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Needs Analysis to Develop Scientific Higher Order Thinking Assessment Based on Dual Space Inquiry for Kinematics Material

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ABSTRACT

The demands of 21st-century learning require students to develop higher-order thinking skills, particularly Scientific Higher Order Thinking (S-HOT), which includes scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognition. This study aims to conduct a needs analysis for the development of S-HOT-based assessment using the Dual Space Inquiry (DSI) approach in kinematics. The study employs a quantitative descriptive method, referring to the preliminary research stage of the Plomp development model, with data collected through questionnaires, observations, interviews, and document analysis.

The results of the needs analysis indicate that students' Scientific Higher Order Thinking (S-HOT) skills have not yet developed optimally, and their implementation in learning remains limited. In addition, the assessments used tend to focus on procedural problem-solving and have not yet accommodated the comprehensive measurement of higher-level scientific thinking processes. These findings reveal a gap between the demands of physics learning and the assessment practices currently implemented.

The implications of this study highlight the importance of developing assessments that not only function to measure learning outcomes but also promote students' higher-level scientific thinking skills. Therefore, it is necessary to develop assessment instruments based on Dual Space Inquiry (DSI) that can comprehensively integrate S-HOT indicators. Future research is recommended to proceed to the stages of development, validation, and practicality testing of S-HOT-based DSI assessments in physics learning.

Keywords: Assessment, Scientific Higher Order Thinking, Dual Space Inquiry, physics learning

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I. INTRODUCTION

In the 21st century, the integration of Information and Communication Technology (ICT) in education has become a necessity that cannot be ignored. [1]. Technological developments have driven a paradigm shift in learning from conventional methods to more interactive, innovative, and digital-based learning [2],[3],[4]. In the context of physics learning, technology not only functions as a medium for conveying information, but also as a learning resource that supports student independence, flexibility, and interactivity [5],[2],[6]. In line with these developments, education is required to develop high-level thinking skills or *Higher Order Thinking Skills* (HOTS)[7],[8]. Higher-order thinking is often associated with Bloom's Taxonomy, especially in relation to the three highest levels of thinking in the revised Bloom's Taxonomy. [9].

In science learning, especially physics, high-level thinking skills are not enough to be understood only as HOTS which focuses on cognitive aspects such as analyzing, evaluating, and creating. [10],[11],[12]. Physics learning requires more comprehensive abilities, namely Scientific Higher Order Thinking (S-HOT), which includes scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognition. [13]. Therefore, the development of thinking skills in physics needs to be directed at the integration between the results and processes of scientific thinking. [14],[15].

However, this condition has not been fully realized in the field. Based on preliminary studies, physics learning is still dominated by approaches oriented towards procedural problem solving and the use of formulas[16]. The assessments used tend to only measure lower-level thinking skills and have not provided space for students to develop scientific thinking skills optimally[9]. In addition, in kinematics material, students often experience difficulty in connecting various representations, such as graphs, mathematical equations, and verbal descriptions, so that conceptual understanding becomes less complete [17],[18],[19]. This shows that the learning and assessments applied do not fully support the development of S-HOT abilities.

On the other hand, various studies have developed assessments based on higher-order thinking skills in physics learning[20],[21],[22],[23],[24]. However, most of these studies still focus on measuring cognitive aspects and have not been designed to comprehensively measure the integration between scientific reasoning, self-efficacy, and metacognition. In addition, research that specifically develops assessments to measure Scientific S-HOT, especially those that integrate an inquiry approach with the use of technology, is still very limited [25],[26]. This condition indicates a clear gap between the demands of 21st-century learning that emphasizes the development of holistic scientific thinking skills and the availability of assessment instruments that are able to measure these abilities comprehensively.

To address this gap, it is necessary to develop assessments that not only measure thinking outcomes but are also able to represent the scientific thinking process as a whole. One approach that can be used is Dual Space Inquiry (DSI). The DSI model is relevant because it is able to integrate the use of digital technology with inquiry activities. DSI combines the principles of inquiry, flexible learning, and the characteristics of mixed learning in the context of physics learning [27]. This conceptual framework is designed based on the characteristics of blended learning, especially in physics learning. The DSI model is a learning concept that utilizes the potential of physical and virtual spaces to facilitate inquiry-based learning, while online spaces include spaces on digital platforms. DSI emphasizes the integration of digital technology throughout the learning process, facilitates various learning styles, and facilitates collaborative learning so that students become more active and creative. Thus, it has the potential to develop and measure S-HOT abilities more optimally.

