Inovasi Kurikulum

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Development of STEM-based worksheets to improve critical thinking on matter topic

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ABSTRACT

The critical thinking skills of elementary school students remain relatively low, especially when studying the topic of changes in the form of matter. This situation requires the availability of contextual, systematic, and integrative learning tools. This study aims to develop a STEM-based Student Worksheet (LKPD) to improve critical thinking skills in IPAS subject among fourth-grade students. The development process followed the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. Assessment was carried out through expert validation, practicality questionnaires from teachers and students, and effectiveness tests using pretest and posttest items. The validation results showed that the LKPD developed was highly feasible in terms of content, language, and visual design. Responses from teachers and students indicated that the LKPD was easy to use and engaging both visually and functionally. The effectiveness evaluation demonstrated a significant improvement in students' critical thinking skills after using the STEM-based LKPD in the learning process. These findings suggest that the developed LKPD is not only valid and practical but also contributes positively to students' learning outcomes. This study recommends the use of STEM-based LKPD as an instructional medium that promotes critical thinking skills from the early stages of education.

ABSTRAK

Keterampilan berpikir kritis peserta didik sekolah dasar masih tergolong rendah, terutama saat mempelajari materi perubahan wujud benda. Kondisi ini menuntut ketersediaan perangkat pembelajaran yang dirancang secara kontekstual, sistematis, dan terintegrasi. Tujuan dari penelitian ini adalah mengembangkan Lembar Kerja Peserta Didik (LKPD) berbasis pendekatan STEM untuk meningkatkan kemampuan berpikir kritis pada mata pelajaran IPAS kelas IV sekolah dasar. Proses pengembangan mengikuti model ADDIE yang mencakup tahap analisis, desain, pengembangan, implementasi, dan evaluasi. Penilaian dilakukan melalui validasi oleh para ahli, angket kepraktisan dari guru dan peserta didik, serta pengukuran efektivitas menggunakan soal pretes dan postes. Hasil validasi menunjukkan bahwa LKPD yang dikembangkan sangat layak digunakan berdasarkan aspek isi, kebahasaan, dan desain tampilan. Respon guru dan peserta didik menunjukkan bahwa LKPD tersebut mudah digunakan dan menarik secara visual maupun fungsional. Evaluasi efektivitas menunjukkan peningkatan keterampilan berpikir kritis peserta didik secara signifikan setelah penggunaan LKPD berbasis STEM dalam proses pembelajaran. Hasil ini menunjukkan bahwa LKPD yang dikembangkan tidak hanya valid dan praktis, tetapi juga memberikan dampak positif terhadap pencapaian hasil belajar peserta didik. Penelitian ini merekomendasikan penggunaan LKPD berbasis STEM sebagai media pembelajaran yang mendorong keterampilan berpikir kritis sejak jenjang pendidikan dasar.

Kata Kunci: berpikir kritis; IPAS; LKPD; STEM

Peer review
This article has been peer-reviewed through the journal's standard double-blind peer review, where both the reviewers and authors are anonymised during review.

INTRODUCTION

The implementation of the Science, Technology, Engineering, and Mathematics (STEM) approach in elementary school Natural and Social Sciences (IPAS) learning has emerged as a promising pedagogical strategy for developing 21st-century competencies. The integration of the four STEM elements encourages students to actively engage in exploration, experimentation, and real-world problem-solving, which in turn strengthens higher-order thinking skills (Pertiwi et al., 2024). One essential skill to be cultivated in early education is critical thinking (Komara & Hadiapurwa, 2023; Setiawan et al., 2024). Students' inability to develop this skill has been shown to negatively affect long-term cognitive achievement, both academically and in contextual decision-making. According to the 2022 PISA survey, Indonesia's ranking in science literacy remains low, highlighting the urgency to improve learning approaches based on critical reasoning (Aditomo & Klieme, 2020). Efforts to integrate IPAS learning with a STEM-based model are considered capable of promoting analytical, logical, and reflective thinking among students regarding various scientific phenomena in their surroundings (Hacıoğlu & Gülhan, 2021). This emphasis is increasingly important considering that critical thinking skills are not only necessary for academic success but also serve as a foundation for scientific literacy and 21st-century life skills (Suparya et al., 2025). The concept of developing STEM-based Student Worksheets (LKPD) presents a strategic solution to enhance the effectiveness of project-based learning and support the achievement of transformative national education goals.

