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Validity of Scientific Higher Order Thinking Assessment Based on Dual Space Inquiry for Static Electricity Material

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ABSTRACT

This research aimed to develop a Scientific Higher Order Thinking (S-HOT) assessment based on Dual Space Inquiry (DSI) for static electricity material and determine the validity level of the developed assessment instrument. The research employed the Research and Development (R&D) method using the Plomp development model, which consists of preliminary research, prototyping phase, and assessment phase. However, the research was limited to the prototyping phase, particularly the validity testing stage. The developed assessment instrument was validated by three experts in physics education using validation sheets covering content feasibility, language appropriateness, presentation feasibility, and graphical feasibility aspects. The validation data were analyzed using Aiken's V formula. The results showed that the developed S-HOT assessment based on DSI obtained valid to highly valid categories in all assessed aspects. The content feasibility aspect obtained an average Aiken's V value of 0.78 with a valid category, while the language appropriateness, presentation feasibility, and graphical feasibility aspects obtained average values of 0.87, 0.91, and 0.88 respectively with highly valid categories. These findings indicate that the developed assessment instrument is feasible to be used in physics learning to facilitate students' higher-order scientific thinking skills, including scientific reasoning, critical thinking, creative thinking, metacognitive skills, and self-efficacy. Therefore, the S-HOT assessment based on Dual Space Inquiry can be used as an alternative assessment instrument to support inquiry-based and technology-integrated physics learning.

Keywords: *Scientific Higher Order Thinking, Dual Space Inquiry, Physics Assessment, Static Electricity*

I. INTRODUCTION

Twenty-first century education requires students to possess *Higher Order Thinking Skills* (HOTS). These skills do not only involve remembering and understanding concepts, but also the ability to analyze, evaluate, and create solutions to problems based on deep conceptual understanding. HOTS has become one of the essential competencies that must be developed in learning because it plays an important role in shaping critical, creative, and reflective thinking skills, as well as students' ability to adapt to the rapid development of science and technology [1]. In this context, education is no longer merely oriented toward knowledge transfer, but also toward how students construct meaning, connect concepts, and solve problems scientifically and systematically.

In science learning, particularly physics, higher-order thinking skills play a very important role because physics learning not only requires students to understand concepts and formulas, but also to analyze natural phenomena, evaluate scientific information, and draw conclusions based on empirical evidence [2]. Along with the increasing demands of 21st-century learning, higher-order thinking skills in science have developed into *Scientific Higher Order Thinking* (S-HOT). S-HOT refers to higher-order thinking skills that are oriented toward scientific processes and include scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognitive abilities in solving scientific problems [3]. Through S-HOT, students are expected not only to understand physics concepts theoretically, but also to interpret scientific phenomena, develop solutions to contextual problems, and independently reflect on their thinking processes.

The implementation of S-HOT in physics learning is highly relevant because physics integrates abstract concepts with real phenomena through experimental activities, observation, and mathematical reasoning [4]. One of the physics topics that requires higher-order scientific thinking skills is static electricity. In this topic, students

are required to understand abstract concepts such as electric charge, Coulomb force, electric field, and electric potential, as well as relate them to phenomena occurring in everyday life. Therefore, physics learning on static electricity requires assessment instruments that not only measure final learning outcomes but also assess students' scientific thinking processes comprehensively.

However, the reality in schools shows that the assessments used in physics learning still tend to focus on *Lower Order Thinking Skills* (LOTS). The assessment instruments commonly used by teachers are still dominated by routine and procedural questions that only emphasize formula application and simple mathematical calculations [5]. As a result, students' abilities in critical thinking, scientific reasoning, evaluating information, and solving contextual problems have not developed optimally. Several studies revealed that students still experience difficulties when dealing with questions that require in-depth analysis, interpretation of phenomena, and evidence-based decision making [6].

