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Development of HOTS-Based Student Worksheets on Force and Motion Materials to Improve Students' Critical Thinking Skills

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ABSTRACT

Critical thinking is an essential higher-order thinking skill in 21st-century learning because it enables students to analyze information, evaluate problems, draw conclusions, and construct logical arguments. However, preliminary observations showed that fourth-grade students still experienced difficulties in developing critical thinking skills in science learning, particularly on the topic of Force and Motion. Therefore, this study aimed to develop a Higher Order Thinking Skills (HOTS)-based Student Worksheet (LKPD) that is valid, practical, and potentially useful for supporting students' critical thinking skills. This study employed a Research and Development (R&D) approach using the 4D development model, consisting of Define, Design, Develop, and Disseminate stages. The limited classroom trial involved 20 fourth-grade students at SD Pelangi. Data were collected through pretests and posttests, material and media expert validation sheets, observations, interviews, and teacher and student response questionnaires. The data were analyzed using validity analysis, practicality analysis, and N-Gain analysis to identify learning improvement. The results showed that the HOTS-based LKPD met highly valid and practical criteria. Material expert validation reached 98%, while media expert validation reached 93%, both categorized as "very valid." The teacher practicality score reached 84%, categorized as "very practical," and student responses showed highly positive results. The classroom trial also indicated an improvement in students' learning outcomes, with the average pretest score increasing from 39.5 to 88.5 in the posttest. The N-Gain score reached 0.80, which is categorized as high. These findings suggest that contextual HOTS-based activities can support students' participation and critical thinking processes in science learning. The developed LKPD can be used as an alternative learning material to support student-centered science instruction. However, further studies involving larger samples and control groups are needed to examine its effectiveness more rigorously.

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INTRODUCTION

Students need to be optimally prepared to face global challenges in the 21st century. One of the most essential competencies required in this era is critical thinking ability. Through critical thinking, students are able to analyze information carefully, examine problems rationally, and make appropriate decisions based on evidence and logical reasoning. According to Robert H. Ennis, critical thinking is reflective and rational thinking focused on deciding what to believe or do (Ennis, 2016). Therefore, schools play an important role in developing students' critical thinking skills through meaningful learning experiences. Education is expected not only to transfer knowledge but also to help students develop their potential, creativity, independence, and problem-solving abilities. Learning activities should be interactive, inspiring, enjoyable, and challenging so that students become actively involved in the learning process. In addition, learning should provide opportunities for students to develop higher-order thinking skills according to their physical and psychological development (Purba & Anas, 2024). The development of learning and innovation skills, including critical thinking, creativity, collaboration, and communication, is considered an essential requirement for students in 21st-century education (Abad et al., 2019; Lubis & Syahputri, 2022).

Critical thinking is closely related to Higher Order Thinking Skills (HOTS), which emphasize students' abilities to analyze, evaluate, and create. HOTS-oriented learning encourages students not only to memorize concepts but also to understand, apply, and solve problems in various contexts. In science learning, HOTS is important because students are expected to investigate scientific phenomena and construct logical explanations based on evidence (Noprinda & Soleh, 2019; Firdaus & Wilujeng, 2018; Putra et al., 2023). Several indicators are commonly used to identify students' critical thinking skills. According to Angelo (1995) cited in Siti (2010), critical thinking includes analytical skills, synthesis skills, problem-solving skills, conclusion-drawing skills, and evaluation skills. These indicators help students process information systematically, connect ideas meaningfully, and make rational judgments based on available evidence. Previous studies have also shown that critical thinking skills can be strengthened through problem-based learning and constructivist learning approaches that actively engage students in knowledge construction processes (Kusumawati et al., 2022).

Critical thinking skills are highly needed in science learning because science is closely related to observation, experimentation, and problem-solving activities. Students who think critically are more capable of identifying relationships between concepts and applying scientific knowledge to everyday situations. Therefore, science learning should provide opportunities for students to actively explore, investigate, and analyze scientific problems. Practical and inquiry-based learning activities have been reported to improve students' science process skills and reasoning abilities (Panuluh, 2022). In the 21st century, education also emphasizes the development of creativity, communication, collaboration, and critical thinking as core competencies. These competencies are necessary for students to face rapid technological and social changes in modern society. Consequently, teachers are required to implement innovative instructional strategies that encourage active learning and higher-order thinking processes (Assingkily et al., 2021).

