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Needs Analysis for Developing Interactive Electronic Student Worksheets Based on Dual Space Inquiry on Kinematics to Stimulate Students' Critical Thinking Skills

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ABSTRACT

This study aimed to analyze the need for developing a Dual Space Inquiry (DSI)-based interactive Electronic Student Worksheets (E-SWS) on kinematics to stimulate students' critical thinking skills. The study was conducted at the define stage of the 4D development model, including front-end analysis, learner analysis, task analysis, concept analysis, and learning objective formulation. Data were collected through observations, interviews, questionnaires, document analysis, and critical thinking tests involving one physics teacher and 30 Grade XI students at SMA Negeri 1 Tigo Nagari. The results showed that students' critical thinking skills were very low across all indicators. In addition, learning remained teacher-centered, student involvement in inquiry activities was limited, and the use of digital teaching materials was not yet optimal. These findings indicate the need for a DSI-based interactive E-SWS that supports inquiry-based and technology-integrated learning to stimulate students' critical thinking skills in kinematics

Keywords: Interactive E-SWS, Dual Space Inquiry, kinematics, critical thinking skills

I. INTRODUCTION

The rapid development of science and technology in the 21st century has significantly transformed nearly every aspect of human life, particularly the field of education. The incorporation of Information and Communication Technology (ICT) into the learning process is no longer considered an additional support system but has become an essential component in improving educational quality and adapting learning practices to modern demands. [1] explained that technology-based learning enables students to access knowledge from various sources beyond the conventional classroom environment. In line with this perspective, [2] stated that teachers are no longer positioned as the sole providers of information, but rather as facilitators who assist students in independently constructing knowledge through digital platforms. Therefore, the optimal implementation of technology-based learning in schools is crucial to equip students with competencies required in the modern era.

Alongside the growing importance of technological literacy, 21st-century education also emphasizes the mastery of higher-order thinking skills, especially critical thinking. The Assessment and Teaching of 21st-Century Skills (ATC21S) identifies Critical Thinking Skills (CTS) as one of the essential competencies students must possess to deal with increasingly complex information and challenges (Saputri et al., 2026). [3] described critical thinking as the capacity to systematically analyze, evaluate, and reflect on information in order to make rational and appropriate decisions. Likewise, [4] argued that critical thinking involves cognitive processes such as analysis, synthesis, and evaluation from multiple viewpoints. The cultivation of critical thinking skills is highly important because it encourages curiosity, creativity, and analytical reasoning, enabling students to formulate innovative questions and identify accurate solutions to real-life problems [5]

Within the context of physics education, critical thinking skills are particularly important because physics studies concepts closely related to natural phenomena and everyday life. According to[6], physics learning is not limited to conceptual understanding but also aims to enable students to apply scientific concepts in real situations. Consequently, students must be trained to think critically in analyzing physical phenomena, interpreting scientific data, and solving problems through scientific approaches. Kinematics, as one of the fundamental topics in physics, strongly requires critical thinking abilities because students must understand concepts of motion, identify relationships among displacement, velocity, acceleration, and time, and analyze motion phenomena in both one-dimensional and two-dimensional contexts [7]

To improve educational quality, the Indonesian government has implemented the Merdeka Curriculum, which emphasizes student-centered learning and the development of higher-order thinking skills [8]Studies on the implementation of the Merdeka Curriculum in senior high school physics subjects indicate that the curriculum provides teachers with flexibility to design teaching materials according to students' needs, characteristics, and local contexts [9]This competency-based curriculum also requires students to master essential 21st-century skills such as critical thinking, creativity, collaboration, and communication (Permendikdasmen No. 12 Tahun 2025). Moreover, physics instruction is expected to be contextual and connected to real-world issues, including renewable energy, transportation systems, and digital technology applications. Nevertheless, despite these progressive educational reforms, many studies still reveal a gap between the intended goals of the Merdeka Curriculum and actual classroom practices in Indonesia.