Based on these problems, there is a gap between ideal conditions and real conditions, namely the unavailability of assessments that can support the development of students' S-HOT skills. To develop an assessment that can assess students' S-HOT, researchers must first analyze the needs of students. Based on this description, this study aims to analyze the needs in the development of Dual Space Inquiry (DSI)-based S-HOT assessments in physics learning in high school, especially in kinematics material. This research is expected to contribute to the development of assessments that are appropriate to the demands of physics learning in the future.

II. METHOD

This study uses a quantitative descriptive method that aims to describe conditions factually and accurately based on numerical data obtained [10],[28],[29] which refers to the latest version of the Plomp development model [30]. The selection of this method is based on the research objective, namely to identify the need for developing a DSI-based S-HOT assessment for Motion kinematics material. The research focused on the preliminary research stage which aims to conduct a comprehensive needs analysis. At this stage, data collection was carried out through initial observations in the field to identify problems in physics learning. This approach allows researchers to collect, process, and analyze data systematically so that an accurate and comprehensive picture of the conditions being studied is obtained. Research conclusions were drawn based on the results of data analysis using descriptive statistics.

The needs analysis in this study focused on several aspects, namely seeing the extent of students' S-HOT abilities, including the implementation of S-HOT indicators in learning, and the characteristics of assessment instruments used by teachers. This study was conducted at Baiturrahmah Padang High School, with research subjects consisting of 1 physics teacher and 45 grade XI MIPA students. The sampling technique used was purposive sampling, namely sample selection based on certain considerations relevant to the research objectives.

Data collection was conducted through questionnaires or surveys, observations, interviews, and document analysis. The questionnaire was used to identify students' S-HOT abilities, including scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognition. Observations were used by researchers to directly observe the research objects to gain a closer look at the activities carried out. Interviews were used to collect data used to obtain information directly from the source. In this study, researchers conducted interviews with one teacher and three students representing high, medium, and low academic abilities to obtain more in-depth information. Meanwhile, document analysis was used to determine the extent to which learning documents, especially assessments used in class, facilitate the achievement of S-HOT indicators. From the surveys, observations, interviews, and document analysis conducted, it was possible to determine what solutions were needed to address the problems encountered in the field.

All instruments used in this study were validated by experts to ensure content validity and alignment with the S-HOT indicators. Data analysis was conducted using descriptive statistical techniques. The data obtained were processed and presented in tables and graphs to provide a clear description of the needs analysis results. The scores obtained were then interpreted based on predetermined criteria to determine the categories of the analysis results.

Table 1. Student Response Criteria

No	*Percentage Range*	*Category*
1	0% − 20%	*Very Poor*
2	21% − 40%	*Poor*
3	41% − 60%	*Fair*
4	61% − 80%	*Good*
5	81% − 100%	*Very Good*

III. RESULTS AND DISCUSSION

Results

1. Results of Analysis of Students' S-HOT Abilities

The results of the initial study regarding the analysis of students' S-HOT needs in physics learning were obtained through a questionnaire given to class XI MIPA students. The questionnaire was designed using a Likert scale containing questions according to research needs. With the aim of measuring S-HOT abilities. Data from this questionnaire were processed using equation 1 to see the percentage of each S-HOT indicator, then the data were analyzed to see the extent of students' S-HOT abilities. The results of the analysis showed that students' abilities in all of these indicators were in the less category. As shown in Figure 1.

$$Percentage = \frac{Acquisition\ score}{Maximum\ score} x\ 100 \qquad (1)$$

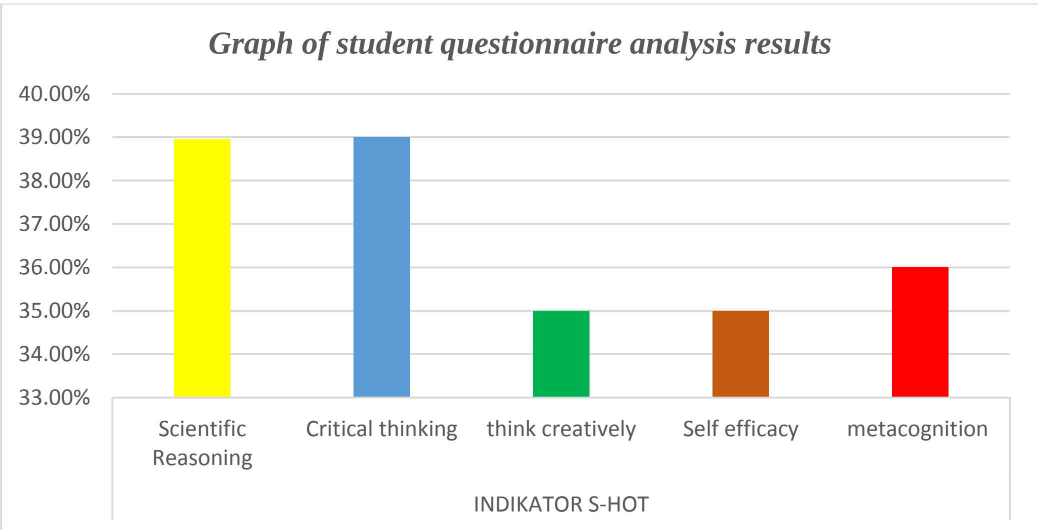

Fig. 1. Graph of Student Questionnaire Analysis Results.

