Development of an Inquiry-Based Worksheet to Practice Cognitive and Science Process on Light Wave Concepts

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Abstract *- This study aims to develop inquiry skills science worksheets to practice cognitive abilities and science process skills. The research used R&D with ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The participants of this research consisted of lecturers, teachers, and students. The research sample consisted of two XI classes as experimental and control classes. The feasibility of the worksheet was analyzed by content validity index (CVI), the improvement of cognitive abilities and science process skills was analyzed using N-Gain, the effectiveness of the worksheet to practice cognitive abilities and science process skills was analyzed using cohen'd effect size, and student responses were analyzed using descriptive quantitative. The overall feasibility of the science inquiry skills worksheet was declared "Feasible" from all aspects of science inquiry skills. The increase in cognitive abilities after learning using the sheet is 0.34 which is included in the moderate category. Meanwhile, the increase in science process skills after learning using worksheets amounted to 0.51 which is included in the moderate category. The effectiveness of worksheets to practice cognitive abilities has a score of 0.53 which is included in the medium criteria. Meanwhile, the effectiveness of worksheets to practice science process skills has a score of 0.63 which is included in the medium category. Students' responses to the inquiry skills science worksheets in terms of interest, pleasure, and convenience have good responses. The worksheets developed are valid and feasible to use as learning tools that support inquiry-based learning and improve cognitive abilities and science process skills in light waves material.*

Keywords*: Science Inquiry Skills; Cognitive Ability; Science Process Skills.*

INTRODUCTION

Physics lessons in the merdeka curriculum are organized into physics comprehension elements and process skills elements (Kemendikbudristek BSKAP, 2022). The physics understanding element is part of the cognitive ability that is important to practice because it significantly affects students' academic achievement (Shi & Qu, 2022). Cognitive ability includes aspects of cognitive processes (remembering, understanding, applying, analyzing, evaluating, and creating) and aspects of knowledge (factual, conceptual, procedural, and metacognitive) (Anderson & Krathwohl, 2001). Meanwhile, process skills are important to introduce students to the scientific method and problem solving in an investigation (Idris et al., 2022). Process skills include the skills of observing, questioning, predicting, planning, performing, processing data/information, evaluating, and communicating (O'Connor & Rosicka, 2020). In addition, merdeka curriculum emphasizes that learning must be student-centered, while the teacher acts as a facilitator (Ramadani, 2022).

Based on interviews with high school physics teachers, the results are that learning has not been fully student-centered and the science process skills of student participants are still lacking, one of which is in the use of measuring instruments. This is in line with the fact that basic process skills such as using measuring instruments are still poor and students' understanding of concepts on average has not reached the passing criteria. Other research also states that the ability to use measuring instruments is still lacking (Putra et al., 2022). Based on other research

also states that students' process skills around 77.3% have a low category (Listiani & Kusuma, 2024). In addition, students who understand light wave material are only 30% and the rest do not understand (Lutfia & Putra, 2020).

Students' science process skills are still relatively low because investigative learning is only carried out several times each semester, student worksheets are verification in nature, and the learning model used by teachers does not support indicators of science process skills (Wahyuni et al., 2020). In addition to low science process skills, students' understanding of light wave material is still relatively low due to inappropriate learning strategies by teachers (Kumalasari & Putra, 2021). Science process skills and cognitive abilities that have not been optimized are due to teaching materials in the form of student worksheets that are not in accordance with the right worksheets to practice these two domains (Yulkifli et al., 2020).

Based on the explanation above, there is a gap between the demands of the merdeka curriculum and the facts in the field. Therefore, a solution is needed to overcome the demands of an independent curriculum, especially in physics learning. The solution that can be applied is physics learning using the inquiry method or inquiry can practice or improve science process skills through direct student participation in scientific phenomenon investigation activities (Biswal & Behera, 2023). Such inquiry-based learning assisted by inquiry-based worksheets can also practice students' process skills in learning effectively (Cholifah & Novita, 2022). Inquiry-based learning includes observing, questioning, predicting, planning, conducting, processing data/information, evaluating, and communicating (O'Connor & Rosicka, 2020). Through these activities, students will be able to gain scientific knowledge such as explaining a phenomenon scientifically, designing scientific investigations, interpreting data through scientific evidence, and evaluating scientific investigations (Dah et al., 2024).