The difficulty in understanding fundamental IPAS concepts often arises from epistemological obstacles experienced by learners during the learning process (Ardi et al., 2025). These obstacles occur when learners encounter a gap between their prior knowledge and the scientific concepts being taught, leading them to interpret the material inaccurately or superficially (Aliyah et al., 2025). The inability to develop critical thinking patterns becomes one of the main factors that exacerbates these obstacles, as learners who are unable to pose in-depth questions, identify cause–effect relationships, or evaluate information objectively tend to experience impediments in the construction of scientific knowledge (Arda et al., 2024; Milala et al., 2024). Such epistemological obstacles affect the low level of comprehension of IPAS content, particularly with respect to concrete phenomena such as changes in the states of matter, which should be directly observable and analyzable through a STEM-based approach (Saputro et al., 2025). This condition is reinforced by field findings in Grade IV at SDN 104192 Tandam Hilir II, which indicate that the learning process is still dominated by one-way lecturing without support from instructional media, such as LKPD, resulting in very limited active participation by learners in constructing scientific understanding. The results of observations and questionnaires reveal that 52% of learners have not yet achieved the minimum mastery criteria (KKM) and feel insufficiently guided during practice due to the absence of systematic learning aids. Interviews with teachers also indicate limitations in designing project-based LKPD as a result of time constraints and limited competencies. Therefore, the epistemological obstacles encountered by both learners and teachers underscore the urgency of developing contextual learning media such as STEM-based LKPD that can systematically and sustainably stimulate learners' activeness, independence, and critical thinking skills.

The strengthening of critical thinking in learning requires the integration of key dimensions of higher-order thinking, including interpretation, analysis, inference, evaluation, and self-regulation (Budiarti et al., 2023; Istiqomarie et al., 2023). These dimensions are interconnected and must be systematically embedded so that learners do not merely memorize information but are able to reason critically (Mooduto, 2025). The implementation of the STEM approach supports this objective by integrating science, technology, engineering, and mathematics, thereby fostering interdisciplinary learning (Antika et al., 2024; Aswirna et al., 2022). Each STEM element plays a significant role: science fosters the exploration of phenomena, technology facilitates digital processes, engineering develops

design skills, and mathematics trains quantitative representation (Khairuna, 2023; Yani et al., 2024; Zulfawati et al., 2022). Collectively, these elements promote the strengthening of 4C competencies that are essential for addressing the challenges of the 21st century (Waluyo & Wahyuni, 2021).

Previous studies have shown that the use of STEM is effective in enhancing 21st-century skills among elementary school students (Pramasdyasari et al., 2024). The primary focus of these studies was on physics learning and on strengthening students' collaborative skills as well as entrepreneurial skills (Rahayu et al., 2025). Other research has developed STEM-based LKPD on the topic of human digestion and has not addressed the material on the various states of matter (Sihombing & Hasruddin, 2024). In addition, STEM-based LKPD on the Pythagorean theorem has been developed, resulting in improved students' problem-solving abilities (Susanti et al., 2025). However, these studies have not specifically targeted the topic of the various states of matter and their changes, even though this material requires systematic and contextual critical thinking skills. Most existing studies have also not developed STEM-based LKPD specifically designed to integrate the five dimensions of critical thinking within IPAS learning activities. Therefore, this study aims to address this gap by developing STEM-based LKPD focused on improving elementary school students' critical thinking skills on the topic of the various states of matter and their changes.

Suboptimal learning conditions necessitate instructional solutions capable of addressing IPAS learning needs in a contextual, integrative, and higher-order thinking–oriented manner. The development of STEM-based LKPD represents a relevant strategy for bridging the gap between instructional content and elementary school students' critical thinking abilities (Sunedi & Syaflin, 2024). LKPD, designed using a STEM approach, not only presents information but also provides learning experiences that emphasize processes of exploration, observation, analysis, and problem-solving based on real-world phenomena (Dezola et al., 2023). The characteristics of such LKPD enable learners to construct understanding independently, collaborate effectively in groups, and connect scientific concepts with everyday life (Pebriana, 2023). When LKPD are developed with an approach that emphasizes the integration of STEM dimensions, learners' thinking processes are systematically stimulated through more complex and meaningful cognitive stages (Octaviani et al., 2024). The provision of STEM-based LKPD also serves as a practical guide for teachers in designing learning activities that align with the demands of the *Merdeka Curriculum* and the needs of 21st-century learners. This urgency underscores that the development of STEM-based LKPD is not merely a pedagogical option, but a strategic necessity for realizing meaningful and transformative IPAS learning at the elementary school level.

This study aims to develop a STEM-based *Lembar Kerja Peserta Didik* (LKPD) for the subject of *Ilmu Pengetahuan Alam dan Sosial* (IPAS) that is aligned with the characteristics of elementary school learners. In addition, this study seeks to assess the practicality of the developed LKPD through usability testing conducted by teachers and learners in real-world learning contexts. Furthermore, this research is directed toward producing an LKPD product that is effective in improving elementary school students' critical thinking skills on the topic of the various states of matter and their changes.

