted as changes in scores following the use of the worksheets. The analysis is presented both in aggregate and based on Facione's critical thinking indicators, whilst taking into account the limited number of items for each indicator. Overall, this analysis was used to describe the improvement in pupils' critical thinking skills following the use of the worksheets. The research flowchart is presented in Figure 1 below:

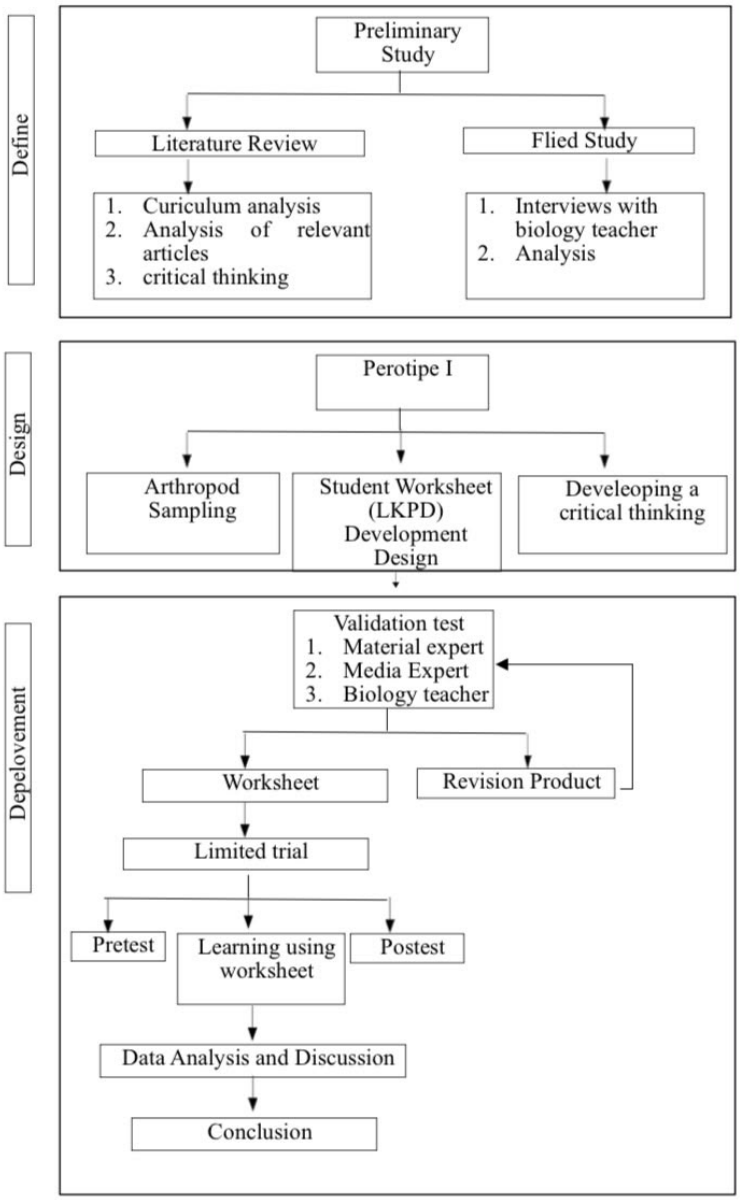

Figure 1. Research Flowchart

RESULTS AND DISCUSSION

This research produced a set of Student Worksheets (LKPD) based on Problem-Based Learning (PBL) covering the topic of arthropods in rice field ecosystems, which were developed through the three stages of the 3-D model: define, design and develop. The LKPDs were structured in accordance with the PBL syntax, ranging from problem orientation, organising pupils, guiding investigations, presenting results, to evaluating the problem-solving process; each stage was designed to meet the need for contextual teaching materials capable of developing critical thinking skills, as outlined in the introduction. The findings from each stage are presented below, together with a discussion (Untayana & Harta, 2016)