Based on the results of document analysis of the assessment instruments used at MAN 2 Padang City, it was found that the physics assessment instruments had not fully accommodated the indicators of *Scientific Higher Order Thinking* optimally. The assessments still focused on conceptual mastery and mathematical calculation skills, while S-HOT indicators such as scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognitive skills had not been systematically integrated into the assessment items. In addition, the questions used were mostly closed-ended and provided limited opportunities for students to develop ideas, conduct evaluations, and reflect on their thinking processes.

The observation results also showed that the physics learning process in the classroom was still dominated by lecture methods and problem-solving exercises. Learning activities involving scientific investigation, analytical discussion, and independent concept exploration were still limited. Teachers tended to use multiple-choice and short essay assessments that emphasized final answers rather than students' scientific thinking processes. These conditions caused students to become less accustomed to dealing with problems requiring higher-order thinking skills and in-depth scientific reasoning.

As an effort to overcome these problems, it is necessary to develop assessments that are capable of evaluating as well as facilitating students' *Scientific Higher Order Thinking* skills. One approach that can be used is *Dual Space Inquiry* (DSI). Dual Space Inquiry is an inquiry-based learning approach that integrates physical learning spaces and virtual learning spaces simultaneously [7]. Through this approach, students not only conduct scientific investigations directly through experiments, but also explore concepts using digital media, interactive simulations, online discussions, and technology-based reflections. The integration of these two learning spaces enables students to obtain more authentic, contextual, and meaningful learning experiences that stimulate deeper scientific thinking skills.

Dual Space Inquiry-based assessments provide opportunities for teachers to evaluate students' learning processes and outcomes more comprehensively. Through this assessment, students' critical thinking, scientific reasoning, creativity, scientific communication, and reflective abilities can be observed more optimally [8]. In addition, DSI-based assessments are more flexible and aligned with the characteristics of 21st-century learning, which integrates digital technology into learning and evaluation processes.

Before being implemented in the learning process, the developed assessment instrument must fulfill validity criteria to ensure its appropriateness as an evaluation tool. Validity is an important aspect to ensure that the instrument is appropriate in terms of content, construct, language, and alignment with learning objectives [9]. A valid assessment instrument can provide accurate information regarding students' *Scientific Higher Order Thinking* abilities and support more effective and meaningful physics learning. Based on these problems, this study aims to analyze the validity of the *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* for static electricity material. This study is expected to produce a valid assessment instrument that is feasible to facilitate students' higher-order scientific thinking skills in physics learning.

II. METHOD

The purpose of this Research and Development (R&D) research was to develop a *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* for static electricity material [10]. The R&D method was chosen because the research produced an assessment product while simultaneously examining the quality and feasibility of the developed instrument. The developed assessment was intended to facilitate students' higher-order scientific thinking skills, including scientific reasoning, critical thinking, creative thinking, self-efficacy, and metacognitive skills [3].

The development procedure employed the Plomp development model, which consists of three phases: *preliminary research*, *prototyping phase*, and *assessment phase* [11]. The Plomp model was selected because it is appropriate for educational product development through systematic stages of needs analysis, design, evaluation, and revision. However, the research was limited to the *prototyping phase*, particularly at the validity testing stage of the developed assessment instrument. Physics teachers and students of MAN 2 Padang were involved as the research subjects. The object of the research was the S-HOT assessment instrument based on *Dual Space Inquiry* for static electricity material. The assessment instrument was validated by several experts in physics education to examine its appropriateness in terms of content, construct, language, and suitability with the *Dual Space Inquiry* approach [7].

To identify problems related to the implementation of assessments in physics learning, a needs analysis was conducted during the *preliminary research* phase through interviews with physics teachers, classroom observations, and document analysis of the assessment instruments used in schools. The analysis revealed that the assessments implemented in physics learning were still dominated by routine and procedural questions focusing on conceptual understanding and formula application, whereas the indicators of *Scientific Higher Order Thinking* had not been optimally integrated [5].