A broader study conducted by [10] involving 125 eleventh-grade students from three public high schools in Lima Puluh Kota Regency, produced similarly concerning findings. The study showed that students' critical thinking skills were very low, with an average score of only 27.80%. The weakest indicators were inference (24.00%) and evaluation (28.00%), which represent advanced levels of critical thinking. In addition, the research found that classroom instruction still relied heavily on non-interactive media such as PowerPoint presentations and conventional videos, which failed to accommodate students' learning preferences, particularly the dominant visual learning style reported by 53.06% of students. Although students generally displayed positive attitudes toward physics learning (65.69%), these positive perceptions did not translate into improved critical thinking skills due to the limitations of existing instructional approaches

The issue of low critical thinking skills in Indonesian physics education has also been supported by several other studies. for example, investigated critical thinking skills through STEM-integrated Project-Based Learning (PjBL) on Newton's Laws and found that students showed low performance in interpretation skills, indicating difficulties in understanding scientific data and drawing conclusions from observations. Similarly, Dewi and Nisa (2025) demonstrated that Problem-Based Learning (PBL) supported by electronic live worksheets effectively improved students' critical thinking skills, with the experimental group achieving an N-Gain score of 0.50 and an Effect Size of 0.70. Another study [11]emphasized the need to develop E-SWS in dynamic electricity learning to stimulate students' critical and creative thinking skills, as traditional teaching approaches were insufficient to support higher-order cognitive processes.

One of the factors contributing to students' low critical thinking skills is the persistence of teacher-centered learning practices. [12] In such classrooms, students tend to act as passive recipients of information, while opportunities to formulate hypotheses, conduct investigations, analyze data, and draw conclusions independently remain limited [12], [13]. Consequently, students have fewer opportunities to develop the reasoning and analytical skills required in physics learning**.**[13]

Another challenge lies in the limited use of technology in instructional materials. Observations and interviews conducted at SMA N 1 Tigo Nagari indicated that the student worksheets currently used are still printed conventionally and have not been transformed into interactive digital formats. Technology is only utilized to prepare worksheets before printing them, rather than being integrated to enhance the learning process itself. In contrast, many studies have demonstrated that technology-based teaching materials can create more engaging and meaningful learning experiences. [14]explained that Electronic Student Worksheets (E-SWS) are digital teaching materials containing learning content, exercises, videos, and interactive simulations that support students' conceptual understanding. Likewise, [1] argued that E-SWS can significantly increase students' learning motivation and interest through interactive features and immediate feedback systems.

Recent studies on E-SWS development further demonstrate its effectiveness. [15] developed a PBL-based live worksheet designed to improve critical thinking and science process skills. Their study revealed that the developed product achieved a very high level of validity and practicality, with expert validation scores above 85% and student response scores exceeding 80%. Statistical analysis also indicated significant improvements in students' critical thinking abilities and science process skills. Similarly, [16]designed an E-SWS based on the Predict-Observe-Explain (POE) model for static fluid topics and obtained a validity score of 0.90, categorized as highly valid. Another study by [17] confirmed that PBL-based E-SWS effectively improved students' critical thinking skills, as reflected in higher N-Gain and Effect Size values compared to conventional instruction. Students also showed highly positive responses toward the use of interactive electronic worksheets.

To maximize the benefits of digital teaching materials, appropriate pedagogical support is required. The Dual Space Inquiry (DSI) framework integrates inquiry activities conducted in both physical and digital learning environments through the stages of orientation, conceptualization, exploration, conclusion and assessment, and reflection [13]. This framework encourages students to actively construct knowledge through observation, investigation, data analysis, and reflection. Previous studies have highlighted the potential of DSI-based learning resources to support scientific literacy, inquiry skills, and meaningful learning experiences in digital learning environments [13], [18]. Therefore, DSI is considered a suitable framework for the development of interactive E-LKPD in physics learning.

The DSI consists of five stages: orientation, conceptualization, exploration, conclusion and assessment, and reflection. During the orientation stage, students observe phenomena and gather relevant information. In the conceptualization stage, they formulate hypotheses and tentative explanations. The exploration stage involves conducting experiments and analyzing data, either physically or virtually. The conclusion stage requires students to formulate evidence-based conclusions and evaluate their findings, while the reflection stage encourages students to discuss ideas and evaluate their understanding collaboratively[13]. Through these interconnected stages, students are actively engaged in constructing knowledge through inquiry, collaboration, and reflection across both physical and digital learning environments.

The application of DSI in kinematics learning is highly relevant because kinematics concepts naturally connect concrete physical experiences with abstract mathematical representations. Students need to understand motion through direct observation while also interpreting graphs, equations, and simulations in digital environments. Therefore, the integration of physical and digital inquiry spaces in the DSI aligns closely with the cognitive demands of kinematics learning [18]conducted a needs analysis for developing an interactive e-book based on the DSI and found that students' scientific literacy skills were generally low, particularly in data interpretation and evaluation of scientific arguments. Their findings also showed that printed teaching materials were still dominant, while the use of digital and interactive learning media remained limited. These results highlight the urgent need for interactive inquiry-based digital teaching materials.