However, in reality, many elementary school students still experience difficulties in developing critical thinking skills. Based on preliminary observations conducted at SD PELANGI, fourth-grade students tended to rely on memorization and showed limited ability in analyzing problems related to science learning. Students also experienced difficulties when asked to explain scientific phenomena or solve contextual problems independently. Although the 2013 Curriculum emphasizes student-centered learning and problem-solving activities, its implementation in the classroom has not yet been optimal. Learning activities are still frequently dominated by teacher explanations and textbook-oriented instruction. As a result, students have limited opportunities to develop analytical and evaluative thinking skills during the learning process.

One factor contributing to students' low critical thinking skills is the limited availability of learning materials that specifically facilitate HOTS-oriented activities. Most existing student worksheets (LKPD) still emphasize Lower Order Thinking Skills (LOTS), such as remembering, understanding, and simple application. Activities that train students to analyze, evaluate, and solve problems critically are still limited. Student Worksheets (LKPD) are important learning tools because they guide students during learning activities and help them achieve instructional objectives. Properly designed LKPD can encourage students to become more active in observing, discussing, experimenting, and solving problems. Therefore, developing HOTS-based LKPD is considered necessary to support students' critical thinking skills in science learning. Various studies have demonstrated the feasibility of HOTS-based worksheets in supporting active learning and higher-order thinking processes (Kholifahtus et al., 2022; Pebriani et al., 2022; Sari et al., 2022; Rasyid et al., 2024).

Previous studies have reported positive results regarding the use of HOTS-based LKPD in elementary education. Research conducted by W. P. Putra showed that HOTS-based E-LKPD developed using the ADDIE model was highly valid and feasible for implementation in elementary science learning. The study also indicated that the developed product contributed positively to students' learning outcomes and critical thinking skills (Putra et al., 2023). Similarly, research conducted by Safriza Ariska Sitorus found that HOTS-based LKPD improved students' critical thinking skills in science subjects. The study reported significant improvement between pretest and posttest scores, supported by a high N-Gain result. In addition, both teachers and students considered the developed LKPD practical and appropriate for classroom use (Sitorus, 2024). Similar findings were reported by Jannah et al. (2025), Simanjuntak et al. (2024), and Sitorus et al. (2024), who found that HOTS-based LKPD significantly supported students' critical thinking development across different educational contexts.

Recent developments in worksheet design have also integrated various learning approaches and technologies, such as STEM-based LKPD, website-assisted LKPD, game-based LKPD, and contextual teaching and learning approaches (Pasaribu & Ulfa, 2023; Sabila et al., 2023; Ruzika, 2024; Ramadhani, 2024; Shaharani & Manalu, 2025). In addition, digital learning resources and visual learning media have been developed to increase students' motivation and engagement during learning activities (Indriani et al., 2024; Siregar, 2025).

Despite the positive findings reported in previous studies regarding the use of HOTS-based LKPD, several gaps in the literature still need to be addressed. Many earlier studies concentrated on digital E-LKPD development or explored broader science topics, with limited attention given to the topic of Force and Motion for fourth-grade elementary school students. In addition, few studies have incorporated hands-on classroom activities that utilize simple and easily accessible objects from students' everyday surroundings. To fill these gaps, the present study develops a HOTS-based LKPD on the topic of Force and Motion by applying the 4D development model (Pada & Bangun, 2023). The distinctive aspect of this study is the integration of practical learning activities involving common classroom materials, such as tables, chairs, and book boxes, to facilitate a more concrete understanding of scientific concepts. These contextual learning experiences are intended to encourage students to actively engage in problem analysis, reasoning, and conclusion drawing, thereby fostering their critical thinking abilities.

The primary objective of this research is to develop a HOTS-based LKPD that meets validity and practicality standards and can support students' critical thinking processes in science learning. Rather than examining instructional effectiveness on a large scale, this study emphasizes product development and feasibility evaluation. Accordingly, the results are expected to contribute to the advancement of innovative science learning resources and serve as a valuable reference for future research on the implementation of HOTS-oriented learning materials in elementary education.

METHOD

Type of Research

This study adopted the Research and Development (R&D) approach to design and assess a Higher Order Thinking Skills (HOTS)-based Student Worksheet (LKPD) for science instruction on the topic of Force and Motion. Research and Development is a systematic process aimed at producing educational products and evaluating their appropriateness for use in learning activities (Aminah & Yusnaldi, 2024). In this research, the developed LKPD was designed to facilitate fourth-grade elementary school students in engaging in learning activities that encourage the development of critical thinking skills through HOTS-oriented tasks.