The *prototyping phase* involved designing assessment indicators, constructing assessment items, determining scoring guidelines, and integrating S-HOT indicators into the assessment tasks. The developed indicators included scientific reasoning, critical thinking, creative thinking, metacognition, and self-efficacy [3]. To ensure the quality of the developed product, formative evaluation was conducted based on Tessmer's formative evaluation model, which includes *self-evaluation*, *expert review*, *one-to-one evaluation*, and *small-group evaluation* [11]. However, the research focused only on the *expert review* stage to determine the validity level of the developed assessment instrument. The research instruments consisted of interview sheets, observation sheets, document analysis sheets, and expert validation sheets. The expert validation sheets were arranged using a Likert scale consisting of five response categories: strongly poor, poor, fair, good, and very good [12]. The Likert scale used in the validation process is presented in Table 1.

Table 1. Likert Scale

Likert Scale	Response Categories
1	Strongly Poor
2	Poor
3	Fair
4	Good
5	Very Good

(Source : Ref [13])

The validity data obtained from the validators were analyzed using Aiken's V index to determine the validity level of the developed assessment instrument [9]. The formula of Aiken's V is presented as follows:

$$V = \frac{\sum s}{n(c-1)}$$

$$s = r - l_0 \qquad (1)$$

The obtained Aiken's V values were interpreted using the validity criteria shown in Table 2 [14].

Table 2. Validity Criteria Based on Aiken's V Index

Likert Scale	Response Categories
V < 0.4	Invalid
$0.4 \leq V \leq 0.8$	Valid
V > 0.8	Highly Valid

(Source : Ref [14])

The developed assessment instrument was categorized as valid if the Aiken's V value was greater than 0.80 [13]. If the obtained value was below the specified criterion, revisions were carried out based on the suggestions and recommendations provided by the validators.

III. RESULTS AND DISCUSSION

RESULT

The validity of the *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* (DSI) for static electricity material was evaluated by three experts consisting of physics lecturers from FMIPA Universitas Negeri Padang. The validation process aimed to determine the feasibility of the developed assessment instrument in terms of content feasibility, language appropriateness, presentation feasibility, and graphical feasibility. The validation results were used as the basis for revising and improving the developed assessment product before implementation in learning activities. The validation data obtained from the experts were analyzed using Aiken's V formula to determine the validity level of each assessment aspect [9].

Based on the results of the validation analysis, the developed S-HOT assessment based on DSI fulfilled the validity criteria and was categorized as valid to highly valid. The obtained results indicate that the developed assessment instrument was appropriate to facilitate students' higher-order scientific thinking skills, including scientific reasoning, critical thinking, creative thinking, metacognitive skills, and self-efficacy [3]. The integration of inquiry activities and digital learning environments within the developed assessment also supports the characteristics of 21st-century learning that emphasize student-centered learning and scientific investigation processes [1].

Table 3. Results of Content Feasibility Validation

Statement	Aiken's V	Category
P1	0.93	Highly Valid
P2	0.83	Highly Valid
P3	0.66	Valid
P4	0.91	Highly Valid
P5	0.66	Valid
P6	0.75	Valid
Average	**0.78**	**Valid**

Based on Table 3, the content feasibility aspect obtained an average Aiken's V value of 0.78 with a valid category. The validators stated that the developed assessment tasks were relevant to the learning objectives and static electricity material. The developed assessment instrument was also considered capable of facilitating students in analyzing scientific phenomena, interpreting information, and solving contextual problems systematically. These findings are consistent with previous studies explaining that inquiry-based assessments can support the development of higher-order thinking skills because students are encouraged to conduct investigation, analysis, and scientific reasoning processes during learning activities [5], [8]. Furthermore, higher-order scientific thinking assessments should encourage students to construct scientific explanations and evaluate evidence critically during problem-solving processes [3].

Table 4. Results of Language Appropriateness Validation

Statement	Aiken's V	Category
P1	0.91	Highly Valid
P2	0.83	Highly Valid
P3	0.83	Highly Valid
P4	0.91	Highly Valid
P5	0.91	Highly Valid
Average	**0.87**	**Highly Valid**

Based on Table 4, the language appropriateness aspect obtained an average Aiken's V value of 0.87 with a highly valid category. The validators considered that the instructions, statements, and scientific terms used in the assessment instrument were clear, communicative, and easy for students to understand. Appropriate language use is important in assessment development because unclear instructions may cause students to misinterpret the assessment tasks. Retnawati [14] explained that assessment instruments should use communicative and systematic language to ensure that the measured abilities truly reflect students' competencies. In addition, effective language presentation can support students' understanding during assessment implementation and increase the effectiveness of assessment activities.