The effectiveness of DSI-based digital teaching materials has also been supported by expert validation studies.) analyzed the validity of a Static Fluid E-Worksheet based on the *Dual Space Inquiry* and found that it met high standards across content, pedagogical, and technical aspects. The uniqueness of the DSI approach lies in its integration of inquiry-based learning with digital technology, allowing students not only to access information digitally but also to actively construct understanding through guided investigation in multiple learning spaces.

Based on the findings and research gap identified above, this study aims to analyze the need for developing a Dual Space Inquiry-based interactive E-SWS on kinematics to stimulate students' critical thinking skills. The results of this needs analysis are expected to provide an empirical foundation for the subsequent design and development of innovative learning materials that support inquiry-based and technology-integrated physics learning.

II. METHOD

This research constitutes the Define stage of the 4D development model (Define, Design, Develop, and Disseminate) proposed by [19]. The Define stage aims to identify and analyze learning needs as a basis for developing an interactive Electronic Student Worksheet (E-SWS) based on the Dual Space Inquiry (DSI) This stage consists of five activities: front-end analysis, learner analysis, task analysis, concept analysis, and formulation of learning objectives

1. Front-End Analysis

   The front-end analysis was conducted to identify problems encountered in physics learning, particularly in kinematics topics. This analysis aimed to examine the current learning conditions, students' learning difficulties, the suitability of the curriculum, and the extent to which existing learning materials support the development of critical thinking skills. Data were collected through classroom observations, teacher interviews, and document analysis. The findings from this stage were used to determine the specifications and characteristics of the interactive E-SWS developed based on the Dual Space Inquiry

2. Learner Analysis

   Learner analysis was conducted to identify students' characteristics, including academic abilities, learning preferences, problem-solving skills, and critical thinking skills. The participants consisted of 30 Grade XI students from SMA N 1 Tigo Nagari. The sample was selected using purposive sampling because the students had studied prerequisite concepts related to kinematics and represented the target users of the developed learning material.

   Students' critical thinking skills were measured using a test instrument consisting of five essay questions developed based on Ennis' critical thinking indicators[20], namely: (1) elementary clarification, (2) basic support, (3) inference, (4) advanced clarification, and (5) strategy and tactics. The results of the learner analysis served as the basis for designing an interactive E-SWS that is appropriate to students' needs and characteristics[21].

3. Task Analysis

   Task analysis was conducted to identify and organize the competencies that students must achieve in learning kinematics. This analysis decomposed the learning outcomes into a sequence of learning activities and identified the knowledge and skills required to achieve the expected competencies. The results of this analysis were used to design learning activities in the interactive E-SWS.

4. Concept Analysis

   Concept analysis aimed to identify and map the key concepts included in the interactive E-SWS. The analysis covered factual, conceptual, procedural, and metacognitive dimensions of knowledge related to kinematics. The resulting concept map served as a guide for organizing the content and activities presented in the developed learning material.

5. Formulation of Learning Objectives

   Learning objectives were formulated based on the results of the task and concept analyses. The objectives were written clearly and measurably to guide the development of the Dual Space Inquiry-based interactive E-SWS and ensure alignment with the expected competencies and critical thinking indicators.

Data Collection Instruments

The instruments used in this study consisted of classroom observation sheets, teacher interview guidelines, student questionnaires, document analysis sheets, and critical thinking skills test questions. Observation sheets and interview guidelines were used to identify learning problems and students' needs in physics learning. Student questionnaires were administered to collect information regarding students' learning experiences, learning difficulties, and perceptions of digital learning materials.

The critical thinking skills test consisted of five essay questions developed based on Ennis' critical thinking indicators [20]. Prior to implementation, the instruments were validated through expert judgment involving physics education lecturers and physics teachers to ensure content relevance, clarity of language, and suitability with the research objectives. Revisions were made based on the suggestions provided by the validators.

Data Analysis

Quantitative data obtained from the critical thinking skills test and questionnaires were analyzed descriptively using percentage analysis. Students' scores were calculated using the following formula:

$$P = \frac{\sum x}{\sum xi} x100\%$$

where (P) is the percentage score, Score Obtained is the total score achieved by students, and Maximum Score is the highest possible score.The percentage results were then categorized according to the criteria adapted from [21] to determine students' critical thinking skill levels and learning needs.

