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Needs Analysis for Developing Critical Thinking–Integrated Electronic Worksheets on Particle Dynamics at the Undergraduate Level

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Abstract: Particle Dynamics learning requires higher-order thinking skills, particularly critical thinking skills. However, many students still experience difficulties in analyzing problems and drawing appropriate inferences related to physics concepts. This study aims to analyze undergraduate students' critical thinking skills profiles and examine the need for developing electronic student worksheets (E-Student Worksheets) for Particle Dynamics learning. A quantitative descriptive approach with a descriptive exploratory design was employed. The participants were 61 undergraduate students from a Physics Education program who had completed or were currently taking the Basic Physics course. The participants were selected using purposive sampling because they had prior exposure to Particle Dynamics concepts, making them suitable for critical thinking skills assessment and needs analysis. Data were collected using two instruments: a critical thinking skills test and a needs analysis questionnaire. The critical thinking skills test consisted of open-ended physics problems designed based on Facione's framework of critical thinking indicators, including interpretation, analysis, evaluation, explanation, and inference. Descriptive statistical analysis using mean scores and percentages was applied to analyze the data. The results indicate that students' critical thinking skills are generally low, with average scores ranging from 35 to 39 across all indicators, particularly in the areas of analysis and inference. Furthermore, the needs analysis results show that all indicators related to instructional material development fall within the "Needed" category (61–80%), supported by students' high digital engagement. These findings imply that instructional materials should be designed to provide structured guidance that facilitates students' reasoning processes in solving Particle Dynamics problems. Therefore, the development of critical thinking–integrated electronic student worksheets is considered urgent and has strong potential to improve the quality of Particle Dynamics learning at the undergraduate level.

Keywords: Critical thinking skills; E-student worksheets (E-LKM); Needs analysis; Particle dynamics; Physics learning

Introduction

Basic physics is a fundamental course that plays a crucial role in developing conceptual understanding and scientific reasoning skills among undergraduate students in science and engineering programs. One of the core topics in basic physics is Particle Dynamics, which requires students to understand the relationship between force, mass, and motion through logical and analytical reasoning processes. However, several studies have reported that students often experience difficulties in learning mechanics concepts due to the abstract nature of the material and the dominance of procedural and mathematical problem-solving approaches in

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physics instruction (Harlipadensi et al., 2023; Wayudi et al., 2023; Cynthia et al., 2023).

In the context of 21st-century education, the development of critical thinking skills has become a primary objective in physics learning. Critical thinking skills involve the ability to interpret information, analyze problems, evaluate arguments, explain reasoning, and draw logical inferences (Rizki et al., 2021; Nicholus et al., 2023; Prahani et al., 2025; Bakri et al., 2023). Previous research has emphasized that these skills are essential for enabling students to understand physics concepts meaningfully and apply them to various problem contexts (Villayah et al., 2025; Sidiq et al., 2022; Hartono et al., 2025). Nevertheless, empirical findings indicate that students' critical thinking skills in physics learning, particularly in mechanics topics, remain at a low level, especially in higher-order indicators such as analysis and inference (Wayudi et al., 2023; Hartono et al., 2025).

Several studies have explored instructional strategies and learning models aimed at improving students' critical thinking skills in physics. Problem-Based Learning and higher-order thinking–oriented instruction have been shown to positively influence students' critical thinking when supported by appropriate learning resources (Khairani et al., 2023; Sidiq et al., 2022; Sudirman et al., 2024). In addition, recent studies highlight the potential of digital learning materials, including electronic modules and electronic student worksheets, in increasing student engagement and facilitating higher-order thinking processes (Hati et al., 2024; Pasaribu et al., 2022; Wiyono et al., 2025). These findings suggest that the effectiveness of instructional models is closely linked to the quality and design of the learning materials used in the learning process.