LITERATURE REVIEW

Student Worksheet

Student Worksheet is an activity-based instructional material designed to guide learners in understanding concepts, completing tasks, and developing thinking skills in a structured manner. The development of high-quality Student Worksheet must meet several essential criteria, including alignment with learning outcomes, relevance of content to learners' contexts, and the capacity to promote both independent and collaborative learning activities (Shinta & Sari, 2024). The primary functions of Student Worksheet include facilitating the learning process, providing explicit guidance to learners, and offering opportunities to practice skills through contextualized exercises (Sari & Fathurrahman, 2024). The objectives of Student Worksheet development include facilitating learners' understanding of concepts, fostering learning independence, and providing a flexible learning format that can be used autonomously (Hasanah et al., 2023). The process of developing Student Worksheet begins with an analysis of learning needs, mapping of learning outcomes, designing procedural steps, and developing instructional content that is aligned with learners' cognitive development levels.

The requirements for developing *Student Worksheets* encompass three main aspects: didactic, constructional, and technical. The didactic aspect involves the principle of meaningfulness of learning materials for learners, while the constructional aspect includes clarity of language, sentence structure, and logical organization of content. The technical aspect covers visual design, consistency of graphic elements, and readability appropriate to the elementary education level (Rani et al., 2024). The advantages of Student Worksheet lie in their ability to enhance active participation, strengthen conceptual understanding, and systematically promote critical thinking skills (Agustin et al., 2024). Based on their form and function, Student Worksheets are classified into several types, including discovery worksheets, guided worksheets, reinforcement worksheets, applicative–integrative worksheets, and practicum worksheets. Each type is tailored to specific learning objectives, for example, practicum worksheets are designed to support the implementation of project-based experimental activities in IPAS learning. The diversity of Student Worksheet types provides flexibility for teachers to adapt instructional media designs to the context of the material and the needs of learners.

Science, Technology, Engineering, and Mathematics (STEM)

The Science, Technology, Engineering, and Mathematics (STEM) approach emphasizes interdisciplinary integration as the core of 21st-century learning development by combining science as an understanding of natural phenomena, technology as innovation for practical problem solving, engineering as the process of designing solutions, and mathematics as a tool for quantitative analysis (Safitri & Tanjung, 2023). This integration promotes the strengthening of critical thinking skills, scientific communication, collaboration, and creativity from the elementary education level (Milala et al., 2024). The STEM approach is not only oriented toward content mastery but also fosters problem-solving abilities through exploration and authentic learning experiences (Sabila et al., 2023). STEM implementation generally employs project-based learning models that require learners to work in teams, design solutions, and develop products in response to contextual issues they encounter (Ikhsan et al., 2025). This process cultivates an integrated mindset and encourages learners to construct and apply knowledge meaningfully, rather than passively receiving information .

The conceptual foundation of the STEM approach is grounded in constructivist theory, which emphasizes learners' active role in constructing knowledge through interaction with the environment and meaningful learning experiences (Bahtiar et al., 2024). Direct engagement in observation, design, and evaluation of solutions within STEM learning reflects constructivist principles that require learners' active participation throughout the entire learning process. In addition, Piaget's theory of cognitive development further strengthens this approach by explaining that knowledge develops through assimilation, accommodation, and cognitive conflict, which are triggered by learners' interactions with real-world problems in their environment (Adhelacahya et al., 2023; Agustina & Yanthi, 2023). The combination of constructivism and cognitive development theory provides a strong theoretical basis for designing STEM learning that promotes higher-order thinking activities, authentic experiences, and the construction of meaning both individually and collaboratively.

Critical Thinking Skills

Critical thinking skills are higher-order cognitive processes that enable learners to analyze, evaluate, and draw logical conclusions based on relevant evidence. These skills play a crucial role in science learning, as they require learners not only to understand concepts but also to assess the accuracy of information and formulate rational solutions to real-world problems (Mareti & Hadiyanti, 2021). Based on recent studies, the main indicators of critical thinking include the ability to interpret data, analyze information structures, formulate appropriate inferences, evaluate arguments objectively, and regulate thinking processes reflectively (Rofik et al., 2025; Sopari et al., 2022). Each of these indicators represents interconnected stages of thinking within a systematic decision-making process, which is essential in problem- and project-based learning at the elementary school level.

Training in critical thinking can be conducted through structured stages, including the ability to analyze problems, synthesize information, solve problems, draw logical conclusions, and evaluate arguments according to rational criteria. This strategy enables learners to actively engage in decision-making processes and formulate solutions grounded in valid evidence (Ilhamdi et al., 2020). Individuals who possess strong critical thinking skills are characterized by sensitivity to logical fallacies, intellectual honesty, openness to alternative perspectives, and the ability to evaluate information before concluding (Charolina et al., 2021; Syukri et al., 2023). Other characteristics include the ability to organize thoughts systematically, to understand the complexity of issues, and to demonstrate persistence in problem-solving. These characteristics indicate that critical thinking is not merely a cognitive activity but also involves mental dispositions and scientific attitudes that are developed through continuous practice and consistent learning experiences.

