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Development of a Digital Integrated Science Teaching Module Based on Problem-Based Learning to Enhance Critical Thinking Skills Among Elementary School Students

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ABSTRACT
This study was conducted in response to the limited critical thinking skills among elementary school students and the need for instructional materials aligned with the Emancipated Curriculum and the Pancasila Student Profile. It aimed to develop a digital Science teaching module integrating Problem-Based Learning (PBL) and to examine its feasibility and preliminary effectiveness in supporting the critical thinking skills of Phase C elementary school students. The study employed a Design and Development (D&D) approach using the ADDIE model, consisting of five stages: analysis, design, development, implementation, and evaluation. Data were collected through interviews, work logs, expert validation questionnaires, and critical thinking skills tests. Participants included three expert validators — a subject matter expert, a media expert, and an instructional design expert — and 20 fifth-grade students. Qualitative data were analyzed through data reduction, categorization, interpretation, and conclusion drawing, while quantitative data were analyzed using percentage, mean score, and normalized gain (N-gain) analyses. The validation results yielded scores of 92.2% from the subject matter expert, 85.4% from the media expert, and 91.2% from the instructional design expert, with an overall mean score of 89.6%, indicating that the module was highly feasible. The limited field trial revealed an increase in students' mean critical thinking score from 57.50 on the pretest to 96.25 on the posttest, with a mean difference of 38.75 points. The mean N-gain score was 0.93, categorized as high. These findings provide preliminary evidence that the developed PBL-based digital Science teaching module is highly feasible and holds strong potential for enhancing fifth-grade students' critical thinking skills in learning the water cycle.

Keywords: Critical Thinking Skills; Digital Teaching Module; Problem-Based Learning

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INTRODUCTION

Rapid advancements in science and technology require education to prepare high-quality, adaptable, and competitive human resources for the twenty-first century (Fajriyani et al., 2023). Students are expected not only to acquire factual knowledge but also to develop essential skills, including critical thinking, creativity, communication, and collaboration. In line with these demands, the Merdeka Curriculum seeks to improve the quality of learning and develop students' competencies and character in accordance with Pancasila values (Ismail et al., 2021), One of its major dimensions is critical reasoning, which encourages students to obtain and process information, analyze ideas, evaluate reasoning, and reflect on their thinking processes (Fadil et al., 2023; Hasanah, 2024). In this study, critical reasoning is used to refer to the dimension of the Pancasila Student Profile, whereas critical thinking skills refer to the specific cognitive abilities measured as the research outcome.

Critical thinking skills are essential because they enable students to process information objectively, analyze problems, evaluate possible explanations, draw evidence-based conclusions, and make reasoned decisions (Agustina et al., 2022; Azizah dkk., 2018). These skills are particularly important in Natural and Social Sciences, locally referred to as IPAS, because students are expected to understand scientific concepts and apply them when examining phenomena encountered in everyday life. However, elementary school students continue to experience difficulties in completing tasks that require them to formulate questions, analyze cause-and-effect relationships, construct arguments, evaluate information, and draw conclusions (Meilasari et al., 2020). Such difficulties indicate that learning activities still need to provide more opportunities for students to engage in investigation, problem-solving, discussion, and scientific reasoning.

The water cycle is an important topic in Phase C IPAS because it helps students understand the continuous movement of water through evaporation, transpiration, condensation, precipitation, and infiltration (Inayah, 2021). Understanding these processes is also necessary for explaining environmental phenomena such as rainfall, flooding, drought, groundwater availability, and the effects of human activities on water resources. Nevertheless, the water cycle contains processes that cannot always be directly observed in their entirety. Its abstract, sequential, and interconnected characteristics may make it difficult for elementary school students to understand the relationships among the stages of the cycle (Tresnaningtyas et al., 2023). Therefore, the topic requires appropriate illustrations, animations, videos, experiments, and contextual problems that can help students visualize the processes and connect scientific concepts with real-life situations.

The preliminary findings obtained through interviews with fifth-grade teachers also revealed several instructional challenges, including low student motivation, a tendency to seek immediate answers, difficulties in responding to higher-order thinking questions, and learning activities that remained predominantly teacher-centered. The teaching materials used in the classroom were mainly conventional materials, student textbooks, and supplementary videos from YouTube. Although these resources provided basic information, they had not been systematically organized to guide students through questioning, investigation, argumentation, evaluation, and conclusion-drawing activities. Consequently,

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students required instructional materials that could present the water cycle visually while simultaneously facilitating active and structured learning.