The development process followed the 4D model, which includes four stages: Define, Design, Develop, and Disseminate. This model was chosen because it offers a structured framework for creating instructional materials that meet standards of validity, practicality, and classroom applicability (Pada & Bangun, 2023). Nevertheless, the scope of this study was limited to the development and initial implementation of the product rather than conducting a large-scale effectiveness evaluation. Consequently, the results should be viewed as evidence of the LKPD's feasibility and its potential to support learning processes, rather than as definitive proof of its effectiveness in improving student outcomes across broader educational contexts.

Research Procedure

1) Define Stage

The define stage aimed to identify instructional problems, analyze students' needs, and formulate learning objectives related to critical thinking skills in science learning. Activities conducted at this stage included initial analysis, student analysis, task analysis, material analysis, and learning objective formulation. Preliminary observations and interviews with teachers revealed that students experienced difficulties in analyzing scientific problems and that existing LKPD materials still focused primarily on Lower Order Thinking Skills (LOTS). Student analysis was conducted to identify the characteristics, learning needs, and academic abilities of fourth-grade students at SD PELANGI. Material analysis focused on the topic of Force and Motion in elementary science learning. The results of these analyses were used as the basis for designing HOTS-oriented learning activities and critical-thinking tasks integrated into the developed LKPD.

2) Design Stage

The design stage involved preparing research instruments, selecting learning media, determining the LKPD format, and developing the initial product design. At this stage, the researcher designed HOTS-based activities that encouraged students to analyze, evaluate, and solve contextual problems related to Force and Motion. The LKPD design integrated direct practical activities using classroom objects such as tables, chairs, and book boxes. Students were guided through observation, experimentation, discussion, and problem-solving activities to support critical thinking processes. In addition, pretest and posttest instruments were developed based on critical-thinking indicators, including analysis, problem-solving, conclusion-drawing, and evaluation skills.

3) Develop Stage

The develop stage involved expert validation, product revision, and limited classroom testing. The developed LKPD was validated by two material experts and one media expert to evaluate the appropriateness of the content, language, presentation, and visual design. Suggestions and recommendations provided by the validators were used to revise and improve the LKPD before implementation. After the revision process, the product was tested in a limited classroom trial involving fourth-grade students at SD PELANGI. During the implementation process, observations, interviews, and questionnaires were conducted to collect information regarding students' responses, teacher perceptions, and the practicality of the developed LKPD. The classroom trial was intended to evaluate the usability and practicality of the product in a real learning context rather than to establish strong causal evidence of instructional effectiveness.

4) Disseminate Stage

The dissemination stage in this study was limited to classroom-level implementation and introduction of the developed product to teachers within the school environment. Unlike broader dissemination processes involving large-scale distribution, this stage focused on presenting the revised LKPD product for limited educational use after it had met feasibility and practicality criteria. Therefore, dissemination in this study refers to limited implementation rather than wide-scale adoption.

Participants and Sampling Technique

The participants in this study were fourth-grade students of SD PELANGI. The limited classroom trial involved 20 students representing the entire fourth-grade class. Therefore, the study used total sampling because all students in the class participated in the implementation of the developed LKPD. In addition to student participants, the study also involved validators consisting of two material experts and one media expert. Classroom teachers participated as respondents in practicality assessments and interviews related to the implementation of the HOTS-based LKPD.

Trial Design

The product developed in this study was a HOTS-based Student Worksheet (LKPD) on the topic of Force and Motion, designed to promote students' critical thinking skills through contextual and inquiry-oriented science learning activities. The LKPD consisted of several components, including learning objectives, activity guidelines, visual illustrations, hands-on experiments, discussion exercises, and Higher Order Thinking Skills (HOTS)-based questions that encouraged students to analyze information, evaluate situations, and formulate logical conclusions. To obtain preliminary evidence regarding the implementation of the product, a limited classroom trial was conducted using a one-group pretest-posttest design. Students completed a pretest before participating in the learning activities with the LKPD and a posttest after the activities were completed. The comparison of pretest and posttest scores was used to examine possible changes in students' critical thinking performance following the use of the developed worksheet. Nevertheless, since no control group was included in the research design, the results should be interpreted with caution and regarded as preliminary indications of learning improvement within the context of educational product development rather than conclusive evidence of instructional effectiveness.