Questionnaire data were analyzed by calculating the percentage of responses for each statement to identify students' needs and perceptions regarding the use of digital learning materials. Qualitative data obtained from observations, interviews, and document analysis were analyzed descriptively through data reduction, coding, categorization, data presentation, and conclusion drawing. This process was carried out to identify patterns related to learning problems, students' needs, and opportunities for integrating the Dual Space Inquiry framework into the interactive E-SWS.

III. RESULTS AND DISCUSSION

Results

The needs analysis was conducted during the Define stage of the 4D development model, which includes front-end analysis, learner analysis, task analysis, concept analysis, and formulation of learning objectives. Data were collected through classroom observations, teacher interviews, student questionnaires, document analysis, and critical thinking skills tests involving one physics teacher and 30 Grade XI students at SMA Negeri 1 Tigo Nagari.

1. Front-End Analysis Results

   The front-end analysis revealed several challenges in physics learning, particularly in kinematics. Classroom observations indicated that learning activities were predominantly teacher-centered, with teachers acting as the primary source of information while students played relatively passive roles. Opportunities for inquiry-based activities, collaborative discussions, and independent knowledge construction were limited.

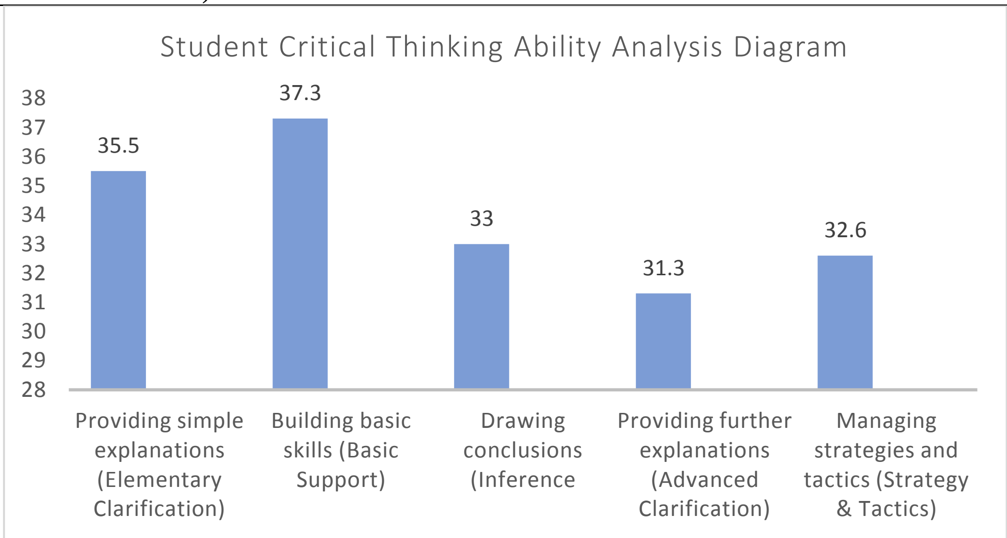
   In addition, the integration of technology in learning was still minimal. Student worksheets (SWS) were used only in printed form and had not been developed into interactive electronic worksheets (E-SWS). Interviews with the physics teacher confirmed that digital learning materials, virtual simulations, and interactive videos had rarely been incorporated into classroom instruction. These conditions may reduce opportunities for students to actively explore concepts, construct explanations, and develop higher-order thinking skills.

2. Learner Analysis Results

Learner analysis focused on students' critical thinking skills, learning styles, attitudes toward physics, and learning motivation. The results of the critical thinking skills test based on Ennis's indicators are presented in Table 1.

Table 1. Results of Students' Critical Thinking Skills Analysis

Indicator	Average (%)	Category
Providing simple explanations (Elementary Clarification)	35.5	Very Low
Building basic skills (Basic Support)	37.3	Very Low
Drawing conclusions (Inference)	33.0	Very Low
Providing further explanations (Advanced Clarification)	31.3	Very Low
Managing strategies and tactics (Strategy & Tactics)	32.6	Very Low



The results indicate that all critical thinking indicators were categorized as very low. The highest score was obtained in the Basic Support indicator (37.3%), while the lowest score was found in Advanced Clarification (31.3%). Low performance in the Advanced Clarification indicator suggests that students experienced difficulties in explaining concepts in greater depth, evaluating arguments, and connecting evidence with scientific reasoning.

Similarly, the low score in the Inference indicator (33.0%) indicates that students encountered challenges in drawing logical conclusions from available information and experimental data. This condition may be associated with learning practices that provide limited opportunities for students to investigate problems independently, analyze evidence, and justify their conclusions.