An electronic module, or e-module, is considered relevant to address these needs because it can integrate written explanations, images, videos, animations, worksheets, hyperlinks, and assessments into a single learning resource (Andini & Hera, 2024). Compared with conventional printed materials, an e-module provides greater flexibility and allows students to revisit learning content according to their individual needs (Kementerian Pendidikan & Kebudayaan, 2017). It can also visualize scientific processes that are difficult to observe directly and provide students with access to a broader range of information. However, the inclusion of digital features alone does not necessarily promote critical thinking. An e-module must also incorporate an instructional framework that requires students to identify problems, seek relevant information, conduct investigations, explain findings, evaluate possible solutions, and reflect on their reasoning.

Previous studies have demonstrated the potential of digital modules in elementary school science learning. Mulyawati et al., (2024) developed an interactive digital module using Articulate Storyline to improve elementary school students' critical thinking skills. The module was considered feasible and produced improvements across several aspects of critical thinking, including analysis, evaluation, creativity, and problem-solving. Another study by Andini & Hera, (2024) developed an inquiry-based e-module on the water cycle for fifth-grade elementary school students. The product was reported to be valid, practical, and effective for science learning. Similarly, Atiyah et al., (2025) developed a flipbook-assisted water cycle e-module for fifth-grade students and found that the product met the validity and practicality criteria for classroom use.

These previous studies confirm that e-modules can support elementary school learning and help students understand water cycle content (Murugiah et al., 2023). Nevertheless, the existing products have primarily emphasized digital interactivity, inquiry-based learning, or the feasibility and practicality of flipbook-assisted modules. Limited attention has been given to the development of a water cycle e-module that systematically integrates the stages of Problem-Based Learning and explicitly measures students' critical thinking skills (Azizah et al., 2018). Therefore, further development is needed to produce an e-module that not only presents digital content but also guides students through contextual problem orientation, collaborative investigation, information analysis, presentation of findings, evaluation of solutions, and reflection.

Problem-Based Learning is considered appropriate for this purpose because it positions students as active participants in constructing knowledge through the investigation of authentic problems (Darmansyah et al., 2023). Through PBL activities, students are encouraged to identify problems, formulate questions, gather and evaluate information, discuss alternative explanations, present arguments, and develop evidence-based solutions. These activities are closely related to the indicators of critical thinking skills assessed in this study. Integrating PBL into a digital IPAS teaching module is therefore expected to transform the module from a source of information into a structured learning tool that facilitates students' critical thinking processes.

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Based on the identified instructional needs and the limitations of previous studies, this study aims to develop a Problem-Based Learning-based digital IPAS teaching module on the water cycle and examine its feasibility and effectiveness in improving the critical thinking skills of Phase C elementary school students. The novelty of this study lies in the systematic integration of PBL stages, digital multimedia content, contextual water cycle problems, and critical thinking indicators within a single instructional module for fifth-grade elementary school students.

METHOD

This study employed the Design and Development (D&D) research method proposed by Richey and Klein, as cited in Puspita et al., (2023). as a strategy to test the effectiveness of a developed product. Richey and Klein (in Puspita et al., 2023) The D&D method was selected because the study focused on designing, developing, validating, and conducting a limited trial of an instructional product. Richey and Klein classify D&D research into two categories: Product and Tool Research and Model Research. This study was categorized as Product and Tool Research because it developed a Problem-Based Learning (PBL)-based digital Science teaching module for the water cycle topic.

The product development process followed the ADDIE model, which is widely used to develop instructional products and learning programs (Marwa et al., 2023), The ADDIE model consists of five stages: analysis, design, development, implementation, and evaluation (Tresnaningtyas et al., 2023). Procedures and outputs of each development stage are presented in Table 1.

Table 1. Procedures for Developing a PBL-Based Digital Science Teaching Module Using the ADDIE Model

ADDIE Model	Research Procedures	Outputs
Analyze	Analyzing students' learning needs, classroom learning problems, the curriculum, water cycle content, critical thinking indicators, and the suitability of the PBL model	Module Development Framework
Design	Designing the module structure, learning components, teaching materials, student worksheets, assessment instruments, digital media, and PBL-based learning activities	Preliminary module design
Development	Developing the digital module, preparing assessment instruments, conducting expert validation, and revising the product based on expert feedback	Validated module and revision results

ADDIE Model	Research Procedures	Outputs
Implementation	Conducting a limited field trial involving 20 fifth-grade students through a pretest, learning activities using the module, and a posttest	Product implementation and critical thinking skills data
Evaluation	Evaluating the suitability of the Evaluating the feasibility of the module, expert recommendations, product revisions, and improvements in students' critical thinking skills, the results of revisions, and improvements in students' critical thinking skills	Final digital module and evaluation results