Despite the growing body of research on digital learning materials, most existing studies focus on the development and effectiveness testing of instructional products (Hati et al., 2024; Wiyono et al., 2025; Sabila et al., 2025). Relatively few studies conduct preliminary investigations in the form of needs analysis to examine students' initial critical thinking skills profiles before developing digital instructional materials (Sihombing et al., 2025; Haris et al., 2025; Liza et al., 2025). Moreover, needs analysis studies related to critical thinking–integrated electronic worksheets are still limited at the undergraduate level, particularly in basic physics courses such as Particle Dynamics (Rahayu et al., 2023; Wayudi et al., 2023; Hartono et al., 2025).

Along with the rapid advancement of digital technology, undergraduate students demonstrate high levels of digital readiness and familiarity with technology-based learning environments (Busyairi et al., 2023; Paminto et al., 2023). However, physics learning at the university level is still largely supported by printed materials and conventional worksheets, which provide limited opportunities for systematically training higher-order thinking skills (Cynthia et al., 2023). This mismatch between students' digital readiness and the instructional materials used indicates the need for innovation in physics learning resources.

Preliminary observations and diagnostic assessments conducted in the Basic Physics course also indicate that students still experience considerable difficulties in solving Particle Dynamics problems that require critical thinking. Many students tend to focus primarily on applying mathematical formulas without adequately interpreting the physical meaning of the problem, analyzing the relationships between variables, or drawing logical conclusions from the given information. As a result, students often demonstrate weaknesses in higher-order critical thinking indicators such as analysis and inference when solving mechanics-related problems. These conditions suggest that students require learning materials that not only present conceptual explanations but also systematically guide them through critical thinking processes in problem-solving activities.

One potential solution to address this gap is the development of Electronic Student Worksheets (E-Student Worksheets). Previous studies indicate that electronic worksheets offer flexibility, interactivity, and opportunities to integrate structured activities that support critical thinking processes (Pasaribu et al., 2022; Sabila et al., 2025; Dinata et al., 2020). When designed based on empirical needs analysis, E-Student Worksheets can guide students through stages of interpretation, analysis, evaluation, explanation, and inference in solving physics problems (Paspania et al., 2024; Haris et al., 2025; Hartono et al., 2025).

Although previous studies have explored the development and implementation of digital learning materials in physics education, most of them primarily focus on evaluating the effectiveness of instructional products after they have been developed. Only a limited number of studies have conducted comprehensive preliminary investigations that examine both students' critical thinking skills profiles and their instructional material needs as a foundation for developing digital learning resources. In addition, research specifically addressing critical thinking–integrated Electronic Student Worksheets in the context of Particle Dynamics at the undergraduate level remains relatively scarce. Therefore, this study offers a state-of-the-art contribution by combining diagnostic assessment of students' critical thinking skills with a systematic needs analysis to provide empirical evidence for the development of critical thinking–integrated Electronic Student Worksheets in basic physics learning.

Therefore, a preliminary study in the form of a needs analysis is necessary to obtain an empirical description of undergraduate students' critical thinking skills profiles and to examine the urgency of developing critical thinking–integrated Electronic Student Worksheets for Particle Dynamics learning. This study specifically focuses on addressing two main research questions: (1) how are undergraduate students' critical thinking skills profiles in Particle Dynamics learning, and (2) to what extent do students need Electronic Student Worksheets integrated with critical thinking skills in basic physics courses. This study aims to analyze students' critical thinking skills profiles and investigate the need for developing Electronic Student Worksheets in Particle Dynamics at the undergraduate level. The findings of this study are expected to provide a strong foundation for the development of digital learning materials that can enhance the quality of basic physics learning.

Method

This research was conducted in the Physics Education Study Program at the undergraduate level during the 2025/2026 academic year. The study focused on the Basic Physics course, particularly on the topic of Particle Dynamics.

This study employed a descriptive quantitative approach with an exploratory descriptive design. This design was selected to obtain an empirical description of undergraduate students' critical thinking skills profiles and to identify the need for developing Electronic Student Worksheets in Particle Dynamics learning. Similar research designs have been widely used in needs analysis studies in physics education to map initial learning conditions prior to instructional material development (Heim et al., 2025; Micoloi et al., 2025; Sihombing et al., 2025; Astra et al., 2024).