METHODS

This study falls within the category of research and development (R&D), with the primary objective of producing a STEM-based *Lembar Kerja Peserta Didik* (LKPD) that is valid, practical, and effective in improving elementary school students' critical thinking skills. The development procedure was systematically structured through the stages of needs analysis, product design, and validation, referring to a modified ADDIE-based development model as described by Branch (2009) in *Instructional Design: The ADDIE Approach*. The study was conducted at SDN 104192 Tandam Hilir II, Deli Serdang Regency, North Sumatra Province, during the even semester of the 2024/2025 academic year. The research subjects involved Grade IV students as users of the LKPD, while the research object was the STEM-based LKPD instructional media product on the topic of changes in the states of matter. The involvement of subject matter experts, media experts, and classroom teachers was carried out at the validation stage to assess the feasibility of the content and the visual design of the developed media.

The research procedure followed a modified ADDIE development model consisting of five main stages: analysis, design, development, implementation, and evaluation. The analysis stage was conducted by collecting initial data on learners' needs and challenges in IPAS learning through observations, interviews, and questionnaires. This information served as the basis for designing the LKPD at the design stage, which included the formulation of learning objectives, concept mapping, mapping of STEM elements, and planning LKPD content aligned with the characteristics of elementary school learners. The initial LKPD product was then developed in the form of a prototype and validated by subject matter experts, media experts, and classroom teachers to obtain feedback on content quality, presentation, and language use. The revised prototype was subsequently implemented in a limited trial with Grade IV students to measure practicality and responses to the use of the instructional media. The effectiveness of the LKPD was assessed at the evaluation stage by administering critical thinking tests before and after its use, which were analyzed quantitatively.

Data were collected through several complementary techniques, namely observation, interviews, questionnaires, documentation, and tests. Observations and interviews were employed at the initial stage to explore learning needs and the actual classroom conditions of Grade IV at SDN 104192 Tandam Hilir II. Questionnaires were used to obtain data from subject matter experts, media experts, classroom teachers, and students regarding the validity, practicality, and quality of the developed LKPD. Documentation served as evidence of the implementation of the development activities. At the same time, essay-based tests were administered before and after the implementation of the LKPD to assess the media's effectiveness in improving critical thinking skills. The research instruments included observation sheets, interview guidelines, validation questionnaires, and pretest and posttest items that had undergone validity and reliability testing. Data analysis techniques employed a descriptive quantitative approach by converting validation and questionnaire results into percentages and calculating improvements in students' critical thinking skills through comparisons of pretest and posttest scores, which were analyzed using an independent samples t-test and gain score analysis, as described by Hake (1999) in *Analyzing Change/Gain Scores*.

RESULTS AND DISCUSSION

Analysis Stage (*Analyze*)

The initial stage in the development of STEM-based LKPD involved a needs analysis. Observation techniques were employed to obtain an empirical overview of the IPAS learning process in Grade IV at SDN 104192 Tandam Hilir II. The observation results indicated that learning was still predominantly teacher-centered, which had a direct impact on the low level of learners' active participation and minimal interaction during the learning process. The limited engagement of learners in practical learning activities was further reinforced by questionnaire and interview data, which revealed the absence of LKPD as a guiding tool during the implementation of project activities in the classroom.

Questionnaire data obtained from learners indicate that the majority of students (84%) show an interest in the IPAS subject. Nevertheless, mastery of the topic of the various states of matter and their changes remains low, as evidenced by 72% of learners reporting that they do not yet understand the topic. These findings are consistent with other results showing that 92% of learners feel most motivated when engaging in practical or project-based activities in the classroom. All respondents (100%) stated that they had never received LKPD as a guiding tool during such activities, even though they participated in IPAS practical activities every semester. The instructional materials used during practical implementation were limited to the IPAS textbook and standard worksheets, without any media specifically designed to

systematically guide learners' exploration. All learners also agreed that IPAS learning would be more effective if it were integrated with technology and supported by project-based LKPD. Furthermore, 88% of learners stated that IPAS learning had not been integrated with other subjects such as mathematics, while only 12% perceived the presence of interdisciplinary integration in their learning activities.