The participants consisted of three expert validators and 20 fifth-grade elementary school students in Phase C at Elementary School of 001 MRDK, Bandung. The validators comprised one subject matter expert, one media expert, and one instructional design expert. The subject matter expert assessed the accuracy, relevance, depth, and alignment of the water cycle content with the Science curriculum; the media expert evaluated the visual appearance, readability, navigation, digital features, and technical quality of the module; and the instructional design expert assessed the organization of learning activities, alignment with the PBL stages, appropriateness for elementary school students, and consistency among learning objectives, materials, activities, and assessments. Data were collected through interviews, worklogs, validation questionnaires, and critical thinking skills tests. Interviews were conducted with fifth-grade teachers to identify learning problems and students' needs, while worklogs documented the module development process. The validation questionnaires included closed-ended items to assess content, media, language, and instructional design, as well as open-ended items to obtain expert comments and suggestions. The main instrument was a critical thinking skills test consisting of 10 essay questions, with each item scored from 0 to 4 and a maximum total score of 40.

Before implementation, the critical thinking skills test was evaluated in terms of content validity, empirical validity, reliability, difficulty level, and discrimination index. Content validity was assessed by [number of validators] experts, empirical validity was analyzed using the Pearson product-moment correlation, and reliability was examined using Cronbach's alpha, which yielded a coefficient of [value]. The item difficulty indices ranged from [value] to [value], while the discrimination indices ranged from [value] to [value]. Based on these results, [number] items were declared valid and suitable for measuring students' critical thinking skills, whereas items that did not meet the criteria were revised before use. Qualitative data from interviews, worklogs, and expert comments were analyzed through data reduction, categorization, interpretation, and conclusion drawing. Quantitative validation data were analyzed by calculating the percentage of the obtained score relative to the maximum possible score. The pretest and posttest data were analyzed descriptively using mean scores, while the improvement in students' critical

thinking skills was determined through normalized gain analysis. An N-gain score of 0.70 or higher was categorized as high, a score from 0.30 to less than 0.70 as moderate, and a score below 0.30 as low. Because the study employed a limited one-group pretest–posttest trial without a control group, the findings were interpreted as preliminary evidence of improvement following the use of the developed module.

FINDINGS

1. Needs Analysis and Product Development

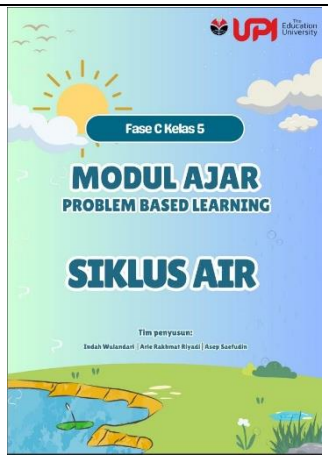
The needs analysis identified three main instructional problems: students' limited critical thinking skills, the inadequate use of teaching materials, and the continued dominance of teacher-centered instruction. Interviews with the fifth-grade teacher indicated that although the school had implemented the Merdeka Curriculum, classroom instruction still relied primarily on existing textbooks, conventional teaching materials, and supplementary YouTube videos. The teacher also reported that students experienced difficulties in responding to higher-order thinking questions, particularly those requiring them to formulate questions, construct arguments, and draw conclusions. Based on these findings, the development process focused on the Phase C water cycle topic, with the learning outcome requiring students to describe the water cycle and explain its relationship with efforts to maintain water availability.

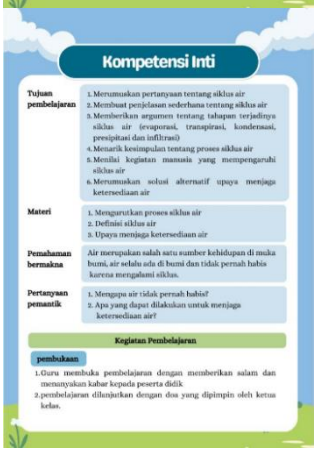
Table 2. Alignment of Learning Outcomes, Water Cycle Content, and Critical Thinking Indicators

Learning Outcomes	Focus Content	Indicators Critical Thinking	Learning Indicators
Students describe the water cycle and its connection to efforts to ensure water availability.	- The water cycle	- Ask a question	- Asking questions about the water cycle
	- The processes of evaporation, condensation, precipitation, infiltration, and transpiration	- Provide a simple explanation	- Provide a simple explanation of the water cycle
	- Definition of the water cycle	- Present an argument	- Provide an explanation of the water cycle
	- Human activities that affect the water cycle	- Drawing conclusions	