Learning using inquiry methods can also practice students' cognitive abilities through exploration of scientific phenomena (Biswal & Behera, 2023). This is in line with the view that inquiry-based learning can improve students' concept understanding and learning motivation, by providing opportunities for students to think about solving a problem (Dah et al., 2024). Learning using inquiry methods combined with teaching materials, technology, methods, etc. is more effective in practicing thinking skills and higher order thinking skills in various countries around the world (Antonio & Prudente, 2023). In addition, the use of inquiry-based worksheets can also improve students' cognitive abilities in learning more effectively (Cholifah & Novita, 2022).

Based on the explanation above, only a few studies have developed worksheets to practice cognitive abilities and process skills, especially on light wave material. Therefore, it is necessary to develop worksheets science inquiry skills on light wave material. This worksheet is expected to answer the demands of the Merdeka curriculum, which emphasizes the importance of applying elements of understanding physics and elements of process skills and making physics learning student-centered.

RESEARCH METHODS

The research method used is *R&D* with the ADDIE research model which is a product development concept, which is applied to build performance-based learning (learner-centered, innovative, authentic, and

inspiring learning) (Branch, 2010). The stages of this research consist of (analysis, design, development, implementation, and evaluation).

This analysis stage has the aim of identifying possible causes of gaps (Branch, 2010). At this stage, an analysis of the needs of teaching materials used in learning will be carried out by conducting observations and interviews with physics teachers in schools, especially in physics learning to identify the needs of teaching materials in schools.

In the design stage, planning for the development of inquiry skills science worksheets will be carried out based on the results of the needs analysis at the analysis stage. In the design stage, researchers will determine learning objectives based on science process skills and physics concepts to be achieved, design inquiry skills science worksheets, and compile validation instruments, cognitive ability tests, science process skills tests, science skills observation sheets, and student response questionnaires.

This development stage aims to produce and validate learning resources (Branch, 2010). Researchers will develop three inquiry skills science worksheets including (1) Reflection and Refraction, (2) Single Slit Diffraction, and (3) Diffraction Grating. Then the worksheets will be validated by five physics education lecturers and two physics teachers to assess the feasibility, and improve the worksheets according to the input and suggestions from the *validators.* The validation results will be analyzed using the scale content validity index/average (S-CVI/Av), with the following formula:

$$S - CVI/Av = \frac{I-CVI}{N} \qquad (1)$$

Description:
S-CVI/Av : Scale content validity index/average
I-CVI : Item content validity (I-CVI)
N : number of items.

The worksheet was declared "Feasible" by seven validators with a score limit $S - CVI/Av$ of 0.80 (Davis, 1992).

The implementation stage of the inquiry skills science worksheet was tested in one of the high schools in Pangandaran district with a *pretest-posttest control group design.* At the *pre-test* and *post-test* stage, the experimental and control classes will be given a cognitive ability test and a validated science process skills test. The pretest and posttest results of the experimental and control classes were analyzed using N-Gain. With the following formula:

$$g = \frac{posttest-pretest}{maximum\ skor-pretest} \qquad (2)$$

The N-gain criteria will be interpreted through Table 1 as follows:

Table 1. N-Gan Categories

N-Gain	Categories
g > 0,8	High
0,8 > g > 0,2	Medium
g< 0.2	Low

The posttest scores of the experimental and control classes will be analyzed using effect size to see the effectiveness of the inquiry skills science worksheet. With the following formula:

$$d = \frac{\bar{X}_1-\bar{X}_2}{SD_{pooled}} \qquad (3)$$

The cohen'd effect size score will be interpreted with the following criteria:

Table 2. Effect Size Categories

d	Categories
g > 0,8	High
0,8 > g > 0,2	Medium
g < 0,2	Low

At the end of the experimental class learning, a student response questionnaire will be given regarding the learning process using the inquiry skills science worksheet. With a scale of 1 strongly disagree to a scale of 4 strongly agree. These results will be

analyzed quantitatively with the following formula:

$$\%response = \frac{mean\ of\ score}{maximum\ score} \times 100\%$$

The results of the learners' responses will be interpreted as follows:

Table 3. Student Response Categories

Response	Categories
0% - 20%	Very Low
21% - 40%	Low
41% - 60%	Good Enough
61% - 80%	Good
81% - 100%	Very Good

The evaluation stage aims to assess the product and the learning process both before and after implementation (Branch, 2010). At this stage, evaluation will be carried out at each stage. The result of the evaluation stage is an inquiry skills science worksheet product to practice students' cognitive abilities and science process skills.