The population of this study consisted of undergraduate students enrolled in the Physics Education Study Program who had taken the Basic Physics course. The sample comprised 61 undergraduate students who had completed or were currently taking the Basic Physics course. The participants were selected using purposive sampling because they had prior exposure to Particle Dynamics concepts, making them suitable subjects for critical thinking skills assessment and needs analysis (Denny et al., 2023; Ramma et al., 2024).

The research variables included students' critical thinking skills and their needs related to instructional materials. Data were collected using two instruments: a critical thinking skills test and a needs analysis questionnaire. The critical thinking skills test consisted of open-ended questions developed based on critical thinking indicators, including interpretation, analysis, evaluation, explanation, and inference. These indicators are widely used in previous studies assessing critical thinking skills in physics learning (Pedraja-Rejas et al., 2024; Walsh et al., 2022).

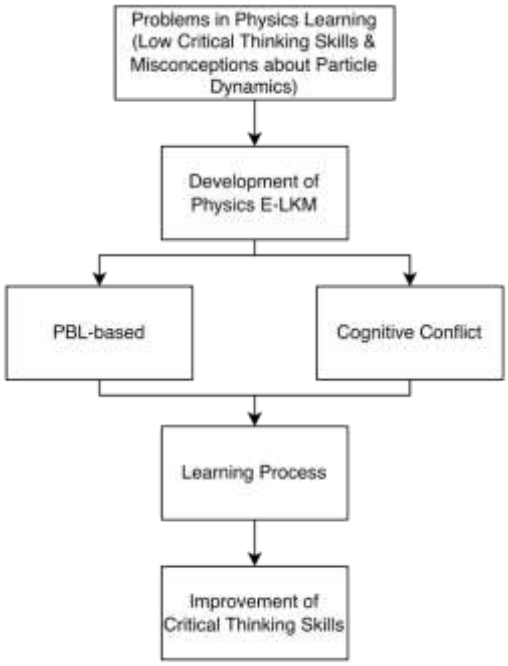

Figure 1. Research procedure flowchart

The second instrument was a needs analysis questionnaire designed to examine students' perceptions of learning difficulties, instructional media usage, digital habits, and problem-solving practices. Needs analysis questionnaires have commonly been used in physics education research to identify gaps between existing instructional materials and students' learning needs (Widya et al., 2021; Susilowati et al., 2021; Haris et al., 2025; Lestari et al., 2024; Rahmadita et al., 2021).

The research was conducted through several stages. The first stage involved preparing the research instruments, including developing the critical thinking skills test and the needs analysis questionnaire based on relevant indicators and literature. The second stage was data collection, in which the critical thinking skills test was administered to students to measure their critical thinking abilities in Particle Dynamics learning.

After completing the test, students were asked to respond to the needs analysis questionnaire to identify their learning difficulties and their perceptions regarding the use of instructional media in physics learning. The final stage involved compiling and organizing the collected data for further analysis.

The collected data were analyzed using descriptive statistical techniques. The results of the critical thinking skills test were analyzed by calculating the mean scores

for each critical thinking indicator, including interpretation, analysis, evaluation, explanation, and inference. These results were used to describe students' critical thinking skills profiles.

Meanwhile, the responses from the needs analysis questionnaire were analyzed using percentage calculations. The percentage values were then categorized based on predefined criteria to determine the level of urgency for developing instructional materials, as commonly applied in similar needs analysis studies (Liza et al., 2025).

Result and Discussion

Students' Critical Thinking Skills Profile

The results of the critical thinking skills test administered to 61 undergraduate students indicate that students' critical thinking skills in Particle Dynamics remain at a low level across all assessed indicators. The average scores for each indicator are presented in Table 1.

Table 1. Average Scores of Students' Critical Thinking Skills Indicators

Critical Thinking Indicator	Average Score
Interpretation	39
Analysis	35
Evaluation	36
Explanation	39
Inference	37

As shown in Table 1, all indicators obtained average scores below 40, indicating low proficiency in critical thinking skills. The lowest score was observed in the analysis indicator (35), followed by inference (37). These findings suggest that students experience difficulties in processing physics problems that require higher-order reasoning, particularly in Particle Dynamics.