Learning Outcomes	Focus Content	Indicators Critical Thinking	Learning Indicators
	- Efforts to ensure water availability	- Give a rating - Formulate alternative solutions	- Drawing conclusions about the water cycle - Assessing human activities that affect the water cycle - Developing alternative solutions to ensure water availability

Based on the needs and curriculum analyses, a Problem-Based Learning (PBL)-based digital Science teaching module was developed for the water cycle topic. The module was designed in B5 portrait format and consisted of a cover page, general information, learning outcomes and objectives, teaching materials, student worksheets, assessment activities, a glossary, and references. Its learning activities were systematically organized according to the five PBL stages and presented through the activity features “Let’s Observe,” “Detective Team,” “Search Mission,” “My Findings,” and “Evaluation.” Representative components of the developed module are presented in Figure 1.

Development Diagram	Description
	The cover of the teaching materials and worksheets includes the title, instructional model, phase, grade level, and the author’s name. Illustrations related to the water cycle have also been included.

Development Diagram	Description
  	The characteristics include activity features adapted from the problem-based learning model and critical thinking skills

Development Diagram	Description
	The activity begins with “Let’s Observe,” which is the first phase of the PBL framework—orienting students to the problem—with the learning objective of formulating the problem. In this activity, students will watch a video presenting a contextual problem related to the water cycle: flooding.
	The second activity, “Detective Team,” is an adaptation of the PBL approach, which involves organizing students to learn. Students will form groups with the teacher’s assistance and assign roles to divide tasks.
	Activity Three, “Search Mission,” is the third syntactic adaptation, which involves guiding individual and group investigations. The learning objective indicators are to create simple explanations and provide arguments. Students will conduct experiments, watch instructional videos, and read materials on the water cycle.

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Development Diagram	Description
	The fourth activity is “My Findings,” which is a PBL component focused on developing and presenting findings. The learning indicators include drawing conclusions, identifying human activities that impact the water cycle, and formulating alternative solutions to ensure water availability.
	Finally, the “Evaluation” activity consists of a reflective journal containing questions related to the learning process during problem-solving.

Figure 1. Main Components and PBL-Based Activities of the Digital Science Teaching Module

Figure 1(a) presents the module cover, which contains the title, instructional model, learning phase, grade level, author’s name, and an illustration representing the water cycle. Figure 1(b) introduces the learning activity features developed by integrating the PBL stages with the critical thinking indicators. Figure 1(c) presents the “Let’s Observe” activity, in which students watch a contextual video about flooding to identify the problem and formulate relevant questions. Figure 1(d) presents the “Detective Team” activity, in which students are organized into learning groups and assign responsibilities to group members.

Figure 1(e) shows the “Search Mission” activity, which guides students in conducting experiments, watching instructional videos, reading learning materials, collecting evidence, and constructing explanations. Figure 1(f) presents the “My Findings” activity, in which students draw conclusions, evaluate human activities that affect the water cycle, formulate alternative solutions to maintain water availability, and present their investigation results. Figure 1(g) presents the “Evaluation” activity, which includes a reflective journal designed to help students evaluate their learning experiences and the problem-solving process.

The five activity features represent a structured translation of the PBL stages into student learning activities. “Let’s Observe” corresponds to orienting students to a contextual problem; “Detective Team” represents organizing students for learning; “Search

Mission" facilitates individual and group investigations; "My Findings" supports the development and presentation of investigation results; and "Evaluation" facilitates reflection on the learning and problem-solving processes. Thus, the developed module serves not only as a source of Science content but also as a structured instructional tool for facilitating students' critical thinking activities.

2. Expert Validation Results and Product Revisions

The developed module was evaluated by one subject matter expert, one media expert, and one instructional design expert. The subject matter expert assessed the accuracy, relevance, depth, and curriculum alignment of the water cycle content. The media expert evaluated visual appearance, readability, navigation, digital features, and technical quality, while the instructional design expert examined the alignment of the learning activities with the PBL stages, learning objectives, student characteristics, and assessment procedures. The validation results are presented in Table 3.

Table 3. Expert Validation Results for the PBL-Based Digital Science Teaching Module

Validator	Ideal Score	Actual Score	Percentage %	Category
Content Expert	90	76 90	92,2%	Highly Acceptable
Media Expert	55	47	85,4%	Highly Acceptable
Instructional Expert	125	114	91,2%	Highly Acceptable
Average	-	-	89,6%	Highly Acceptable

As presented in Table 3, the subject matter expert assigned a score of 92.2%, the media expert assigned a score of 85.4%, and the instructional design expert assigned a score of 91.2%. The overall mean validation score was 89.6%, placing the module in the highly feasible category. These findings indicate that the module met the required criteria in terms of content quality, media design, and instructional organization. Nevertheless, revisions were conducted based on the qualitative comments and recommendations provided by the experts. A summary of the revisions is presented in Table 4.