The overall data from observations, questionnaires, and interviews indicate that learners' critical thinking skills have not developed optimally due to monotonous instructional methods and limited access to relevant supporting media. These findings provide a rational basis for designing a STEM-based LKPD that is not only relevant to learners' needs but also serves as an integrative medium between subject matter and real-world experiences. The use of lecture-based methods tends to hinder learners' independent exploration of concepts, particularly when instruction is delivered without the support of instructional media such as LKPD (Dezola et al., 2023). The development of LKPD grounded in the actual needs of the classroom is therefore expected to stimulate learners' active engagement, deepen conceptual understanding, and systematically foster critical thinking skills.

Design Stage (*Design*)

The design stage was conducted after the needs analysis and the characteristics of learners had been successfully identified through observations, questionnaires, and interviews. This process involved organizing learning materials and designing instruments to measure the achievement of learning objectives. The selected material focused on the topic of "the various states of matter and their changes" for Grade IV at SDN 104192 Tandam Hilir II. The evaluation instruments, in the form of pretest and posttest items, were developed based on a blueprint aligned with critical thinking indicators and were subsequently reviewed by validators to obtain feedback regarding item clarity, difficulty, readability, and contextual appropriateness.

Validasi instrumen menghasilkan beberapa saran penting, seperti perlunya penyempurnaan redaksi soal, penyesuaian tingkat kesulitan, serta penghilangan makna ganda dalam beberapa item pertanyaan. Uji validitas menunjukkan bahwa dari 12 butir soal, hanya 10 soal yang layak digunakan karena memenuhi batas r hitung > r tabel, sementara dua soal lainnya dinyatakan tidak valid. Reliabilitas instrumen mencapai nilai 0.827 yang menunjukkan bahwa keseluruhan soal memiliki konsistensi internal yang sangat baik. Analisis tingkat kesukaran mengklasifikasikan empat soal dalam kategori sedang dan delapan soal dalam kategori sukar. Analisis daya pembeda memperlihatkan bahwa satu soal tergolong sangat baik, tiga soal baik, dan delapan soal cukup baik. Pemetaan antara capaian pembelajaran dan tujuan pembelajaran telah dirumuskan dengan sistematis, yang memuat indikator kemampuan peserta didik dalam menyimpulkan, membandingkan, dan mengurutkan proses perubahan wujud benda melalui aktivitas membaca serta proyek berbasis eksperimen (Hasanah *et al*., 2023; Khaira *et al*., 2023). Seluruh hasil ini dijadikan dasar untuk memilih dan merevisi item soal yang akan digunakan pada pretest dan postes di tahap implementasi selanjutnya.

Development Stage (*Develop*)

The development stage was carried out to refine the instruments and the STEM-based LKPD product through expert validation. The validation process aimed to ensure that the developed instruments met standards of content feasibility, design, and language. This process involved experts from three main fields, namely subject matter, media, and language. All validators reviewed the content, visual structure, and language quality of the LKPD. The evaluation was conducted comprehensively to ensure that the product could be effectively used in IPAS learning at the elementary school level.

The assessment provided covered two aspects, namely qualitative evaluation and feedback in the form of improvement suggestions. Several recommendations included adjusting the layout design to appear more engaging and well structured, using language that conforms to the *Pedoman Umum Ejaan Bahasa Indonesia* (PUEBI), and simplifying the content to align with the cognitive development level of elementary school learners. The researcher addressed all of these suggestions by revising the visual, linguistic, and content aspects of the LKPD. These improvements were made to ensure that the LKPD assessment instrument is not only technically feasible but also capable of supporting an effective, engaging, and learner-appropriate learning process (Agustina & Yanthi, 2023).

The evaluation of the STEM-based LKPD was conducted by a team of experts using an evaluation instrument that had been previously validated. The evaluators consisted of six experts representing the fields of subject matter, media, and language, each of whom provided assessments based on indicators of content feasibility, presentation structure, and linguistic clarity. The primary objective of this stage was to ensure that the developed LKPD met comprehensive validity criteria prior to its implementation in learning activities. The level of agreement on the validity of the LKPD was analyzed using the Cohen's Kappa formula, which is commonly applied in development research to measure content validity (Cohen, 1960). Based on the calculation results, the average validity scores from the three expert domains are presented in **Table 1.**

Table 1. Results of the LKPD Validity Testing

No	Experts	Expert Evaluation	Category
1	Subject Matter Expert	0.701	High
2	Media Expert	0.500	Moderate
3	Language Expert	0.571	Moderate

Source: Research 2025

The quantitative assessment of the quality of the STEM-based LKPD indicated very high validity across various aspects. The subject matter expert awarded the highest score of 100% on the indicators of content currency, presentation technique, and supporting presentation elements, while the lowest score recorded was 92% on the indicator of content accuracy. Overall, the score range fell between 92% and 97.14%, indicating comprehensive content feasibility of the LKPD. Qualitative feedback from the subject matter expert included recommendations to present relevant subheadings, condense content to avoid excessive length, and add engaging images to enhance reading interest (Syukri et al., 2023). Revisions were made to the structure, narrative, and visual elements to ensure that the LKPD was not only content-valid but also communicative and aligned with learners' characteristics. The media expert evaluation resulted in a score of 90.83%, categorized as very valid, with critiques related to text density and image size. The researcher subsequently revised the layout and media visualization to ensure proportionality and improved observability for elementary school learners.