Interpretation Skills

The interpretation indicator obtained an average score of 39, indicating that students still experience difficulties in identifying relevant information, understanding problem statements, and translating physical situations into appropriate representations. In Particle Dynamics learning, interpretation skills are essential for recognizing forces acting on objects and understanding the physical meaning of motion conditions before applying mathematical formulations.

The low interpretation score suggests that students may not yet be accustomed to engaging in conceptual reasoning at the initial stage of problem solving. Similar findings have been reported in previous studies, which indicate that students tend to directly apply formulas without fully interpreting physical situations, leading to misconceptions and errors in subsequent problem-solving stages (Wayudi et al., 2023; Hartono et al., 2025).

Analysis Skills

Analysis skills obtained the lowest average score among all indicators, with a value of 35. This finding indicates that students face significant challenges in breaking down physics problems into relevant components, identifying relationships between forces, mass, and motion, and selecting appropriate physical principles to explain observed phenomena. In the context of Particle Dynamics, strong analytical skills are required to apply Newton's laws and consider multiple interacting forces simultaneously.

The low performance in analysis skills can be attributed to the abstract nature of Particle Dynamics and the dominance of procedural approaches in physics instruction. Students often focus on substituting values into equations rather than analyzing the causal relationships underlying motion. Previous studies have reported similar weaknesses in students' analytical reasoning in mechanics when instructional materials do not explicitly guide students to analyze physical situations conceptually (Harlipadensi et al., 2023; Wayudi et al., 2023; Cynthia et al., 2023).

Inference Skills

Inference skills obtained an average score of 37, indicating that students experience difficulties in drawing logical conclusions based on analysis results. Inference is a higher-order critical thinking skill that requires students to synthesize information, justify conclusions, and connect mathematical outcomes with physical meaning.

The low inference score suggests that students often stop at obtaining numerical results without reflecting on their physical implications. This finding aligns with previous research reporting that students struggle to justify their answers or predict physical outcomes based on underlying principles (Aristawati et al., 2023; Wayudi et al., 2023; Hartono et al., 2025). Weak inference skills may also be linked to poor analytical performance, as inadequate analysis limits students' ability to construct valid conclusions (Sidiq et al., 2022; Sudirman et al., 2024).

Needs Analysis of Instructional Materials

To examine students' needs related to instructional materials in Particle Dynamics learning, a needs analysis questionnaire was administered. The results are summarized in Table 2.

Table 2. Results of Students' Needs Analysis

Indicator	Percentage (%)	Category
Learning Difficulties	68.76	Needed
Use of Learning Media	77.51	Needed
Students' Digital Habits	75.02	Needed
Problem-Solving Practices	67.87	Needed

As shown in Table 2, all indicators fall within the "Needed" category, with percentages ranging from 61% to 80%. The highest percentage is observed in the use of learning media (77.51%), indicating that students perceive the current instructional materials as insufficient to support their learning needs in Particle Dynamics.

Pedagogical Interpretation of Needs Analysis Results

The results of the needs analysis (Table 2) provide important pedagogical insights into the learning conditions experienced by students in Particle Dynamics. The percentage indicating learning difficulties (68.76%) suggests that a considerable proportion of students struggle to understand concepts and solve problems effectively. This finding is consistent with the low critical thinking scores presented in Table 1, indicating a close relationship between students' learning difficulties and their limited higher-order thinking skills.

The high percentage related to the use of learning media (77.51%) reinforces the argument that existing instructional materials have not sufficiently supported students' learning processes. From a pedagogical perspective, this indicates that the current learning media may not provide adequate scaffolding to guide students through the complex reasoning processes required in Particle Dynamics, such as identifying forces, analyzing motion, and drawing logical conclusions. Previous studies have emphasized that instructional materials lacking structured guidance tend to encourage procedural learning rather than conceptual understanding (Paul et al., 2024; Sari et al., 2022; Hati et al., 2024).

Furthermore, the high level of students' digital habits (75.02%) reflects strong technological readiness and familiarity with digital learning environments. Pedagogically, this condition represents a significant opportunity to implement technology-enhanced learning materials without encountering substantial technical barriers. However, high digital engagement alone does not automatically lead to improved learning outcomes (Ubaidillah et al., 2023). Without well-designed instructional structures, digital tools may function merely as content delivery platforms rather than facilitators of higher-order thinking (Tsalatsiyah et al., 2022; Wiyono et al., 2025; Dinata et al., 2020).