The low score in the Strategy and Tactics indicator (32.6%) further suggests that students had difficulty planning systematic approaches to problem solving. These findings collectively indicate that students' critical thinking skills require substantial improvement, particularly in higher-order cognitive processes involving reasoning, evaluation, and decision making.

Questionnaire results showed that students generally had positive attitudes toward physics, with an average score of 111.2 out of 120. Learning motivation was categorized as moderate, with an average score of 95.7. However, students' self-assessment of critical thinking skills was relatively low, with an average score of 93.7 out of 140, supporting the findings obtained from the critical thinking test.

Regarding learning preferences, students tended to favor visual and kinesthetic learning styles, obtaining average scores of 110 and 106, respectively. These results suggest that conventional text-based worksheets may not adequately accommodate students' preferred learning styles. Therefore, more interactive and technology-supported learning materials may be needed to facilitate active engagement in learning.

3. Task and Concept Analysis Results

Task analysis identified several essential competencies that students must achieve in kinematics learning, including distinguishing distance from displacement, differentiating speed from velocity, analyzing uniform and uniformly accelerated linear motion, interpreting motion graphs, and solving kinematics problems using appropriate equations.

Concept analysis mapped the kinematics content into factual, conceptual, procedural, and metacognitive knowledge dimensions. The analysis revealed that existing teaching materials mainly emphasized factual and conceptual knowledge, while procedural and metacognitive aspects received less attention. As a result, students had limited opportunities to practice reasoning processes, problem-solving strategies, and reflective thinking, which are important components of critical thinking.

4. Formulation of Learning Objectives

   Based on the results of the front-end, learner, task, and concept analyses, learning objectives were formulated to align with the Dual Space Inquiry framework and critical thinking indicators. The objectives emphasize students' ability to investigate physical phenomena, analyze relationships among kinematics variables, construct evidence-based explanations, and draw logical conclusions.

   One example of the formulated learning objective is: "Through observation activities and virtual simulations, students are able to analyze the relationship between displacement, velocity, and acceleration in uniformly accelerated motion and draw logical conclusions with at least 75% accuracy."

Discussion

The needs analysis revealed a mismatch between the demands of 21st-century physics education and current classroom practices. Developing critical thinking skills requires learning environments that actively engage students in questioning, investigating, analyzing evidence, and constructing explanations. However, the findings indicate that learning activities remain largely teacher-centered, limiting opportunities for students to engage in higher-order thinking processes. As a result, students demonstrated very low performance across all critical thinking indicators.

1. Low Critical Thinking Skills

   The results indicate that students' critical thinking skills remain very low across all indicators. The weakest indicators were Advanced Clarification (31.3%) and Inference (33.0%). These indicators require students to evaluate arguments, identify assumptions, interpret evidence, and draw logical conclusions. Such skills belong to higher-order thinking processes and are generally developed through active inquiry and reflective learning experiences rather than passive knowledge acquisition [10]. The low achievement in these indicators may be related to the learning practices observed in the classroom. Students were rarely involved in activities requiring them to formulate explanations, evaluate evidence, or justify conclusions. As a result, students tended to focus on obtaining answers rather than understanding the reasoning process behind those answers. This finding supports previous studies showing that limited opportunities for inquiry and argumentation contribute to low critical thinking performance in physics learning

2. Teacher-Centered Learning and Limited Inquiry Activities

   The findings revealed that physics instruction was still predominantly teacher-centered. In this learning environment, teachers function as the primary source of information, while students play relatively passive roles. Such conditions may limit students' opportunities to develop analytical reasoning, problem-solving abilities, and scientific argumentation skills. Previous studies have reported that teacher-centered instruction often emphasizes content transmission rather than knowledge construction, resulting in lower levels of student engagement and critical thinking development In contrast, inquiry-based learning encourages students to formulate questions, investigate problems, analyze evidence, and construct conclusions independently. Therefore, the lack of inquiry activities observed in this study may contribute to the low critical thinking skills demonstrated by students.

3. Limited Integration of Technology in Physics Learning

   Another important finding is the limited use of technology in classroom learning. Although students are familiar with digital technology in daily life, learning activities still rely heavily on printed worksheets and conventional instructional methods. This situation is inconsistent with the demands of 21st-century learning, which emphasize the integration of technology to support active and meaningful learning experiences. Technology-based learning materials can provide visualizations, simulations, and interactive activities that help students understand abstract concepts more effectively. Previous studies have shown that interactive E-LKPD can improve student engagement and facilitate the development of critical thinking skills by providing opportunities for exploration, investigation, and immediate feedback. Therefore, the transformation of conventional worksheets into interactive digital learning materials is necessary to support more effective physics learning.