The linguistic aspect validated by the language expert obtained a total score of 92.78%, categorized as very valid. The assessment covered clarity, communicative quality, appropriateness to learners' developmental levels, as well as language conventions and the use of terms or icons. Improvement suggestions were primarily focused on the introductory section, particularly regarding font usage, spelling, and the effectiveness of sentence structure. Revisions were subsequently made to align the LKPD manuscript with elementary-level language conventions, ensuring that the content is conveyed clearly and optimally.
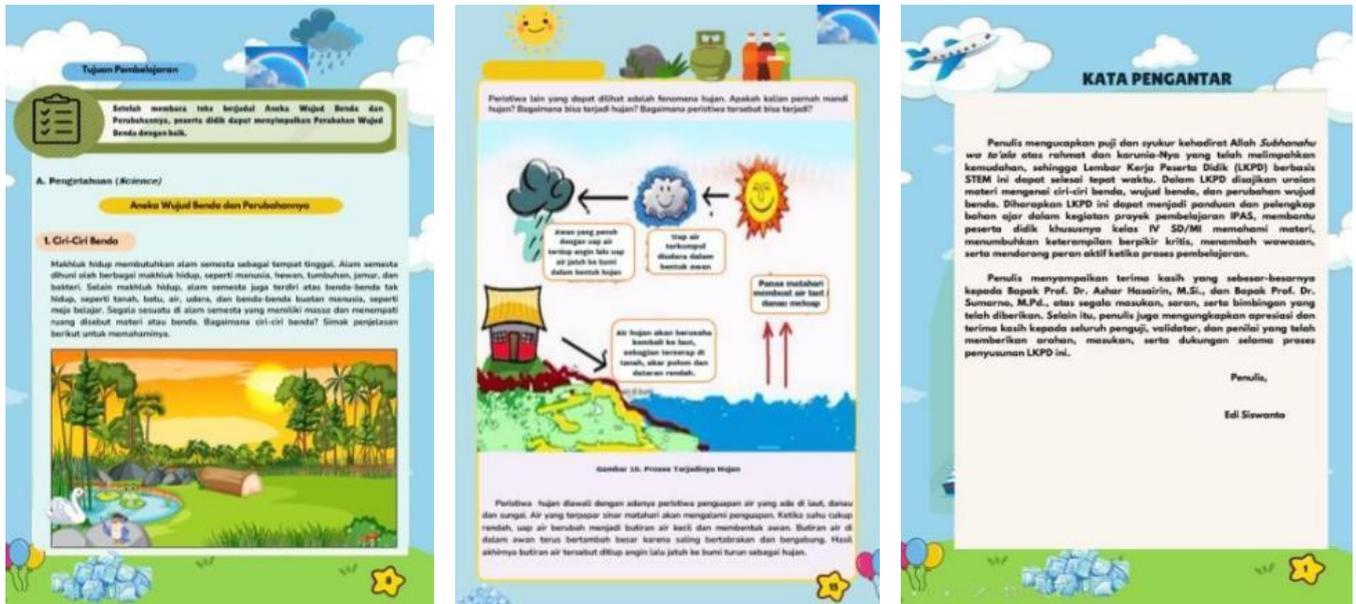
Figure 1. Final Appearance of the STEM-Based LKPD
Source: Research 2025

Figure 1 illustrates the final outcome of the development of the STEM-based *Student Worksheet* (LKPD), which was prepared through the stages of analysis, design, and expert validation. This LKPD was designed to support IPAS learning on the topic of the various states of matter and their changes by emphasizing the contextual integration of science, technology, engineering, and mathematics. The visual design, content structure, and selection of learning activities were tailored to the characteristics of elementary school learners in order to encourage active engagement and the development of critical thinking skills during the learning process.

Implementation Stage (*Implementation*)

The implementation stage in this study aimed to examine the practicality of the STEM-based LKPD through two trial scales, namely small-group and large-group trials. The small-group trial involved nine Grade V students to obtain an initial overview of the product's practicality. The large-group trial consisted of thirty students and was conducted to collect more comprehensive data. Instructions for using the LKPD were provided prior to the learning activities to ensure that learners understood the sequence of tasks (Budiarti et al., 2023). Questionnaires were administered after the learning activities as feedback on ease of use, visual design quality, language clarity, and the usefulness of the LKPD in supporting contextual learning, as presented in **Table 2**.