RESULTS AND DISCUSSION

Results

At the analysis stage, interviews were conducted with three different Physics teachers. The results of these interviews show that physics learning has not fully practiced science process skills. In addition, students' cognitive abilities and science process skills are still relatively low.

Based on the analysis stage, the worksheets to practice cognitive abilities and science process skills were designed as follows:

Table 4. Worksheet Design

Component	Description
Problem Presentation	Presenting a problem in everyday life
Problem Identification	Questioning the problem presented in the problem presentation and asking for a problem-solving plan.
Formulate a Hypothesis	Formulate a hypothesis from the results of problem identification
Variable Identification	Determine dependent, independent, and control variables
Determine Tools and Materials	Determine the tools and materials used during the investigation
Designing an Inquiry	Design an investigation and sketch the investigation according to the hypothesis results
Measurement	Conduct an investigation based on the investigation design
Data Analysis	Analyzing experimental results through graphs and comparing experimental results with hypotheses
Conclusion	Summarize the results of the investigation and write down the concepts found in accordance with previous theories

Then the design is developed at the development stage. After that, a feasibility test was carried out with aspects of conformity with process skills indicators in the Merdeka curriculum. The feasibility of inquiry skills science worksheets was validated by seven validators who are experts in their fields. The results of the validation analysis of the inquiry skills science worksheet are as follows:

Table 5. Worksheet Item Validation Results

Aspects	Work sheet 1	Work sheet 2	Work sheet 3
Observing	0,875	0,875	0,875
Questioning and predicting	1,000	1,000	1,000
Planning and conducting	1,000	1,000	1,000
Processing and analyzing	1,000	1,000	1,000
Evaluate and reflection	0,875	0,875	0,875

After getting the item validation results. The next step is to analyze the scale content validity index/average (S-CVI/Av). The worksheet is declared valid with a limit of

0.80 (Davis, 1992) The results are as follows:

Table 6. Worksheet Validation Results

Worksheet	S-CVI/Av	Criteria
Reflection and refraction	0,934	Valid
Single slit diffraction	0,934	Valid
Diffraction grating	0,934	Valid

Here is an example of the first page of the inquiry skills science worksheet that has been validated and improved:

Figure 1. Example of Science Inquiry Skills Worksheet Home Page

After validation and improvement, the next step is to measure effectiveness by conducting trials in experimental classes with inquiry skills science worksheets and control classes with conventional worksheets. The N-Gain results of the two classes are shown in Table 7.

Table 7. Hasil Skor N-Gain

Class-Variable	Mean of Pretest	Mean of Posttest	g	Kategori
Experiment-cognitive ability	27,69	51,73	0,34	Medium
Experiment-science process skills	16,15	60,38	0,51	Medium
Control-cognitive ability	31,96	42,32	0,15	Low
Control-science process skills	20,00	43,21	0,26	Low

The effectiveness of inquiry skills science worksheets to train cognitive abilities and science process skills is presented in Table 7.

Table 8. Effectiveness of cognitive ability and science process skills

Variable	Experiment	Control	d	Category
Cognitive ability	51,73	42,32	0,53	Medium
Science process skills	60,38	43,21	0,63	Medium

In addition, the experimental class after learning will fill out a student response questionnaire containing interest, pleasure, and convenience. The results of the response questionnaire are as follows:

Table 9. Student Response Results

Aspect	Sub-aspect	Score (%)
Interest	Interest in inquiry skills science worksheets	83,33
	Interest in experimental learning	81,06
Fun	Enjoyment of experimental learning	81,82
Ease	Learning atmosphere	77,27
	Ease of using the worksheet	75,27
	Presentation of inquiry skills science worksheet	76,52
		78,03

Aspect	Sub-aspect	Score (%)
	Picture on inquiry skills science worksheet	78,79
	Activities in the inquiry skills science worksheet	78,79
	Instructions in the inquiry skills science worksheet	77,27
	Language in inquiry skills science worksheet	81,82
	Enough space to write down answers	

Discussion

Based on the explanation above, inquiry skills science worksheets are needed by high schools to meet the demands of the Merdeka curriculum. In addition, students' science process skills and cognitive abilities are low. This is in line with the results of previous research that student process skills of around 77.3% have a low category (Listiani & Kusuma, 2024). In addition, students who understand light wave material are only 30% and the rest do not understand (Lutfia & Putra, 2020)

The feasibility of the inquiry skills science worksheets was declared "valid" for the worksheets on reflection and refraction, single slit diffraction, and diffraction gratings, meaning that the worksheets were declared suitable for physics research and learning.