The questionnaire results showed that students' S-HOT abilities ranged from 35% to 39% across all indicators. Scientific reasoning scored 38.95%, critical thinking 39%, creative thinking and self-efficacy each 35%, and metacognition 36%. This relatively narrow range of scores indicates that no indicator developed significantly compared to the others. This indicates that students' S-HOT abilities have not yet developed evenly and optimally across all aspects.

2. Observation Results of S-HOT Implementation in Learning

Observations show that the implementation of the S-HOT indicators in the learning process is still suboptimal. Scientific reasoning was recorded at 28% and critical thinking at 32%, indicating that activities involving analysis and reasoning are still limited. Meanwhile, creative thinking scored 48%, self-efficacy 52%, and metacognition 44%, as shown in Figure 2.

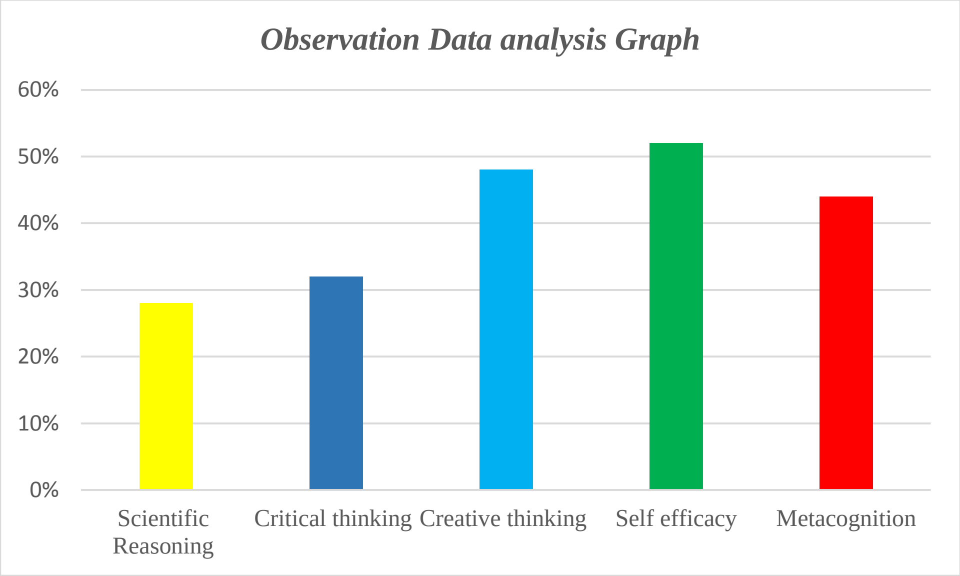

Fig. 2. Results of Observation Data Analysis

This difference in achievement indicates that the learning process primarily supports non-cognitive aspects such as student self-confidence, but has not yet optimally facilitated higher-order thinking skills that require analytical processes and scientific reasoning. This also indicates that the designed learning activities have not fully directed students to actively engage in in-depth exploration and problem-solving.

3. Document Analysis (Assessment)

The results of the document analysis indicate that the assessment instruments used by teachers are still dominated by procedural questions. The percentage of occurrence of indicators for scientific reasoning and creative thinking was 32%, critical thinking 24%, self-efficacy 48%, and metacognition 44%, respectively, as shown in Figure 3.