Table 4. Summary of Product Revisions Based on Expert Input

Revision Component	Expert Input	Revised Result
Module Cover	The cover does not yet represent the content of the water cycle material	Illustrations, background colors, and fonts have been improved
PBL Steps	Some steps do not yet follow the PBL syntax	Activity names and order have been adjusted to align with the PBL stages

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Revision Component	Expert Input	Revised Result
Let's Observe	The problem does not yet illustrate the water cycle process	The image has been replaced with a contextual video about flooding
Teaching materials	Real-life images are needed	Real-life images such as lakes, ice, and air have been added

The revisions improved the module's conceptual accuracy, visual quality, contextual relevance, and alignment with the PBL stages. After the suggested revisions had been completed, the module was used in a limited field trial involving 20 fifth-grade students.

3. Improvement in Students' Critical Thinking Skills

After the product was deemed suitable and revised, the PBL-based digital IPAS teaching module was implemented with 20 fifth-grade students at SDN 001 MRDK in Bandung. The implementation consisted of a pre-test, the use of the teaching module, and a post-test. The test instrument consisted of 10 essay questions with a maximum score of 4 per item and a maximum total score of 40. The results of the implementation showed an increase in the average critical thinking score from 57.5 on the pre-test to 96.25 on the post-test.

Tabel 5. Mean Pretest and Posttest Scores of Students' Critical Thinking Skills

Test Data	Mean Skor	Category
Pre-test	57,5	Poor
Post-test	96,25	Excellent
Improvement	38,75	-

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The mean critical thinking skills score increased from 57.50 on the pretest to 96.25 on the posttest, representing a mean difference of 38.75 points. This result indicates that students achieved higher critical thinking skills scores after participating in learning activities using the developed module. A visual comparison of the pretest and posttest mean scores is presented in Figure 2.

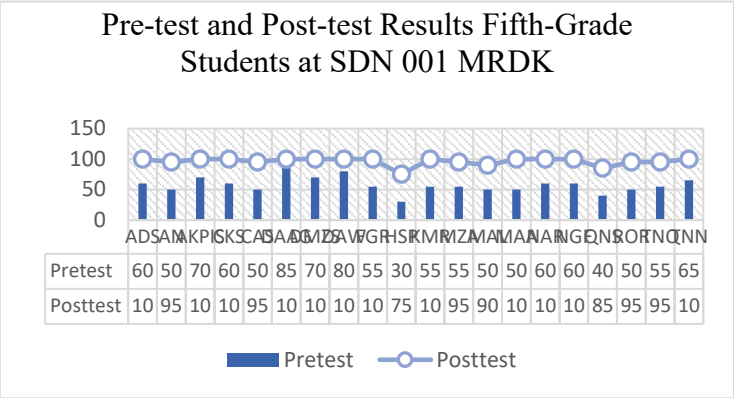


Figure 2. Comparison of the Average Pre-Test and Post-Test Scores for Students' Critical Thinking Skills

The pretest scores were also analyzed according to the six critical thinking indicators to identify students' initial strengths and difficulties. The results are presented in Table 6.

Table 6. Students' Pretest Performance by Critical Thinking Indicator

No	Question Indicator	Percentage % of Correct Answers
1.	Formulating questions about the water cycle C4)	25%
2.	Providing a simple explanation of the water cycle (C4)	98%
3.	Presenting arguments regarding events in the water cycle (evaporation, transpiration, condensation, precipitation, and infiltration)	48%
4.	Drawing conclusions about the definition of the water cycle (C4)	39%
5.	Evaluating human activities that affect the water cycle (C4)	80%
6.	Formulating alternative solutions to ensure water availability (C5)	91%

As presented in Table 6, students' initial performance varied across the critical thinking indicators. The lowest percentage was found in formulating questions about the water cycle, with a score of 25%. Drawing conclusions obtained 39%, while presenting arguments about water cycle processes obtained 48%. These results indicate that, before

the module was implemented, students experienced greater difficulty in formulating relevant questions, constructing evidence-based arguments, and drawing conclusions.

In contrast, the indicator of providing a simple explanation obtained the highest percentage, at 98%. Formulating alternative solutions obtained 91%, while evaluating human activities affecting the water cycle obtained 80%. These results provide a descriptive profile of students' initial critical thinking skills and demonstrate that their performance was not evenly distributed across the six indicators. The results should not be interpreted as indicating that all higher-order skills had already been mastered, because the scores were obtained from different questions representing different indicators and levels of task complexity.