Table 2. Trial Results

Trial	Number of Students	Score (%)	Criteria

Small Group	9	86.81	Highly Practical
Large Group	30	87.08	Highly Practical

Sumber: Penelitian 2025

The results of the analysis indicate that the score for the small group reached 86.81%, while the large group achieved 87.08%. The overall average score was 86.95%, which falls into the *highly practical* category. These high scores reflect that the STEM-based LKPD can be effectively implemented in IPAS learning on the topic of various states of matter and their changes (Adhelacahya et al., 2023; Octaviani et al., 2024). Active student engagement in the learning process was well facilitated, in line with efforts to integrate elements of science, technology, engineering, and mathematics in an applied manner at the elementary school level.

Evaluation Stage (Evaluasi)

The evaluation stage represents the final phase in the development process of the STEM-based LKPD and is intended to refine the product based on the results of previous trials. This evaluation was conducted after expert validation and the implementation of small-group and large-group trials had been completed. The researcher identified various inputs and suggestions provided by material, media, and language experts, as well as feedback from students as the direct users of the LKPD. All of these inputs were systematically analyzed to support comprehensive revisions to the content, media visualization, and language use, ensuring that the developed LKPD aligns with the characteristics and needs of elementary school students.

The revisions included adjusting the content to ensure alignment with learning outcomes, refining the layout and visual appearance to enhance communicative clarity, and improving sentence structure and word choice to comply with Indonesian language conventions and to be easily understood by students. This evaluation process demonstrates that the development of the LKPD did not end at the validation stage but continued through product reconstruction based on empirical and pedagogical reflection. The final product has met the feasibility criteria as evidenced by a comprehensive multi-source analysis and demonstrates readiness for implementation in IPAS learning on the topic of various forms of matter and their changes.

The practicality test of the STEM-based LKPD was conducted to obtain empirical data on teachers' and students' responses during the science learning process. The assessment of practicality was carried out after the learning activities were completed using a practicality evaluation questionnaire, as presented in **Table 3**.

Table 3. Practicality Test Data of the LKPD

Respondents	Score (%)	Criteria
Teacher	89.44	Highly Practical
Student	88.40	Highly Practical

Source: Research 2025

A score of **89.44%** from teachers indicates that the LKPD is considered easy to use, communicative, and aligned with instructional needs. Meanwhile, a score of **88.40%** from students demonstrates that the LKPD is easy to understand, features engaging visual elements, and effectively encourages active participation during learning activities. The consistency between teachers' and students' responses

indicates that the product is practically feasible and suitable for classroom implementation (Antika et al., 2024).

The effectiveness of the LKPD was measured through pretests and posttests administered to 25 students in the experimental class. The mean pretest score of 65.24 increased to 79.12 in the posttest, with the score range improving from 55–75 to 77–88. This change indicates a significant improvement in students' understanding after the learning intervention. In the control class, which used a standard LKPD, the mean pretest score of 66.72 increased only slightly to 69.16, with the minimum score rising from 55 to 63 and the maximum from 75 to 78. Compared to the experimental class, the improvement in the control class was relatively lower. The distribution of students' critical thinking skills across categories is presented in **Table 4**.

Table 4. Students' Critical Thinking Skill Achievement in the Control Class and Experimental Class

Categories	Interval	Experiment		Control	
		Pretest	Postest	Pretest	Postest
Very Poor Critical Thinking	0-50	-	-	-	-
Poor Critical Thinking	51-69	16	-	17	15
Fair Critical Thinking	70-79	9	12	8	10
Good Critical Thinking	80-89	-	13	-	-
Excellent Critical Thinking	90-100	-	-	-	-

Sumber: Penelitian 2025

The experimental class demonstrated a shift from the **"low critical"** category (64%) to the **"moderately critical"** (48%) and **"critical"** (52%) categories after the implementation of the learning intervention. In contrast, the control class remained predominantly in the **"low critical"** category in the post-test (60%), although there was a modest increase in the **"moderately critical"** category from 32% to 40%. The differences between the two groups were analyzed using an independent samples *t*-test, as presented in **Table 5**.

Table 5. T Test Result

Class	N	Mean	Std. Dev	Sig. (2-tailed)
Experiment	25	79.12	4.42	0.000
Control	25	69.16	3.45	

Source: Research 2025

The significance value of **0.000 < 0.05** indicates a statistically significant difference in mean scores between the two groups. This result leads to the rejection of the null hypothesis and the acceptance of the alternative hypothesis, which states that learning activities using STEM-based LKPD have a significant effect on improving students' critical thinking skills. The N-Gain analysis further supports this finding, showing that the experimental class achieved a score of **63%** (moderately effective category), while the control class reached only **35%** (less effective category). This difference confirms that the integration of the STEM approach within the LKPD contributes significantly to enhancing learning effectiveness on the topic of states of matter and their changes (Adhelacahya et al., 2023).