Data Collection Techniques

This study used multiple data collection techniques, including tests, questionnaires, observations, interviews, and validation sheets. The use of multiple instruments aimed to strengthen the credibility of the findings and provide comprehensive information regarding the validity, practicality, and potential effectiveness of the developed LKPD. Observation techniques were used to identify classroom conditions, student participation, and learning activities during the implementation process. Interviews with classroom teachers were conducted to collect information regarding students' learning difficulties, the use of LKPD in science learning, and teacher perceptions toward HOTS-oriented instruction. Validation sheets were distributed to material experts and media experts to evaluate the feasibility of the LKPD content, presentation, language, and design aspects. Teacher practicality questionnaires and student response questionnaires were administered after the classroom trial to evaluate the practicality and usability of the developed product.

Research Instruments

The study employed several instruments systematically designed in accordance with the research objectives. The instruments are summarized in the following table.

Table 1. Research Instrument

Instrument	Respondents	Number of Items	Scale	Purpose
Material Validation Sheet	Material Experts	20 items	Likert Scale (1–5)	Assess content feasibility and HOTS integration
Media Validation	Media Expert	15 items	Likert Scale	Assess visual design and

Sheet			(1–5)	presentation
Teacher Practicality Questionnaire	Classroom Teacher	15 items	Likert Scale (1–5)	Evaluate practicality and usability
Student Response Questionnaire	Students	10 items	Likert Scale (1–5)	Identify students'responses toward the LKPD
Pretest and Posttest	Students	10 essay items	Score 0–100	Measure critical thinking improvement
Observation Sheet	Researcher	10 aspects	Checklist	Observe learning activities
Interview Guide	Teacher	Open-ended	Qualitative	Obtain supporting classroom information

The pretest and posttest instruments consisted of 10 essay items developed to measure students' critical-thinking skills in learning the topic of Force and Motion. The items were constructed based on critical-thinking indicators adapted from Angelo (1995), namely analytical skills, problem-solving skills, conclusion-drawing skills, and evaluation skills. Each item required students to analyze scientific situations, interpret data or observations, solve contextual problems, and provide logical explanations supported by scientific reasoning.

Before implementation, the pretest and posttest instruments were reviewed and validated by two experts consisting of a science education lecturer and a classroom teacher. The validation process focused on several aspects, including content relevance, alignment with learning objectives, suitability of HOTS indicators, clarity of instructions, language appropriateness, and the correspondence between the essay items and critical-thinking indicators. The experts evaluated whether each item accurately represented the targeted critical-thinking skills, namely analytical skills, problem-solving skills, conclusion-drawing skills, and evaluation skills. In addition, the validators examined the contextual suitability of the questions related to the topic of Force and Motion and assessed the appropriateness of the scoring rubric used for essay assessment.

Several revisions were conducted based on expert feedback before the classroom implementation. The revisions included improving question wording to avoid ambiguity, adjusting the level of difficulty to match students' cognitive levels, refining contextual problem situations, and clarifying the scoring criteria in the rubric. These revisions were intended to improve the validity and readability of the instruments.Statistical reliability testing was not conducted because the instrument used essay-based responses and was limited to classroom-scale implementation. However, scoring consistency was maintained through the use of an analytic scoring rubric with clearly defined criteria for each critical-thinking indicator. The rubric provided standardized guidelines for assessing students' answers systematically and objectively.

To minimize subjective judgment, all student responses were scored using the same assessment procedures and criteria. The scoring process emphasized consistency in evaluating conceptual accuracy, logical reasoning, completeness of explanation, and the appropriateness of scientific arguments. The use of detailed scoring descriptors helped maintain assessment reliability across the pretest and posttest evaluations. To ensure a clear relationship between the indicators and the test items, the instrument blueprint is presented in the following table.