Table 5. Results of Presentation Feasibility Validation

Statement	Aiken's V	Category
P1	0.83	Highly Valid
P2	1.00	Highly Valid
P3	1.00	Highly Valid
P4	0.91	Highly Valid
P5	0.83	Highly Valid
Average	**0.91**	**Highly Valid**

Based on Table 5, the presentation feasibility aspect obtained an average Aiken's V value of 0.91 with a highly valid category. This result indicates that the developed assessment instrument had a systematic structure, coherent organization, and presentation format aligned with the learning objectives. The validators stated that the assessment tasks were arranged from simple to more complex levels, enabling students to gradually develop their scientific thinking skills. A systematic presentation also supports the implementation of inquiry-based assessment because students can follow the scientific investigation process more effectively. This finding is supported by previous studies showing that well-structured assessment presentations can improve students' engagement and understanding during learning and assessment activities [15]. In addition, assessment structures integrated with inquiry processes can facilitate students in constructing concepts independently and reflecting on their scientific thinking processes [19].

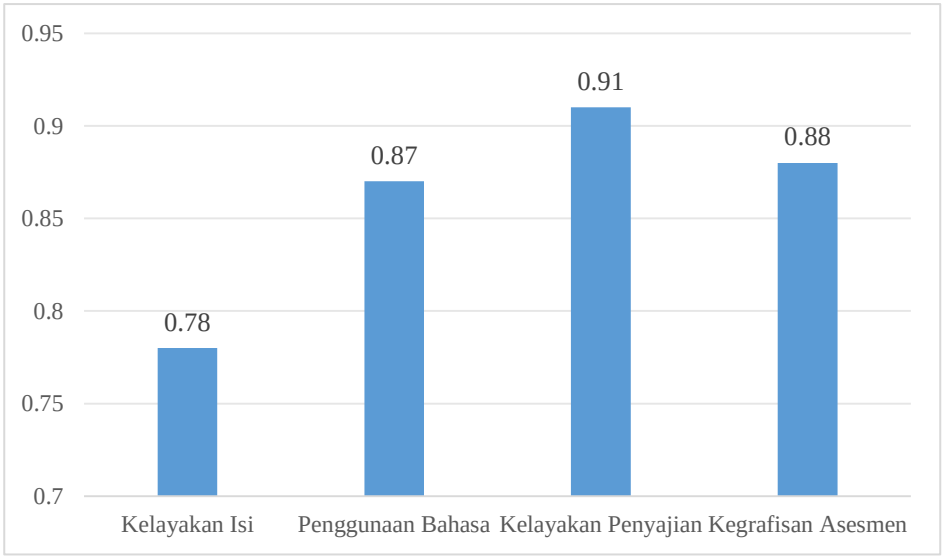

Fig. 1. Results of S-HOT Assessment Validation

Figure 1 shows the average validation results of the developed *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* (DSI) for static electricity material. The validation results include four assessed aspects, namely content feasibility, language appropriateness, presentation feasibility, and graphical feasibility.

Based on Figure 1, the presentation feasibility aspect obtained the highest average validity score of 0.91 with a highly valid category. This result indicates that the developed assessment instrument had a systematic structure, coherent organization, and presentation format aligned with the learning objectives. Meanwhile, the content feasibility aspect obtained the lowest average score of 0.78, although it still belonged to the valid category. The language appropriateness and graphical feasibility aspects obtained average scores of 0.87 and 0.88 respectively, both categorized as highly valid. Overall, the validation results indicate that all assessed aspects fulfilled the validity criteria and demonstrated that the developed S-HOT assessment based on *Dual Space Inquiry* is feasible to be used as an assessment instrument to facilitate students' higher-order scientific thinking skills in physics learning. These findings are supported by previous studies stating that inquiry-based and technology-integrated assessments are capable of improving students' scientific reasoning and critical thinking skills effectively [5], [7], [15].