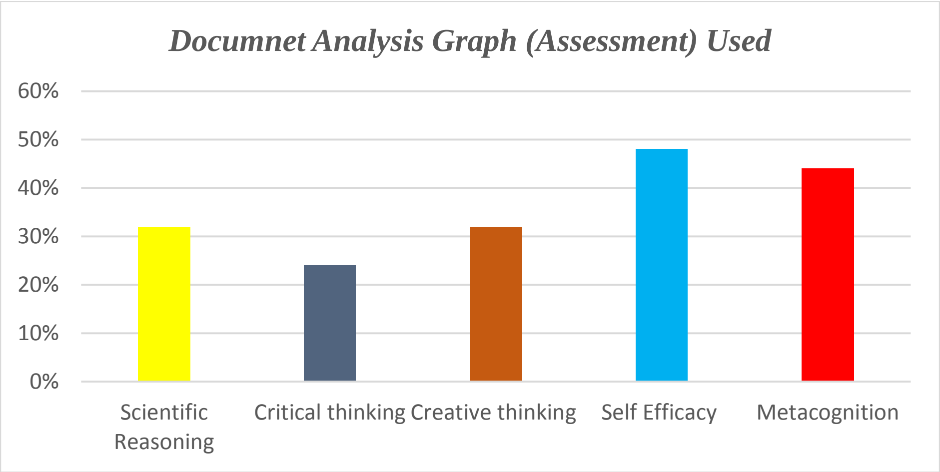

Fig. 3. Analysis of Document (Assessment) Used in Class

The low proportion of critical thinking indicators indicates that the questions given do not require students to conduct in-depth analysis or evaluate a problem. Furthermore, the question format, which tends to be similar to the previous example, indicates that the assessment focuses more on applying formulas than developing thinking processes. This results in students being more accustomed to following established steps rather than developing independent problem-solving strategies.

4. Interview Findings

Interviews with teachers and students confirmed previous findings. Interviews with physics teachers revealed that they rarely provide questions that require students to think critically and reason deeply. Most of the questions used are still oriented towards memorizing formulas or calculations with the same patterns as examples given in class. Teachers also stated that time constraints and a lack of guidance and examples of S-HOT-based assessments are major obstacles in developing assessments that require high-level scientific thinking skills.

On the other hand, interviews with high-ability students tended to prefer calculation problems because they were easy to follow mathematical steps. Medium-ability students felt hesitant when asked to provide scientific reasons or opinions, while low-ability students tended to avoid calculation problems and preferred contextual questions that did not require analysis. These findings indicate that students are not yet accustomed to facing assessments that require in-depth scientific thinking. As a result, students experience difficulties when faced with questions that require a more complex understanding of concepts and do not rely solely on the use of formulas.

Discussion

The research results show that students' S-HOT abilities have not developed optimally across all indicators. This condition does not occur by chance, but is directly related to the learning and assessment methods used in the classroom. When students are frequently given procedural and formula-based problems, they tend to simply follow the steps to solve them without understanding the rationale behind them. As a result, abilities such as scientific reasoning and critical thinking do not develop optimally.

These findings demonstrate a clear cause-and-effect relationship: the type of assessment used influences how students think. Assessments that only require a final answer will cause students to focus on the outcome, rather than the thinking process. Conversely, if assessments are designed to require analysis and reasoning, students will be more accustomed to deep thinking.

This finding is in line with previous research which stated that routine question-based assessments only measure the ability to reproduce knowledge and are less effective in developing high-level scientific thinking skills [31],[32]. he research shows that students who are accustomed to working on procedural questions tend to experience difficulties when facing problems that require a deeper understanding of concepts and reasoning [33]. This strengthens the finding that low S-HOT abilities do not only come from students, but also from the characteristics of the learning and assessment used.

In addition, students' difficulties in understanding kinematics material are also related to their inability to connect various forms of representation, such as graphs, equations, and verbal explanations [34]. If learning does not train these skills in an integrated manner, students will understand concepts in isolation. As a result, metacognitive abilities will also be low because students are not accustomed to reflecting on how they think and solve problems.

Another finding suggests that the assessments used were not designed to measure the comprehensive integration of S-HOT skills. The questions primarily assess the final outcome, rather than the thinking process. As a result, students lack the skills to develop problem-solving strategies, evaluate their actions, and correct errors. [35],[36]. This condition shows that assessment has not yet functioned as a tool to develop thinking skills, but is still limited as a tool to measure learning outcomes.

Based on these results, it is clear that the main problem lies in the suboptimal assessment design for measuring and developing students' S-HOT abilities. Assessments that focus solely on the final results result in students' scientific thinking processes not being optimally facilitated. This situation indicates the need to develop assessment instruments capable of comprehensively integrating S-HOT indicators, thus assessing not only the answers but also the underlying thinking processes.

Thus, it is necessary to develop an assessment that is able to integrate the characteristics of physics learning with the S-HOT indicators, so that it not only measures learning outcomes, but can also encourage the development of high-level scientific thinking skills in students as a whole.

IV. CONCLUSION

Based on the needs analysis, this study obtained several key findings. Students' Scientific Higher Order Thinking (S-HOT) abilities have not developed optimally, and their implementation in learning remains limited. Furthermore, the assessments used do not fully accommodate the measurement of the scientific thinking process as as whole. These findings indicate a gap between the demands of physics learning and the learning and assessment practices implemented. Therefore, developing a Dual Space Inquiry (DSI)-based assessment is crucial as an effort to comprehensively integrate S-HOT indicators and support the development of students' scientific thinking skills. Further research is recommended to continue to the development, validation, and testing stages of the practicality of DSI-based assessment in physics learning.

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