Table 2. Instrument Blueprint

Critical-Thinking Indicator	Description of Skills Measured	Item Numbers
Analytical Skills	Analyzing relationships between force, motion, and observed phenomena	1, 2, 3
Problem-Solving Skills	Solving contextual problems related to force and motion concepts	4, 5, 6
Conclusion-Drawing Skills	Drawing logical conclusions based on experiments or observations	7, 8
Evaluation Skills	Evaluating arguments, solutions, or scientific explanations critically	9, 10

The analytical skill items focused on students' ability to identify causes and effects in motion phenomena and interpret experimental situations. The problem-solving items required students to apply scientific concepts in solving daily-life problems related to force and motion. The conclusion-drawing items assessed students' ability to formulate logical conclusions from observations and data interpretation, while the evaluation items measured students' ability to assess the appropriateness of scientific explanations and justify their reasoning critically. Before implementation, all instruments were reviewed and validated by experts to ensure content appropriateness, clarity of language, and alignment with the learning objectives and HOTS indicators. The revision process was conducted based on expert suggestions to improve the quality and consistency of the instruments prior to classroom implementation. Instrument reliability was strengthened through repeated expert review and refinement processes conducted before the field trial.

To ensure consistent and objective assessment of students' responses, the essay items in the pretest and posttest were evaluated using an analytic scoring rubric. The rubric was designed based on the critical-thinking indicators adapted from Angelo (1995), namely analytical skills, problem-solving skills, conclusion-drawing skills, and evaluation skills. Each response was scored according to the accuracy of concepts, logical reasoning, completeness of explanation, and the students' ability to provide scientific justification. The scoring rubric used a scale ranging from 1 to 4 for each indicator, where higher scores represented better critical-thinking performance. The assessment criteria are summarized in the following table.

Table 3. Assesment Criteria Summarized

Score	Analytical Skills	Problem-Solving Skills	Conclusion-Drawing Skills	Evaluation Skills
4	Accurately analyzes relationships between concepts and identifies relevant information completely	Solves problems correctly with logical and systematic procedures	Draws clear, logical, and scientifically accurate conclusions	Critically evaluates arguments or solutions with strong justification
3	Analyzes most concepts correctly with minor inaccuracies	Solves problems appropriately but with limited explanation	Draws conclusions that are generally correct but less detailed	Evaluates arguments with adequate justification
2	Shows partial understanding but analysis is incomplete	Solves problems partially with several conceptual errors	Draws incomplete or less logical conclusions	Provides limited evaluation and weak justification
1	Shows minimal understanding and inaccurate analysis	Unable to solve problems appropriately	Draws incorrect or unsupported conclusions	Unable to evaluate arguments logically

Each essay item was assessed using the relevant criteria according to the targeted indicator. The total score obtained by students was then converted into a scale of 0–100. The use of this rubric helped ensure scoring consistency and objectivity in measuring students' critical-thinking improvement from pretest to posttest. In addition, the rubric supported the validity of the N-Gain analysis by providing standardized scoring procedures for all student responses.

Data Analysis Technique

The assessment results obtained from expert validation sheets, teacher questionnaires, and student questionnaires were analyzed using percentage-based feasibility calculations. The feasibility percentage was calculated using the following formula:

$$P = \frac{\text{Total Obtained Score}}{\text{Maximum Score}} \times 100\ \%$$

The feasibility criteria used in this study are presented in the following table.

Table 4. Feasibility Criteria

Achievement Percentage	Interpretation
82–100%	Very Feasible
62–81%	Feasible
41–61%	Fairly Feasible
21–40%	Less Feasible
<20%	Not Feasible

The practicality level of the LKPD was determined based on teacher and student questionnaire responses using the same percentage interpretation criteria. To maintain consistency, all practicality and feasibility categories in this study referred to the same interpretation framework. The improvement of students' critical thinking skills was analyzed using the N-Gain Score derived from pretest and posttest results. The N-Gain formula proposed by Hake is presented as follows:

$$\text{N-Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal Score- Ideal Score}}$$

Description:

1. N-Gain = normalized gain value
2. Posttest Score = score after implementation of the LKPD
3. Pretest Score = score before implementation of the LKPD
4. Ideal Score = maximum achievable score

The N-Gain interpretation criteria are presented below.

Table 5. N-Gain Interpretation Criteria

N-Gain Value	Category
(g > 0.7)	High
(0.3 \leq g \leq 0.7)	Medium
(g < 0.3)	Low

In this study, the N-Gain value was interpreted separately from percentage-based feasibility and practicality results to avoid inconsistency in effectiveness reporting. The N-Gain score represented the level of improvement in students' critical thinking skills, while percentage values represented product feasibility and practicality assessments.