Discussion

The discussion in this study aims to provide an in-depth interpretation of the results of the development of the STEM-based LKPD based on the findings from the validity, practicality, and effectiveness tests. The product was developed to enhance the critical thinking skills of fourth-grade students on the topic of states of matter and their changes (Rofik et al., 2025). The validation results indicate that the LKPD meets the criteria for content feasibility, visual presentation, and appropriate language use in accordance with students' developmental levels. Expert evaluations confirmed that the product demonstrates a very high level of validity, indicating that the LKPD aligns with quality indicators as an instructional material for IPAS learning (Octaviani et al., 2024).

The increase in students' active participation is reflected in the results of the practicality test, which show very high scores from both teachers and students. Teachers reported that the LKPD is easy to use, engaging, and aligned with instructional needs, while students responded positively to its visual design, language use, and ease of understanding the material (Milala et al., 2024). These findings are supported by previous studies indicating that interactive and contextual learning products are effective in enhancing students' critical thinking skills and engagement (Rosyiddin et al., 2023; Setiawan et al., 2024). The practicality data therefore suggest that the LKPD is able to facilitate a more enjoyable and meaningful learning process.

The learning approach employed in this STEM-based LKPD directly addresses the epistemological barriers often experienced by students, where gaps exist between their prior knowledge and the scientific concepts being taught. By providing contextual, project-based learning experiences, this LKPD helps students bridge these gaps, enabling them to construct knowledge more deeply rather than merely memorizing content. This approach is particularly important given the initial findings at SDN 104192 Tandam Hilir II, which indicated that learning was still dominated by one-way lecture methods and the absence of an LKPD, resulting in very limited active student participation in building scientific understanding.

The success of the LKPD in enhancing critical thinking skills is also supported by the integration of higher-order thinking dimensions, including interpretation, analysis, inference, evaluation, and self-regulation. Through the activities provided in the LKPD, students are trained not merely to memorize content but to reason criticallya process reinforced by the interdisciplinary STEM approach. Each STEM element contributes to strengthening the 4C competencies (Critical Thinking, Creativity, Communication, Collaboration), which are essential for the 21st century (Weng et al., 2022). These findings align with previous studies demonstrating that the STEM approach is effective in enhancing 21st-century skills among elementary school students (Yıldız & Ecevit, 2024). However, this study successfully addresses a gap in prior research by specifically targeting the topic of various states of matter and their changes, while designing the LKPD to systematically integrate all five dimensions of critical thinking, which had not been explicitly addressed in earlier studies.

The effectiveness of using the LKPD is evidenced by statistical tests showing a significant improvement in critical thinking skills in the experimental class compared to the control class. Results from the *t*-test and N-Gain analysis support that learning with the STEM-based LKPD is more effective than using a standard LKPD. These findings are reinforced by previous studies indicating that a well-designed LKPD can facilitate students' analytical and reflective thinking (Nurhaisa et al., 2023; Sabila et al., 2023). This achievement is also supported by learning theories—constructivist, behaviorist, and cognitive—that emphasize active student engagement, the provision of stimuli, and information processing as the foundation for designing STEM-based learning.

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CONCLUSION

The development of a STEM-based Student Worksheet (LKPD) on the topic of states of matter and their changes has produced a product that is valid, practical, and effective. The validity of the LKPD was rated very high based on evaluations from content, media, and language experts, indicating that it meets the criteria for content accuracy, visual design, and language use appropriate for elementary-level IPAS learning. The practicality of the product was also rated very high, as reflected in the positive responses from teachers and students, who reported that the LKPD is easy to use, engaging, and supports the overall learning process effectively.

The effectiveness of the LKPD is demonstrated by the improvement in students' critical thinking skills in the experimental class, as evidenced by the study results and the significantly higher post-test scores compared to the control class. These findings confirm that the STEM-based IPAS LKPD developed in this study can serve as a valid instructional tool capable of substantively enhancing the quality of IPAS learning at the elementary level. Therefore, it is recommended that teachers begin to integrate STEM-based LKPD more systematically into IPAS teaching and learning activities to make instruction more contextual, active, and oriented toward strengthening critical thinking skills. Future research is suggested to adapt this model to other IPAS themes and implement it on a larger scale to examine the consistency of its effectiveness across different student characteristics and learning environments.

AUTHOR'S NOTE

The author declares that there are no conflicts of interest related to the publication of this article. The author also affirms that the data and content of the article are free from plagiarism.

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