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Define Stage

1. Analysis of learning needs and issues

Interviews with Year 10 Biology teachers revealed that the teaching of biodiversity is still dominated by the lecture method, with the teacher at the centre of the learning process, whilst the available teaching materials remain conventional and do not specifically foster critical thinking skills. Observations revealed that pupils still struggle to relate biological concepts to real-world phenomena in their surroundings and to draw conclusions based on observational evidence; consequently, the six indicators of critical thinking identified by Facione—interpretation, analysis, evaluation, inference, explanation and self-regulation—have not developed optimally. This situation is consistent with the findings of Cahyani et al. (2025), who stated that the teaching of biodiversity in secondary schools has not yet fully facilitated the development of pupils' critical thinking skills. These findings indicate a need for more contextual teaching materials capable of engaging pupils in problem-solving activities.

2. Task and Concept Analysis

Task and concept analysis was carried out. Task and concept analysis is used to analyse the curriculum implemented in the learning process. The results of this analysis indicate that the curriculum used in the school is the Merdeka Curriculum, which guides pupils not only to understand the concept of biodiversity but also to analyse the role of arthropods in rice field ecosystems and relate this to real-world environmental issues (Fatmawati et al., 2024). Based on these findings, a Problem-Based Learning (PBL)-based worksheet was developed, using contextual problems relating to the rice field ecosystem as the basis for learning activities and Facione's six indicators of critical thinking as a reference for designing the activities and questions. Thus, the results of the 'Define' stage formed the basis for determining the content, context and initial requirements of the product, which were subsequently developed during the 'Design' stage.

Design Stage

The next stage is Design, which involves designing Problem-Based Learning (PBL)-based worksheets based on the results of the analysis carried out in the Define stage. The worksheets consist of instructions for use, learning objectives, basic theory on biodiversity, contextual problems, investigative activities, problem-solving questions, presentation of results, and reflection (Yuliandriati et al., 2019). The activities are structured in accordance with the PBL syntax and are aligned with Facione's indicators of critical thinking, including interpretation, analysis, evaluation, inference, explanation and self-regulation. The worksheets also include illustrations of arthropods, problems relating to rice paddy ecosystems, and supporting reading materials to help pupils connect concepts with real-world phenomena and formulate solutions based on evidence. Examples of the structure and activities of the worksheets are presented in Figure 2 and Figure 3.

Figure 3. Example of a Problem-Based Learning (PBL)-based student worksheet on arthropods in the rice paddy ecosystem

Develov Stage

The development stage involved expert validation and product revision. Validation was carried out by one subject matter expert, one media expert and one biology teacher to assess the suitability of the content, PBL, language, presentation, layout and the alignment of the worksheets with the learning objectives (Sari et al., 2020). Revisions were made based on the validators' assessments and feedback, resulting in worksheets deemed suitable for use. A.

1. Subject-matter expert validation

Subject-matter expert validation was carried out to assess the suitability of the content, the Problem-Based Learning (PBL) components, language usage, and the presentation of the material in the worksheets. Validators were selected based on the alignment of their competencies with the product being developed; specifically, they had an academic background in Biology, professional experience in the scientific field, and experience in developing Biology teaching materials. The instrument used was a subject matter expert assessment sheet employing a Likert scale, covering the relevance of the material, the alignment of activities with PBL principles, language usage, and the systematic presentation of the LKPD. The assessment results showed that each aspect achieved a score of 80 per cent, with an overall score of 56 out of a maximum of 70, or 80 per cent. Based on the assessment by the subject matter experts involved, the LKPD falls into the 'Valid' category and can be used following revisions in accordance with the validators' feedback.