RESULTS AND DISCUSSION

Result

The findings of this study are presented based on the stages of the Research and Development (R&D) process used to develop the HOTS-based Student Worksheet (LKPD). The development procedure followed the 4D model, which consists of the Define, Design, Develop, and Disseminate phases. This section describes the outcomes of each development stage, including the characteristics of the resulting product, expert validation results, practicality evaluation, and the findings from its limited implementation in a fourth-grade elementary school classroom. The developed LKPD focused on the topic of Force and Motion and was designed to support students' critical thinking processes through HOTS-oriented learning activities. The results provide evidence regarding the feasibility and practical use of the developed product in elementary science learning contexts.

Define Stage

The define stage aimed to identify learning needs, analyze classroom problems, and determine the instructional requirements needed in developing the HOTS-based LKPD. This stage included initial analysis, student analysis, and concept analysis.

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a. Initial Analysis

The initial analysis was conducted through classroom observations, teacher interviews, and student questionnaires at SD PELANGI. The results showed that teachers still relied primarily on textbooks as the main learning source. Existing learning materials mainly contained routine exercises emphasizing Lower Order Thinking Skills (LOTS), such as remembering and understanding, while activities encouraging analysis, evaluation, and problem-solving were still limited.

Observation results also indicated that students experienced difficulties when faced with contextual or HOTS-oriented questions different from textbook examples. Students tended to memorize answers rather than analyze scientific problems critically. Therefore, teachers required innovative learning materials capable of facilitating students' higher-order thinking skills, particularly in science learning on the topic of Force and Motion.

b. Student Analysis

Student analysis was conducted to identify students' characteristics, learning needs, and critical thinking abilities. Data were collected through needs-analysis questionnaires distributed to fourth-grade students. The findings showed that students preferred learning activities involving direct practice, attractive illustrations, and contextual examples related to daily life. These findings became the basis for designing HOTS-based LKPD activities integrating direct classroom practices and problem-solving tasks.

c. Concept Analysis

Concept analysis focused on identifying the learning concepts related to Force and Motion in elementary science learning. The analysis included determining learning objectives, arranging learning materials, and integrating HOTS indicators into learning activities. The developed LKPD emphasized analysis, evaluation, and problem-solving activities related to everyday scientific phenomena.

2. Design Stage

At the design stage, the researcher prepared the initial LKPD product design based on the results obtained during the define stage. The LKPD was designed according to HOTS-oriented learning principles and integrated activities requiring students to analyze, evaluate, and solve contextual problems. The structure of the LKPD consisted of the cover page, identity section, preface, table of contents, learning objectives, instructions for use, learning materials, practical activities, discussion tasks, and HOTS-oriented evaluation questions. The activities were arranged according to Anderson's revised Bloom's Taxonomy, particularly focusing on analysis, evaluation, and creation skills. The LKPD design also integrated direct practical activities using classroom objects such as tables, chairs, and book boxes to help students understand Force and Motion concepts concretely. Attractive illustrations, contextual examples, and guided activities were included to increase students' learning motivation and participation.

3. Develop Stage

The develop stage involved product realization, expert validation, product revision, and limited classroom testing. The HOTS-based LKPD was developed using the Canva application with a visual design adjusted to elementary students' characteristics. After the product was completed, expert validation was conducted involving two material experts and one media expert from the Faculty of Tarbiyah at Universitas Islam Negeri Sumatera Utara. The validation process aimed to evaluate the feasibility of the developed LKPD in terms of content, presentation, language, and visual appearance.

Table 6. Media Expert Validation Results

Assessment Aspect	Percentage	Category
Visual Appearance	92%	Very Valid

Assessment Aspect	Percentage	Category
Presentation	94%	Very Valid
Language	93%	Very Valid
Overall Average	93%	Very Valid

Media experts suggested improving the brightness of the background color and adding more visual illustrations to increase students' interest and readability. After revisions were completed, the LKPD obtained an average validation score of 93%, categorized as "very valid."

Table 7. Material Expert Validation Results

Assessment Aspect	Percentage	Category
Content Feasibility	98%	Very Valid
Learning Objectives	97%	Very Valid
HOTS Integration	98%	Very Valid
Language Accuracy	99%	Very Valid
Overall Average	98%	Very Valid

Material experts suggested correcting several writing errors, adding visual explanations regarding gravity and magnetism concepts, and improving the appropriateness of illustrations. After three revision stages, the LKPD obtained an average score of 98% and was categorized as "very valid." The validation results indicated that the developed LKPD met the feasibility criteria and could be implemented in classroom learning activities. These findings are consistent with research conducted by Hasarah (2023), which also reported that HOTS-based learning materials could achieve high validity levels when evaluated through material, presentation, and language aspects.