DISCUSSION

The findings of this research indicate that the developed *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* (DSI) has fulfilled the validity criteria in all assessed aspects, namely content feasibility, language appropriateness, presentation feasibility, and graphical feasibility. The high validity scores indicate that the developed assessment instrument was systematically designed in accordance with higher-order thinking indicators and inquiry-based physics learning characteristics [3], [25]. The use of Aiken's V analysis also strengthens the validity of the instrument because Aiken's V is widely used to determine the appropriateness and relevance of educational assessment instruments based on expert judgment [9].

The developed assessment instrument was designed to facilitate students' higher-order scientific thinking skills, including scientific reasoning, critical thinking, creative thinking, metacognitive skills, and self-efficacy. This finding is consistent with previous studies explaining that higher-order thinking assessments are capable of supporting students in analyzing phenomena, evaluating evidence, and solving contextual scientific problems systematically [8], [16], [24]. In physics learning, higher-order scientific thinking skills are important because students are required not only to understand concepts but also to apply scientific reasoning and problem-solving skills in real situations [2], [27].

The integration of the *Dual Space Inquiry* approach within the developed assessment instrument also contributed significantly to the validity of the product. The integration of physical and digital learning spaces allows students to conduct scientific investigations more actively and interactively [7]. Previous studies stated that inquiry-based learning integrated with digital technology can improve students' engagement, critical thinking skills, and scientific reasoning abilities because students are encouraged to explore concepts through investigation and reflective thinking activities [17], [20], [29].

The content feasibility aspect obtained a valid category, indicating that the developed assessment instrument was aligned with the learning objectives and static electricity material. The developed assessment tasks were considered capable of facilitating students in analyzing scientific phenomena and solving contextual problems. Inquiry-oriented assessments are considered effective in supporting higher-order thinking processes because students are encouraged to investigate, analyze, and construct scientific explanations independently [5], [8]. The language appropriateness aspect obtained a highly valid category. The validators stated that the instructions, statements, and scientific terms used in the assessment instrument were clear, communicative, and easy for students to understand. Appropriate language use is important because effective assessment language can reduce misconceptions and improve students' understanding during assessment implementation [14], [15]. The presentation feasibility aspect obtained the highest validity score among all assessed aspects. This result indicates that the developed assessment instrument had a systematic structure, coherent organization, and presentation format aligned with the learning objectives. Systematic assessment presentation is important because it helps students follow scientific investigation stages gradually and logically [12], [19].

The graphical feasibility aspect also obtained a highly valid category. The validators considered that the layout, typography, and visual appearance of the developed assessment instrument were attractive and appropriate for students. Attractive graphical design is important because it can improve students' motivation, concentration, and engagement during assessment activities [6], [18]. Previous studies also explained that multimedia-supported and technology-integrated assessments can improve the effectiveness of learning evaluation processes and provide more meaningful learning experiences for students [21], [22], [23]. Overall, the findings of this research indicate that the developed *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* is feasible to be used as an assessment instrument in physics learning, especially on static electricity material. The developed assessment instrument not only measures students' conceptual understanding but also facilitates scientific investigation, analytical thinking, and reflective learning processes. Therefore, the developed assessment can become an alternative assessment tool to support meaningful, inquiry-oriented, and technology-integrated physics learning in the 21st century [1], [28], [30].

IV. CONCLUSION

This research aimed to develop a *Scientific Higher Order Thinking* (S-HOT) assessment based on *Dual Space Inquiry* (DSI) for static electricity material and determine its validity level. The validation results showed that the developed assessment instrument obtained valid to highly valid categories in terms of content feasibility,

language appropriateness, presentation feasibility, and graphical feasibility. These findings indicate that the developed assessment instrument is feasible to be used in physics learning to facilitate students' higher-order scientific thinking skills. Therefore, the S-HOT assessment based on *Dual Space Inquiry* can be used as an alternative assessment instrument to support inquiry-based and technology-integrated physics learning.

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