In this context, Electronic Student Worksheets are considered more appropriate than conventional e-modules. Unlike e-modules, which typically emphasize content presentation, E-Student Worksheets are activity-oriented and designed to actively engage students in problem-solving processes. E-Student Worksheets can incorporate guided questions, interactive tasks, and step-by-step reasoning prompts aligned with critical thinking indicators, thereby supporting students' cognitive development more effectively (Al-Kamzari et al., 2025; Wiyono et al., 2025; Sabila et al., 2025). This activity-based nature makes E-Student Worksheets particularly suitable for addressing students' difficulties in analysis and inference, which were identified as the weakest indicators in this study.

Overall, the needs analysis results indicate a strong alignment between students' learning challenges, their readiness to engage with digital technologies, and the pedagogical potential of Electronic Student Worksheets. These findings strengthen the urgency of developing E-Student Worksheets integrated with critical thinking skills as a targeted instructional solution for improving Particle Dynamics learning at the undergraduate level.

Pedagogical Implications for Particle Dynamics Learning

The findings of this study provide important pedagogical implications for the teaching and learning of Particle Dynamics at the undergraduate level. The low scores observed in analysis and inference skills indicate that students require structured instructional support to engage in higher-order thinking processes, rather than relying solely on procedural problem-solving. This suggests that instructional practices should shift from an emphasis on formula application toward learning activities that explicitly promote conceptual reasoning and critical thinking.

The identified learning difficulties, combined with the high demand for innovative learning media, highlight the need for instructional materials that function as cognitive scaffolds. In this context, Electronic Student Worksheets offer pedagogical advantages by guiding students through sequential stages of interpretation, analysis, evaluation, explanation, and inference. Such structured guidance can help students organize their thinking processes when dealing with abstract concepts and complex force–motion relationships in Particle Dynamics (Cynthia et al., 2023).

Furthermore, the high level of students' digital habits indicates that the integration of digital instructional materials is pedagogically feasible and contextually appropriate. However, digital integration should not merely involve the digitization of conventional materials. Instead, instructional materials must be designed to actively engage students in problem-solving activities that stimulate higher-order

thinking skills. Previous studies have emphasized that technology-enhanced learning is most effective when digital tools are used to support meaningful learning processes rather than passive content consumption (Wiyono et al., 2025).

Compared to conventional e-modules, Electronic Student Worksheets place greater emphasis on student activity and cognitive engagement. E-Student Worksheets can incorporate guided questions, interactive tasks, and immediate feedback mechanisms that support students' reasoning processes during learning. This activity-oriented design is particularly relevant for addressing weaknesses in analysis and inference skills, which were identified as the most critical challenges in this study (Wiyono et al., 2025).

Overall, the pedagogical implications of this study suggest that the development of critical thinking–integrated Electronic Student Worksheets has strong potential to improve the quality of Particle Dynamics learning. By aligning instructional materials with students' cognitive needs and digital readiness, educators can create learning environments that better support the development of higher-order thinking skills in undergraduate physics education.

Contribution and Positioning of the Study

This study contributes to physics education research by positioning itself as a preliminary and foundational investigation focusing on students' critical thinking skills profiles and instructional material needs in Particle Dynamics learning. Unlike many previous studies that primarily emphasize the development and effectiveness testing of digital instructional materials, this study addresses an earlier and essential stage of the instructional design process through systematic needs analysis and diagnostic assessment (Haris et al., 2025; Liza et al., 2025).

Most existing studies on Electronic Student Worksheets and digital learning materials in physics have focused on implementation outcomes, such as learning achievement improvement or effectiveness comparisons between instructional models (Hati et al., 2024). While these studies provide valuable insights into the potential benefits of digital instructional materials, they often assume that the instructional products align with students' actual learning conditions. This study addresses this gap by providing empirical evidence regarding students' critical thinking weaknesses and their perceived instructional needs prior to product development.