4. Disseminate Stage

The dissemination stage in this study was limited to classroom-level implementation involving fourth-grade students at SD PELANGI. Unlike broader dissemination processes, this stage focused on introducing and implementing the revised LKPD in a limited educational setting after it had met validity and practicality criteria. The limited classroom trial involved 20 fourth-grade students representing the entire class. During implementation, students used the HOTS-based LKPD in science learning activities related to Force and Motion. Teacher and student response questionnaires were distributed after the learning activities to evaluate the practicality of the developed product.

Table 8. Teacher Practicality Results

Assessment Aspect	Percentage	Category
Ease of Use	84%	Very Practical
Learning Implementation	85%	Very Practical
Material Clarity	83%	Very Practical
Overall Average	84%	Very Practical

The teacher practicality results showed that the LKPD was easy to use, systematically arranged, and helpful in guiding learning activities. Teachers also stated that the HOTS-oriented tasks encouraged students to become more active during classroom discussions and problem-solving activities.

Table 9. Student Response Results

Assessment Aspect	Percentage	Category
Attractiveness	100%	Very Practical
Ease of Understanding	98%	Very Practical
Learning Motivation	99%	Very Practical

Assessment Aspect	Percentage	Category
Overall Average	99%	Very Practical

Student responses indicated that the LKPD was attractive, easy to understand, and helpful in learning Force and Motion concepts. Students showed enthusiasm during practical activities and discussions because the LKPD integrated direct classroom experiences and contextual examples. The separation of teacher practicality and student responses clarified the different perspectives regarding product usability and implementation during classroom learning.

5. Learning Improvement Results

Learning Improvement Results was conducted through a limited one-group pretest-posttest classroom trial. The purpose of the test was to identify students' learning improvement after using the HOTS-based LKPD.

Table 10. Pretest and Posttest Results

Assessment	Average Score
Pretest	39.5
Posttest	88.5

The results showed a substantial increase in students' average scores after the implementation of the HOTS-based LKPD. The average pretest score was 39.5, while the average posttest score increased to 88.5.

Table 9. N-Gain Analysis Results

N-Gain Score	Category
0.80	High

The findings suggest that the HOTS-based LKPD shows promising potential to support students' critical thinking activities. In this study, the N-Gain value was interpreted separately from percentage-based practicality and feasibility scores to maintain consistency in data interpretation. Therefore, the N-Gain score reflected learning improvement, while percentage values represented validity and practicality assessments. These findings are supported by research conducted by Firmansyah, which reported that HOTS-based LKPD effectively improved students' critical thinking skills and learning participation in elementary science learning.

Discussion

The findings of this study indicate that the HOTS-based LKPD developed through the 4D model achieved high validity and practicality results and demonstrated promising potential for supporting students' critical thinking processes in science learning. The expert validation results showed that the LKPD met appropriate standards in terms of content feasibility, presentation, language, and visual design. In addition, teacher and student responses indicated that the LKPD was practical, attractive, and easy to implement during classroom learning activities on the topic of Force and Motion. These findings are consistent with the view that well-designed instructional materials can facilitate meaningful learning experiences and support higher-order thinking development among elementary school students (Thiagarajan et al., 1974).

The implementation results showed an increase in students' posttest scores compared to their pretest scores. The average pretest score increased from 39.5 to 88.5, while the N-Gain result reached 0.80 and was categorized as high. These findings suggest that the use of HOTS-based LKPD may support students' learning improvement and critical thinking activities during science learning. However, the findings should be interpreted cautiously because the study used a limited one-group classroom trial involving only 20 students without a comparison group.

Therefore, the results cannot fully establish causal effectiveness or confirm that the score improvement was influenced solely by the developed LKPD.

One important empirical finding observed during the implementation process was the increase in students' participation during classroom activities. Students appeared more actively involved in observing, discussing, and solving contextual problems related to Force and Motion concepts. The integration of direct practical activities using classroom objects, such as pushing tables, pulling chairs, and lifting boxes, appeared to help students connect abstract science concepts with real-life experiences. This indicates that contextual learning activities integrated into the LKPD may contribute positively to students' engagement during learning. Such findings support constructivist learning theory, which emphasizes that students learn more effectively when knowledge is connected to authentic experiences and active exploration (Vygotsky, 1978).