4. Why Dual Space Inquiry Is More Suitable Than Conventional Inquiry Models

   Although conventional inquiry models have been widely used to promote active learning, their implementation is often limited to classroom or laboratory activities. Consequently, learning opportunities may become constrained by time, facilities, and classroom conditions. The Dual Space Inquiry (DSI) offers a broader learning environment by integrating physical and digital inquiry spaces. Through this approach, students can conduct investigations both inside and outside the classroom using digital tools and virtual simulations. This characteristic is particularly relevant for kinematics learning, where abstract concepts such as velocity, acceleration, and motion graphs can be visualized more effectively through technology-supported inquiry activities. In addition, the DSI systematically guides students through orientation, conceptualization, exploration, conclusion and assessment, and reflection phases. These phases directly support the development of critical thinking skills by engaging students in questioning, investigating, analyzing evidence, drawing conclusions, and evaluating their own reasoning processes.

5. Comparison with PBL- and POE-Based E-SWS

Several studies have reported that Problem-Based Learning (PBL)-based E-SWS can improve critical thinking skills by engaging students in solving contextual problems. However, PBL mainly emphasizes problem-solving processes and may provide less structured guidance for scientific investigations. Similarly, Predict-Observe-Explain (POE)-based E-SWS has been shown to improve conceptual understanding by encouraging students to predict outcomes, observe phenomena, and explain discrepancies between predictions and observations. Nevertheless, POE generally focuses on conceptual change and may not fully support extended inquiry processes. Compared with these approaches, DSI integrates inquiry processes with digital learning environments. Students are not only required to solve problems or explain phenomena but are also guided to formulate hypotheses, investigate evidence, interpret data, draw conclusions, and reflect on their learning experiences. Therefore, DSI provides more comprehensive support for developing critical thinking skills, particularly in the areas of inference and advanced clarification that were identified as weaknesses in this study.

6. The Role of Digital Inquiry in Developing Critical Thinking

Digital inquiry environments enable students to explore scientific phenomena through simulations, virtual experiments, and interactive learning resources. These tools allow students to manipulate variables, observe outcomes repeatedly, and test hypotheses in ways that are difficult to achieve through traditional instruction alone.For kinematics learning, digital simulations can visualize relationships among displacement, velocity, acceleration, and time. Through repeated exploration and analysis, students develop deeper conceptual understanding and stronger reasoning abilities. Previous studies have demonstrated that technology-supported inquiry learning can significantly enhance students' critical thinking and scientific reasoning skills because it promotes evidence-based investigation and reflective thinking

7. Implications for E-SWS Development

Based on the findings, the proposed E-SWS should not merely convert printed worksheets into digital form. Instead, it should be designed to facilitate inquiry activities aligned with the Dual Space Inquiry. The E-SWS should incorporate interactive simulations, guided investigations, data analysis activities, reflective questions, and self-assessment features. These components can provide structured opportunities for students to practice all five critical thinking indicators proposed by Ennis, thereby addressing the learning needs identified in this study.

8. Limitations of the Study

This needs analysis involved only 30 Grade XI students from one school, which limits the generalizability of the findings. Furthermore, the study was conducted only at the Define stage of the 4D development model. Future studies should continue through the Design, Develop, and Disseminate stages to evaluate the validity, practicality, and effectiveness of the developed E-SWS in improving students' critical thinking skills.

IV. CONCLUSION

This needs analysis conducted at the Define stage of the 4D development model revealed that students' critical thinking skills in kinematics remain low and that current physics learning has not fully supported the development of higher-order thinking skills. Learning activities are still predominantly teacher-centered, while the use of technology and inquiry-based learning materials remains limited. These findings indicate a gap between the demands of 21st-century learning and actual classroom practices.

Therefore, the development of an interactive E-SWS based on the Dual Space Inquiry (DSI) is necessary to support the integration of inquiry activities and digital learning environments in physics instruction. The proposed E-SWS is expected to provide students with structured opportunities to investigate, analyze evidence, draw conclusions, and reflect on their learning processes, thereby promoting critical thinking skills. For physics teachers, the development of DSI-based E-SWS can serve as an alternative learning resource that aligns with curriculum goals and the demands of 21st-century education. Future research should proceed to the Design, Develop, and Disseminate stages to evaluate the validity, practicality, and effectiveness of the developed product.

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