Furthermore, this study specifically focuses on Particle Dynamics, a core topic in basic physics that is conceptually demanding and closely associated with higher-order thinking skills. By examining critical thinking indicators at the undergraduate level, this research extends existing findings in physics education that have largely concentrated on general mechanics topics or secondary education contexts (Wayudi et al., 2023; Cynthia et al., 2023; Wahyuni et al., 2024). As such, this study enriches the literature by offering context-specific insights into undergraduate physics learning challenges.

From a methodological perspective, the use of a descriptive quantitative approach combined with critical thinking indicators and needs analysis instruments allows this study to generate a comprehensive picture of students' learning conditions. This approach supports the argument that effective instructional material development should be grounded in empirical data rather than assumptions about learners' needs (Asokawati et al., 2023; Darmaji et al., 2023; Haris et al., 2025).

Overall, this study positions itself as a critical foundation for subsequent research stages, including the design, development, and evaluation of critical thinking–integrated Electronic Student Worksheets. The findings serve as a reference point for educators and researchers seeking to develop instructional materials that are pedagogically relevant, contextually appropriate, and aligned with students' cognitive characteristics in undergraduate physics education.

Limitations and Future Research

Despite the contributions of this study, several limitations should be acknowledged. First, this study employed a descriptive quantitative design, which allows for the identification of students' critical thinking skills profiles and instructional material needs but does not examine the effectiveness of specific instructional interventions. As a result, causal relationships between instructional materials and learning outcomes cannot be established.

Second, the participants were limited to undergraduate students from a single study program, which may restrict the generalizability of the findings to broader contexts or different institutional settings. Variations in curriculum implementation, instructional strategies, and student characteristics across institutions may influence students' critical thinking skills and learning needs.

Third, the instruments used in this study focused on selected indicators of critical thinking skills and students' perceptions of instructional needs. Although these instruments provide valuable insights into students' learning conditions, future studies may consider incorporating additional data sources, such as classroom observations or interviews, to obtain a more comprehensive understanding of learning processes in Particle Dynamics.

Based on these limitations, future research is recommended to extend this study through the design and development of Electronic Student Worksheets integrated with critical thinking skills. Subsequent studies may also examine the validity, practicality, and effectiveness of the developed instructional materials using experimental or quasi-experimental designs. Additionally, future research could explore the implementation of such materials in different physics topics or educational contexts to further strengthen the generalizability of the findings.

Conclusion

This study concludes that undergraduate students' critical thinking skills in Particle Dynamics remain at a low level across all assessed indicators, including interpretation, analysis, evaluation, explanation, and inference. The average scores for these indicators range from 35 to 39, with analysis and inference identified as the weakest aspects. These findings indicate that students experience difficulties in analyzing physical problems and drawing logical conclusions based on conceptual understanding. The results of the needs analysis further reveal that all indicators related to instructional material development fall within the "Needed" category, with percentages ranging from 61% to 80%. The highest level of need is observed in the use of learning media, supported by students' high level of digital engagement. This condition indicates that the integration of digital learning resources has strong potential to support physics instruction in higher education, particularly in facilitating structured learning activities that can train students' critical thinking processes in solving Particle Dynamics problems. From a practical perspective, these findings suggest that physics instruction at the undergraduate level requires learning materials that not only present conceptual explanations but also guide students through systematic stages of critical thinking, such as interpreting problems, analyzing relationships between variables, evaluating possible solutions, and drawing logical conclusions. Electronic Student Worksheets integrated with critical thinking skills can therefore serve as an alternative digital learning resource to support more interactive and higher-order thinking–oriented physics learning. This study contributes to the field of physics education by providing empirical evidence regarding students' critical thinking skills profiles and their learning material needs as a foundation for the development of digital-based instructional resources. The results provide important guidance for the design of critical thinking–integrated Electronic Student Worksheets in Particle Dynamics learning. Future research is recommended to focus on the development, validation, and experimental testing of Electronic Student Worksheets integrated with critical thinking skills to examine their effectiveness in improving students' conceptual understanding and higher-order thinking abilities in basic physics courses.

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