The practicality results also provide important evidence regarding the usability of the developed LKPD. Teacher responses showed that the LKPD helped organize learning activities more systematically and encouraged students to become more active during discussions and problem-solving sessions. Student responses further indicated that the visual appearance, illustrations, and activity-based tasks increased their motivation and interest in learning science. These findings suggest that well-designed HOTS-oriented worksheets can support active classroom participation and facilitate more student-centered learning processes. Similar results were reported by Prastowo (2015), who argued that attractive and systematically organized worksheets can enhance students' engagement and learning motivation.

The findings of this study also strengthen the practical argument that LKPD design should move beyond LOTS-oriented activities emphasizing memorization and routine exercises. The developed LKPD included analysis-oriented questions, observation tasks, and contextual problem-solving activities requiring students to explain phenomena, analyze information, and construct conclusions. As a result, the learning process became more interactive and encouraged students to engage in higher-order thinking activities rather than simply recalling information from textbooks. This is in line with the framework proposed by Anderson and Krathwohl (2001), which highlights analyzing, evaluating, and creating as essential dimensions of higher-order cognitive processes.

Nevertheless, several alternative explanations should also be considered when interpreting the improvement in students' scores. The increase in posttest results may have been influenced not only by the LKPD itself but also by teacher guidance during instruction, repeated exposure to learning materials, classroom interaction, and students' familiarity with the test format. Since the study involved a one-group trial without a control group, these external factors could not be fully controlled during implementation.

In addition, the limited number of participants restricts the generalizability of the findings. The classroom trial was conducted only with fourth-grade students at SD PELANGI, meaning that the results may not fully represent broader elementary school contexts with different student characteristics and learning environments. Therefore, the findings should primarily be viewed as evidence of product feasibility and promising instructional potential within a limited development setting.

Compared to previous studies, this research contributes specifically by integrating direct classroom-based practical activities into the HOTS-based LKPD on the topic of Force and Motion. Rather than focusing solely on digital worksheet formats or general science topics, the developed LKPD emphasized contextual learning experiences closely related to students' daily activities. This contextual aspect appeared to support students' engagement and understanding during classroom implementation. The findings also align with previous research showing that HOTS-oriented learning materials can foster critical thinking skills and improve students' learning outcomes in science education (Facione, 2015).

The HOTS-based LKPD developed in this study demonstrated strong validity and practicality results and showed promising potential to support students' learning participation and critical thinking activities. However, further studies involving larger samples, experimental designs, and control groups are still needed to examine the instructional effectiveness of HOTS-based LKPD more rigorously and to determine the extent to which the product contributes directly to students' critical thinking improvement.

This study successfully developed a HOTS-based Student Worksheet (LKPD) on Force and Motion for fourth-grade elementary students using the 4D development model. The developed LKPD was designed to support students' critical thinking through contextual activities, direct practice, illustrations, discussion tasks, and HOTS-oriented problem-solving exercises.

The results showed that the LKPD was highly feasible and practical for classroom use. Media expert validation reached 93%, while material expert validation reached 98%, both categorized as "very valid." The practicality assessment also showed positive results, with teacher practicality reaching 84% and student responses indicating that the LKPD was attractive, easy to understand, and useful in supporting science learning.

The discussion results indicate that the HOTS-based LKPD has promising potential to support students' critical thinking activities. This can be seen from the increase in students' average pretest score from 39.5 to 88.5 in the posttest, with an N-Gain score of 0.80 in the high category. The use of contextual activities, such as observing and practicing Force and Motion concepts through objects around the classroom, helped students connect scientific concepts with real-life situations and encouraged more active participation during learning.

However, the findings should be interpreted cautiously because the study was conducted in a limited classroom trial involving only 20 students and used a one-group pretest-posttest design without a control group. Therefore, future researchers are advised to test the HOTS-based LKPD with larger samples, different school contexts, and experimental or quasi-experimental designs. Further studies may also examine the long-term impact of HOTS-based LKPD on students' critical thinking skills, learning motivation, and science learning achievement.

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AUTHOR CONTRIBUTION STATEMENT

IP conceived and designed the study, developed the HOTS-based Student Worksheet (LKPD), collected and analyzed the data, interpreted the findings, and wrote the manuscript. NA served as the research supervisor, provided academic guidance throughout the study, reviewed the research design and data analysis, and critically revised the manuscript. Both authors read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors declare that this research was prepared, researched, written, and edited without the use of artificial intelligence (AI) tools or techniques.

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