Expert input on the subject matter primarily concerned the comprehensiveness of the theoretical foundation and the implementation of PBL methodology. In Figure 3, the basic theory prior to revision dealt directly with Arthropoda in rice field ecosystems without explaining biodiversity as the theoretical foundation, whilst the initial reading materials remained limited. Revisions were made by adding material on biodiversity and supplementing the reading materials so that pupils would have prior knowledge before working on the worksheets. Revisions in Figure 4 were also made to Activity 1, which previously directed pupils straight to identification without first providing an orientation to the problem. Following the revision, the activity begins with the observation of authentic problems within the rice field ecosystem, followed by problem identification and formulation, ensuring that the sequence of activities is more in line with the PBL syntax. Consequently, the validation result of 80 per cent not only serves as the basis for improving the completeness of the material, reading materials and PBL activities, but also demonstrates the suitability of the worksheets based on the

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assessment of the validators involved. The revised documents are presented in Figures 3 and 4 below:

Figure 3. Before and After Revision

2. Media expert

Media expert validation was carried out to assess the presentation and graphic design of the LKPD, covering layout, illustrations, readability and visual appearance. Validators were selected based on the relevance of their expertise to the product being developed, namely those with an academic background and professional experience in information technology (IT), educational media and the teaching of Biology. The validation results showed that the

presentation aspect scored 90 per cent, whilst the graphic design aspect scored 92.5 per cent, with an overall score of 55 out of a maximum of 60, or 91.6 per cent; thus, based on the assessment of the media experts involved, the LKPD falls into the 'highly valid' category.

These validation results were obtained following revisions based on feedback from the validators, particularly regarding the accuracy of image layout and improvements to the visual quality of the LKPD. Prior to revision, some images were not positioned proportionally, meaning the visual presentation was not optimal; following revision, the position and size of the illustrations, as well as the layout between components, were improved to make the LKPD more structured, engaging, communicative and user-friendly for learning activities. The changes before and after the revisions are presented in Figure 4 and Figure 5. These findings are consistent with Putri et al. (2022), Putri et al. (2022), who emphasised the importance of visual presentation and design in the development of worksheets, as well as Herawati et al. (2022), who demonstrated that the quality of the media is a crucial aspect of the suitability of PBL-based worksheets.

Figure 4. Before Revision

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Gambar 2. Permasalahan Ekosistem sawah
Sumber : Ilustrasi data gambar pribadi

Figure 5. After Revision

3. Validation by biology teachers

Validation by biology teachers was carried out to assess the appropriateness of the presentation of the teaching materials, the suitability of the content, and the language used in the worksheets in relation to learning needs. Validators were selected on the basis of their relevant competencies, namely having an academic background in biology as well as professional experience in teaching biology at a level appropriate to the product being developed. The instrument used was a validation sheet employing a Likert scale. The assessment results showed that all aspects achieved a percentage of 00 per cent, with an overall score of 45 out of a maximum of 45 or 100 per cent; thus, based on the assessment by the biology teachers involved, the worksheets were categorised as highly valid and met the criteria for suitability for use in the pilot phase.

The teachers' assessment results indicated that the worksheets were aligned with the learning outcomes and objectives, featured an engaging presentation, and utilised appropriate and easily understandable language. This assessment further reinforced the results of the revisions carried out based on feedback from subject matter experts and media experts, ensuring that the product's content, presentation, and layout are more suitable for use in the classroom. Consequently, based on the assessments by subject matter experts, media experts and the biology teachers involved, the worksheets have met the eligibility criteria to proceed to the pilot phase; these validation results are presented as an assessment of suitability by the validators involved and are not intended as evidence of validity that can be broadly generalised. A summary of the validation results is presented in Table 1 and Figure 6 below:

Table 1. Overall Validation Results

No	Assesment Aspect	Presentage%	Category
	Subject-matter expert validation		
1	Content suitability	80	Valid
2	PBL content	80	Valid
3	Language	80	Valid
4	Presentation	80	Valid
5	Content suitability	80	Valid
	Average	**80**	**Valid**
	Media expert validation		
1	Presentation	90	Hightly Valid
2	Graphics	92,5	Hightly Valid
	Average	**91,6**	**Hightly Valid**
	Biology teacher validation		
1	Media presentation	100	Hightly Valid
2	Content suitability	100	Hightly Valid
3	Language	100	Hightly Valid
	Average biology teacher	**100**	**Hightly Valid**

(Wati & Yuliani, 2020).