The magnitude of improvement in students' critical thinking skills was subsequently analyzed using the normalized gain. The results are presented in Table 7 below.

Table 7. Normalized Gain of Students' Critical Thinking Skills

No	Name	Pretest	Postest	N-gain
1.	ADS	60	100	1
2.	AN	50	95	0,9
3.	AKPIS	70	100	1
4.	CKS	60	100	1
5.	CAS	50	95	0,9
6.	DAAG	85	100	1
7.	DMZS	70	100	1
8.	DAW	80	100	1
9.	FGR	55	100	1
10.	HSP	30	75	0,642857
11.	KMR	55	100	1
12.	MZA	55	95	0,888889
13.	MAL	50	90	0,8
14.	MAA	50	100	1
15.	NAR	60	100	1
16.	NGF	60	100	1
17.	QNS	40	85	0,75
18.	ROR	50	95	0,9
19.	TNQ	55	95	0,888889
20.	TNN	65	100	1
Average		57,5	96,25	0,933532

The mean N-gain score was 0.93, which was classified as high. This finding indicates a high level of improvement in students' critical thinking skills following the implementation of the PBL-based digital Science teaching module. However, because the study involved a limited one-group pretest–posttest trial without a control group, the result should be interpreted as preliminary evidence of the module's effectiveness rather than as definitive evidence of a causal effect.

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Figure 5. Implementation of the PBL-Based Digital Science Teaching Module

Note: (a) students observing a contextual problem presented in the module; (b) students conducting a group investigation; (c) students discussing the results of the water cycle activity; and (d) students presenting their findings.

DISCUSSION

The needs analysis revealed three interrelated instructional problems: students' limited critical thinking skills, the inadequate use of teaching materials, and the continued dominance of teacher-centered instruction. The available textbooks and supplementary videos had not been systematically designed to guide students in formulating questions, conducting investigations, presenting arguments, and drawing conclusions. Therefore, aligning the water cycle content, learning outcomes, PBL stages, and critical thinking indicators was necessary to ensure that the developed module functioned as both a learning resource and a structured learning guide (Sa'adah et al., 2020).

The organization of the module into the activities "Let's Observe," "Detective Team," "Search Mission," "My Findings," and "Evaluation" reflects the principles of constructivist learning theory (Ardianti et al., 2021). Constructivism views learning as an active process in which students construct understanding by connecting prior knowledge with new experiences, evidence, social interaction, and reflection. In the developed module, students were encouraged to identify contextual problems, conduct investigations, discuss evidence, present findings, and reflect on possible solutions rather than merely receive information about the water cycle (Mulyawati et al., 2024).

The use of videos, illustrations, readings, and experimental activities in the module can also be explained through the Cognitive Theory of Multimedia Learning. According to this theory, meaningful learning occurs when students select relevant verbal and visual information, organize it into coherent mental representations, and integrate it with prior knowledge (Maulida, 2022). In this study, multimedia components supported students in visualizing water cycle processes such as evaporation, condensation, precipitation, transpiration, and infiltration, which cannot always be directly observed as one continuous process.

The expert validation results showed that the developed digital Science teaching module was highly feasible in terms of content, media, and instructional design. The overall validation score of 89.6% indicated that the module met the required criteria for content

accuracy, visual presentation, technical quality, learning organization, and alignment with the PBL stages. Revisions to the module cover, activity sequence, contextual problems, and realistic images further improved the consistency between the module's content, visual design, learning objectives, and characteristics of elementary school students (Darmawati & Mustadi, 2023).

The students' mean critical thinking skills score increased from 57.50 on the pretest to 96.25 on the posttest, representing a mean difference of 38.75 points. The mean N-gain score of 0.93 was categorized as high, indicating a substantial improvement in students' critical thinking skills following the implementation of the developed module. This finding is consistent with (Pongsapan & Patak, 2021). who reported that PBL supports critical thinking by encouraging students to analyze problems, evaluate information, construct explanations, and formulate solutions.

The differences in students' initial performance across the critical thinking indicators can be interpreted using Sa'adah et al., (2020), critical thinking framework. identifies interpretation, analysis, evaluation, inference, explanation, and self-regulation as core cognitive skills involved in critical thinking. In this study, the lower pretest scores in formulating questions, presenting arguments, and drawing conclusions indicate that students initially experienced greater difficulty analyzing relationships, justifying claims with evidence, and making inferences from available information.