Science inquiry skill worksheets have a contribution in practiceing students' cognitive abilities with systematic scientific stages from observing problems, predicting/questioning, planning investigations, conducting investigations, analyzing data from investigations, drawing conclusions, and evaluating investigations. Each stage encourages thinking activities starting from the observing and predicting stages to practice the ability to remember (C1) and understand (C2), the planning and experimentation stages develop the ability to apply concepts (C3), while the analyzing, concluding, and evaluating stages stimulate the ability to analyze (C4). This is in line with Biswal & Behera (2023) that learning using inquiry, especially in science learning, can effectively practice students' cognitive abilities through activities of active involvement in questioning, collecting data / information with scientific phenomena. In addition, learning using inquiry methods combined with teaching materials, technology, methods, etc. is more effective than traditional learning in terms of level thinking skills and higher order thinking skills in various countries in the world (Antonio & Prudente, 2023).

Science worksheets based on *inquiry skills* have an important role in practiceing students' science process skills by presenting systematic stages of scientific activities and oriented to direct student involvement in investigative activities. The worksheet structure consisting of observing, predicting/questioning, planning, doing, analyzing data, concluding, and evaluating stages encourages students to be actively involved in the scientific process. The observing stage practices the skills to identify objects and phenomena, while the predicting/questioning stage develops the ability to formulate hypotheses and scientific questions. Planning and conducting experiments strengthens the ability to design and carry out scientific procedures independently. Furthermore, the stages of analyzing data, concluding, and evaluating allow students to develop skills in interpreting results, making logical conclusions, and reflecting on the experimental process that has been carried out. This contribution is in line with the results of research by Masruhah et al. (2022) which shows that inquiry-based student worksheets can significantly improve science process skills. This is reinforced by Biswal & Behera (2023) who emphasized

that inquiry learning provides opportunities for students to be directly involved in real scientific activities, so that science process skills can develop more optimally. Similar support is also shown in the research of Şahintepe et al. (2020), which found that inquiry-based learning more effective than traditional methods, with statistically significant results and direct observation of the improvement of science process skills in the experimental group. Thus, inquiry worksheets serve not only as learning aids, but also as a medium for strengthening science process skills that are essential in 21st century learning.

In addition, the inquiry skills science worksheet was analyzed from student responses. The response of students in the aspect of interest has a score of 82.2% with "very good" criteria, which means that students are very interested in learning using inquiry skills science worksheets and learning with experimental methods. From the aspect of pleasure, the response score is 79.6% with the category "good" which means that experimental learning using inquiry skills science worksheets is preferred compared to traditional learning. In addition, from the aspect of the ease of learning students using inquiry skills science worksheets have a score of 78.1% in the "good" category, meaning that learning using inquiry skills science worksheets makes it easy for students to understand the material of light wave symptoms. Overall, students responded well or positively to the inquiry skills science worksheet. This is also supported by previous research that learning using inquiry-based worksheets students respond positively to learning (Yalyn et al., 2022).

CONCLUSION

Based on the results and discussion, the worksheet was declared "Feasible" from seven validators to practice cognitive abilities and science process skills. The increase in cognitive abilities after learning using worksheets is 0.34 which is included in the moderate category. Meanwhile, the increase in science process skills after learning using worksheets amounted to 0.51 which is included in the moderate category. The effectiveness of inquiry skills science worksheets to practice cognitive abilities is 0.53 with a medium category while to practice process skills is 0.63 with a medium category. In terms of student responses to the inquiry skills science worksheets from the aspects of interest, fun, and ease have a good response. Thus, the worksheets developed are valid and feasible to use as learning tools that support inquiry-based learning and improve cognitive skills and science processes in light waves material. Recommendations for using inquiry skills science worksheets for physics learning are to practice them often because students must get used to using them and there are new terms that they do not understand.

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