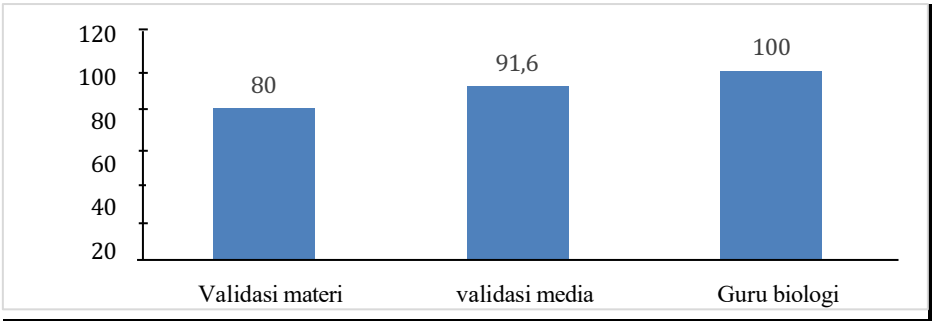

Figure 6. Overall Validation Results

4. Limited Results of the Students' Critical Thinking Test

limited test was conducted on 42 pupils using a pre-test and post-test to assess changes in critical thinking skills following the use of Problem-Based Learning (PBL)-based worksheets on the topic of arthropods in rice field ecosystems. The analysis revealed that the mean pre-test score was 30, whilst the mean post-test score was 41, indicating an increase in the mean score of 11 points. Based on the N-Gain calculation, a value of 0.79 was obtained, which falls within the 'high' category and indicates a relative improvement in critical thinking skills following the use of the worksheets.

Furthermore, a Shapiro–Wilk test was conducted on the difference between the pre-test and post-test scores. The test results showed that the data were not normally distributed; therefore, the difference in scores was analysed using the Wilcoxon Signed-Rank Test. The test results showed a significance level of < 0.05, indicating a significant difference between the pre-test and post-test scores for the same pupils. An analysis based on Facione's six indicators of critical thinking was also carried out to illustrate changes in the abilities of interpretation, analysis, evaluation, inference, explanation and self-regulation. Thus, the limited test results indicate an improvement in critical thinking skills following the use of the worksheets, whilst the N-Gain indicates the magnitude of the relative improvement. However, as the study employed a one-

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group pre-test–post-test design without a control group, these findings are not intended as evidence that the changes in critical thinking skills were solely attributable to the worksheets.