Overall, the findings provide preliminary evidence that the PBL-based digital Science teaching module is highly feasible and has the potential to support the improvement of fifth-grade students' critical thinking skills on the water cycle topic (Meilasari et al., 2020). Theoretically, the findings demonstrate the complementary roles of constructivist learning, multimedia learning, and critical thinking frameworks in supporting active, visual, and reasoning-oriented learning. However, because the study involved only 20 students in a one-group pretest–posttest trial without a control group, the improvement should be interpreted as preliminary rather than definitive evidence of the module's effectiveness.

CONCLUSION

This study developed a Problem-Based Learning-based digital Science teaching module on the water cycle using the ADDIE model. The module was designed based on students' learning needs, Phase C Science learning outcomes, critical thinking indicators, and the stages of Problem-Based Learning, which were translated into contextual activities involving problem observation, group investigation, presentation of findings, and reflection. The expert validation results produced an overall mean score of 89.6%, indicating that the module was highly feasible in terms of content, media, and instructional design. The students' mean critical thinking skills score increased from 57.50 on the pretest to 96.25 on the posttest, with a mean N-gain score of 0.93 in the high category. These findings provide preliminary evidence that the developed module is feasible and has the potential to support the improvement of fifth-grade students' critical thinking skills in learning about the water cycle.

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Further research should examine the PBL-based digital Science teaching module with a larger and more diverse sample involving several schools to strengthen the generalizability of the findings. Experimental or quasi-experimental designs involving control or comparison groups are also recommended to determine the effectiveness of the module more rigorously and to distinguish its contribution from other factors influencing students' learning outcomes. Future studies may develop similar modules for other Phase C Science topics and investigate additional learning outcomes, including scientific literacy, problem-solving, creativity, collaboration, and the retention of critical thinking skills over time.

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The author declares that artificial intelligence (AI) was used to a limited extent in the preparation of this manuscript, specifically for language editing, grammar checking, improving sentence clarity, and enhancing the manuscript's readability. AI was not used to generate research data, perform data analysis, replace the author's interpretation, or determine the research findings and conclusions. All AI-generated content has been reviewed, verified, and re-edited by the author. The author remains fully responsible for the accuracy, originality, integrity, and validity of the entire manuscript.

REFERENCES

Agustina, N. S., Robandi, B., Rosmiati, I., & Maulana, Y. (2022). Analisis Pedagogical Content Knowledge terhadap Buku Guru IPAS pada Muatan IPA Sekolah Dasar Kurikulum Merdeka. Jurnal Basicedu, 6(5), 9180–9187. https://doi.org/https://doi.org/10.31004/basicedu.v6i5.3662

Andini, A. T., & Hera, T. (2024). Development of Inquiry Based E-Module on Water Cycle Topic for Class V Elementary School Students. Science Education Journal Department of Science Education Universitas Negeri Padang, 7(2), 138–146.

Ardianti, R., Sujarwanto, E., & Surahman., E. (2021). Problem-based Learning: Apa dan Bagaimana. Journal for Physics Education and Applied Physics, 3(1), 27–33. https://doi.org/https://jurnal.unsil.ac.id/index.php/diffraction/article/download/4416/2049

Atiyah, D. N., Rufi'i., & Suhari. (2025). Development of a Water Cycle E-module Assisted by a Flipbook Application for 5th Grade Elementary School Students Dwi Nastiti Atiyah 1 , Rufi'i 2 , Suhari 3. TEKNODIKA, 23(02), 219–228.

Azizah, M., Sulianto, J., & Cintang, N. (2018). Analysis of Critical Thinking Skills of Elementary School Students in Learning Mathematics Curriculum 2013. Jurnal Penelitian Pendidikan, 35(1), 61–70.

Darmansyah, A., Susanti, A., & Rahman, A. . (2023). Pengembangan Modul Ajar Berbasis Problem Based Learning untuk Meningkatkan Literasi Finansial Siswa Sekolah Dasar. JURNAL BASICEDU, 7(6), 3630–3645. https://doi.org/https://doi.org/10.31004/basicedu.v7i6.6349 ISSN

Darmawati, Y., & Mustadi, A. (2023). Jurnal Prima Edukasia , 11 (2), 142-151 The Effect of Problem-Based Learning on the Critical Thinking Skills of Elementary School Students. Jurnal Prima Edukasia, 11(2), 142–151.

Fadil, K., Amran, A., & Alfaien, N. I. (2023). Peningkatan kualitas pendidikan dasar melalui implementasi Kurikulum Merdeka Belajar dalam mewujudkan suistanable developments goal's. ATTADIB, 7(2), 1–27.