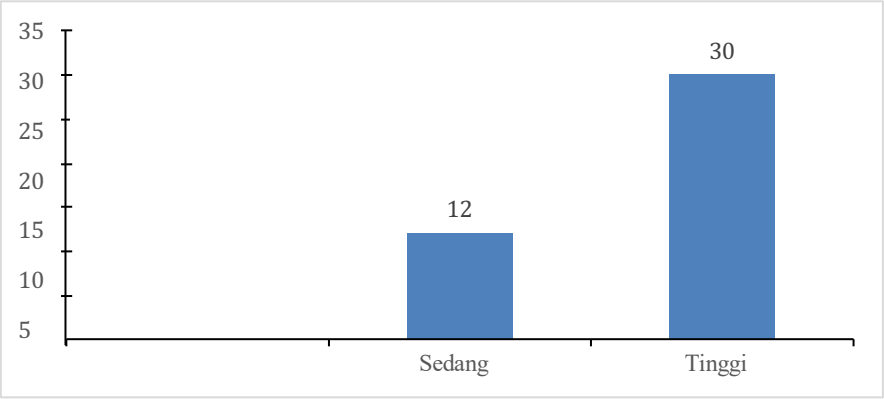

Figure. 7 Diagram N-Gain Test Result

The improvement in critical thinking skills can be attributed to the activities in the worksheets, which are designed to encourage pupils to observe problems, identify information, analyse relationships between phenomena, evaluate evidence, draw conclusions and formulate solutions. Learner-centred activities provide opportunities for active engagement in the process of inquiry and problem-solving, whilst the material on Arthropoda, linked to real-world conditions in the surrounding environment, makes learning more contextual and meaningful. Learners not only study concepts theoretically but also apply them to understand issues relating to Arthropoda in rice field ecosystems and relate these to everyday life. This type of contextual learning has the potential to enhance pupils' engagement, motivation and curiosity regarding the subject matter (Adinia et al., 2026). Overall, the PBL-based worksheets on Arthropoda in rice field ecosystems, developed using the 3D model, are deemed suitable for use in Biology lessons and demonstrate an improvement in pupils' critical thinking skills following their use. This is evidenced by the increase in the average pre-test and post-test scores for each critical thinking indicator in Table 2.

Tabel 2. Average Score of Critical Thinking Skills

No	Critical Thinking Indicators	Pretest	Postest	N-Gain	Category
1	Interpretation	60,71	88,69	0,71	Tinggi
2	Analysis	69,04	95,23	0,84	Tinggi
3	Evaluation	76,19	96,42	0,85	Tinggi
4	Inference	69,64	95,03	0,83	Tinggi
5	Explanation	72,91	95,23	0,82	Tinggi
6	Self-Regulation	65,4	95,83	0,87	Tinggi
	Average	**68,98**	**94,40**	**0,82**	**Tinggi**

(Ariq & Fitrihidajati, 2021).

Based on Table 2, there was an improvement in critical thinking across all indicators following the use of the developed worksheets. The indicator for explaining phenomena scientifically increased from a pre-test average score of 68.98 to 94.40 in the post-test, with an N-Gain of 0.82, which falls within the 'high' category.

The results indicate that pupils' critical thinking skills improved following the use of Problem-Based Learning (PBL)-based worksheets. The evaluation and analysis indicators showed N-Gain values of 0.85 and 0.84 respectively, both falling within the high category, indicating an improvement in pupils' ability to assess information and evidence, as well as to analyse the relationships between organisms and the factors influencing rice field ecosystems. Meanwhile, the self-regulation indicator achieved the highest N-Gain of 0.87, indicating the

greatest relative improvement and likely relating to reflective activities that guided pupils to review the process and outcomes of problem-solving.

The interpretation indicator showed an N-Gain of 0.71, the lowest among the six indicators, although it still falls within the high category. This can be attributed to the relatively low initial score for the interpretation indicator, namely 60.71, as well as the demands of interpretative skills, which require pupils to understand and make sense of information before undertaking further analysis. Overall, all critical thinking indicators showed an improvement following the use of the worksheets, with an N-Gain of 0.87 for self-regulation, 0.85 for evaluation, 0.84 for analysis, 0.83 for inference, 0.82 for explanation, and 0.71 for interpretation. These findings illustrate an improvement in critical thinking skills following the use of the worksheets, whilst the N-Gain values are used to indicate the magnitude of the relative improvement and should not be interpreted as causal evidence of the worksheets' effectiveness (Dewey et al., 2022).

CONCLUSION

The Problem-Based Learning (PBL)-based worksheets on the topic of arthropods in rice field ecosystems, developed using the 3D model (Define, Design and Develop), meet the feasibility criteria based on the validators' assessment and the results of the product revisions. A pilot study indicated an improvement in pupils' critical thinking skills following the use of the worksheets across all six Facione indicators. The worksheets developed can be used as supplementary teaching materials to facilitate critical thinking skills in the topic of arthropods in rice field ecosystems. For further development, it is recommended to conduct trials with a more diverse range of students and in different school contexts, as well as to refine the activities that facilitate the 'interpretation' indicator and its application to other topics or educational levels.

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