Fajriyani, D., Fauzi, A., Kurniawati, M. D., Dewo, A. Y. P., Baihaqi, A. F., & Nasution, Z. (2023). Tantangan Kompetensi SDM dalam Menghadapi Era Digital: Sebuah Literatur Review. Jurnal Ilmu Sosial, Manajemen, Akuntansi Dan Bisnis, 4(6), 1004–1013. https://doi.org/https://doi.org/10.31933/jemsi.v4i6

Hasanah, N. H. N. (2024). Pengembangan Teknologi berbasis Kurikulum Merdekan di Sekolah Dasar Dalam menguatkan profil Pancasila. Hamka Insight, 2(2), 1–7. https://doi.org/10.51574/hamka.v2i2.109

Inayah, N. I. (2021). Integrasi Dimensi Profil Pelajar Pancasila dalam Mata Pelajaran Pendidikan Agama Islam Menghadapi Era 4.0 di SMK Negeri Tambakboyo Novita Nur 'Inayah. Journal of Education and Learning Sciences, 1(1), 1–13.

Ismail, S., Suhana, S., & Zakiah, Q. Y. (2021). Analisis Kebijakan Penguatan Pendidikan Karakter Dalam Mewujudkan Pelajar Pancasila Di Sekolah. Jurnal Manajemen Pendidikan, 2(1), 76 – 84. https://doi.org/https://Dinastirev.Org/Jmpis/Article/View/388

Kementerian Pendidikan & Kebudayaan. (2017). Panduan Praktis Penyusunan E-Modul Pembelajaran. Direktorat Pembinaan SMA, Ditjen Pendidikan Dasar dan Menengah. In Direktorat Pembinaan SMA, Ditjen Pendidikan Dasar dan Menengah. Jakarta: DPSMA. (pp. 1–56).

Marwa, N. W. S., Usman, H., & Qodriani, B. (2023). Persepsi Guru Sekolah Dasar Terhadap Mata Pelajaran IPAS Pada Kurikulum Merdeka. Metodik Didaktik, 18(2), 54–64. https://doi.org/10.17509/md.v18i2.53304

Maulida, U. (2022). Pengembangan Modul Ajar Berbasis Kurikulum Merdeka. Tarbawi : Jurnal Pemikiran Dan Pendidikan Islam, 5(2), 130–138. https://doi.org/10.51476/tarbawi.v5i2.392

Meilasari, S., Damris, M., & Yelianti, U. (2020). Kajian model pembelajaran PBL di sekolah. BIOEDUSAINS: Jurnal Pendidikan Biologi Dan Sains, 3(2), 109–207. https://doi.org/https://doi.org/10.31539/bioedusains.v3i2.1849 KAJIAN

Mulyawati, Y., Sukmanasa, E., Rostikawati, R. T., Maharani, N. D., & Azizah, A. . (2024). A NEW APPROACH TO ELEMENTARY LEARNING : AN INTERACTIVE DIGITAL MODULE FOR CRITICAL THINKING WITH ARTICULATE STORYLINE. PEDAGOGIA: JURNAL ILMIAH PENDIDIKAN, 16(02), 97–102.

Murugiah, L., Ismail, R., Taib, H. M., Applanaidu, S. D., & Long, M. N. H. B. (2023). Children's understanding of financial literacy and parents' choice of financial knowledge learning methods in Malaysia. MethodsX, 11(August), 1–12. https://doi.org/10.1016/j.mex.2023.102383

Pongsapan, N. P., & Patak, A. A. (2021). Improving content, organization, vocabulary, language use, and mechanics using movie trailer media. International Journal of Evaluation and Research in Education, 10(2), 728–737. https://doi.org/10.11591/ijere.v10i2.21162

Puspita, E. I., Rustini, T., & Dewi, D. A. (2023). Journal of Educational Learning and Innovation. Educational Learning and Innovation, 1(2), 98–116. https://doi.org/10.46229/elia.v1i2

Sa'adah, M., Suryaningsih, S., & Muslim, B. (2020). Pemanfaatan multimedia interaktif pada materi hidrokarbon untuk menumbuhkan keterampilan berpikir kritis siswa. Jurnal Inovasi Pendidikan IPA, 6(2), 184–194. https://doi.org/10.21831/jipi.v6i2.29680

Tresnaningtyas, R. P., Alfi, C., & Fatih, M. (2023). Pengembangan media pembelajaran puzzle berbasis make a match untuk meningkatkan kemampuan berpikir kritis siswa kelas IV SD. Pendas: Jurnal Ilmiah Pendidikan Dasar, 8(1), 6037-6048.