Vol 12 No 1 2026 DOI : https://doi.org/10.24036/jppf.v12i1.44 Page : 24-33
JURNAL PENELITIAN PEMBELAJARAN FISIKA (JPPF)
Journal of Physics Learning Research
ISSN 2252-3014 (Print) | ISSN 2746-8445 (Electronic)

Design and Validity of Electronic Assessment to Assess Students' Critical Thinking Abilities on Rectilinear Motion Topic

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ARTICLE INFORMATION

Received : 2026-02-11
Revised : 2026-03-31
Accepted : 2026-03-31

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KEYWORDS :

Design and Validity, Electronic Assessments, Critical Thinking, Rectilinear Motion

ABSTRACT

Learning in the 21st century must include 4C skills, including critical thinking skills, especially in physics learning. Students' critical thinking skills need to be assessed to prepare them for the 21st century. Assessment instruments that specifically evaluate students' critical thinking skills on linear motion material are not yet available. Therefore, this study aims to develop a valid electronic assessment to evaluate students' critical thinking skills on linear motion material. This research is a development study (R&D) using the Plomp model. The data collection instruments used were interview sheets, self-evaluation sheets, and validation sheets. The electronic assessment developed was validated by three validators. Electronic assessment has a high validity category in terms of content, learning design, visual communication, and software usage, according to the validity analysis results. Based on the validation results with an average score of 0.85, it indicates that the electronic assessment used to evaluate students' critical thinking skills on the topic of linear motion is considered valid and suitable for use for use in assessing students' critical thinking skills.

INTRODUCTION

Education in the 21st century, also known as the era of the industrial revolution 4.0, goes hand in hand with the use of digital technology and 21st-century learning skills. The 21st-century skills, or 4Cs, include creative thinking, critical thinking and problem solving, communication, and collaboration (Partono et al., 2021). Critical thinking is a 21st-century skill that plays a crucial role in education. Critical thinking involves the ability to analyze, evaluate, and synthesize information, as well as make decisions based on evidence and logic (Amelia & Chusni, 2024; Azizah & Hidayat, 2024). Mastering these skills makes students better prepared to face the rapidly changing times. Therefore, students are required to master these skills, especially in the field of education.

Critical thinking abilities are one of the 21st-century abilities that play an important role in education. Critical thinking is crucial in preparing students to solve problems, explain reasons, and evaluate information. Students who think critically can analyze data or information in a systematic manner based on logic when investigating data or facts. People

who think critically do not simply accept statements as true just because they are consider true (Savitri & Kholiq, 2023). The current Merdeka Curriculum focuses on the development of 21st-century competencies, which include critical thinking, problem-solving, effective communication, and collaboration in various learning contexts. Putri et al. (2025) stated that the Merdeka Curriculum implemented in Indonesia is a strategic step to enhance learning effectiveness through a more meaningful, adaptive, and student-centered process. This curriculum is designed to equip students with various essential skills covering cognitive, affective, and psychomotor domains, thereby promoting the improvement of both the learning process and its outcomes. Therefore, critical thinking needs to be cultivated in school learning, including in physics lessons.

Critical thinking abilities play an important role in learning physics, particularly in the topic of rectilinear motion. In the topic of rectilinear motion, critical thinking skills help students understand basic concepts, such as velocity, acceleration, and the relationships between various kinematic variables. Through critical thinking, students can identify problems, formulate hypotheses, and conduct data analysis to reach valid conclusions. Moreover, critical thinking allows students to evaluate experimental results and relate them to existing theories, thereby deepening their conceptual understanding (Fitriah et al., 2021).
Students' critical thinking abilities can be measured using assessments. Critical thinking can be practiced during the educational process. To assess critical thinking skills, a learning assessment is needed. Learning assessment is one of the elements used to obtain data about the quality of students. In the process of learning, assessment is often carried out by teachers to provide a variety of continuous and comprehensive information about the processes and results that students have achieved (Octaviawati et al., 2025). With the advancement of technology, conventional assessments have begun to transform into e-assessments, which convert printed evaluation sheets into a more interactive electronic version (Alruwais, 2021). Assessment is a systematic, planned, and ongoing process of collecting, analyzing, and interpreting information about students' learning progress to make appropriate decisions based on established criteria and considerations (Ramdani et al., 2025).

Assessments are conducted to find evidence or evidence-based considerations regarding the achievement of learning objectives (Anggreaena et al., 2022). Assessments that adhere to principles including validity, reliability, and practicality need to be developed so that the results can provide an accurate picture of student abilities (Arta, 2024). Therefore, good assessments can be used to assess students' critical thinking skills.

Researchers have conducted an initial study that included interviews with teachers, curriculum analysis, and document analysis at SMAN 6 Padang, as well as a literature review. The results of interviews conducted with three physics teachers at SMAN 6 Padang showed that the teachers understood the importance of critical thinking abilities as one of the abilities that students should have in 21st-century learning. Regarding current assessment practices, teachers have indeed utilized technology such as Quizizz; however, the assessments used in physics learning today are not specifically designed to evaluate students' critical thinking abilities. The assessments used mainly focus on gauging students' perceptions of learning, rather than directly testing critical thinking abilities.

Several studies have shown that students' critical thinking skills are still classified as moderate to low. Research by Asniar et al. (2022) showed that the average score for students' critical thinking skills in solving physics problems was in the low category, at 53.6%. Research by Amelia & Chusni (2024) showed that the majority of students had low critical thinking skills, at 24.2%. Low critical thinking skills are caused by several factors, including students' tendency to memorize material and formulas rather than understand concepts (Arif et al., 2019). Therefore, students' low critical thinking skills can be stimulated by providing higher-order thinking problems.

Based on the interview results, one factor for the absence of critical thinking assessments is that teachers face difficulties in creating questions based on indicators of critical thinking abilities. The findings from the interviews are in line with the results of the document analysis of the rectilinear motion assessment questions used in that school. The analysis of the three assessment questions used by the teacher found that the questions are still considered unsuitable for assessing students' critical thinking abilities according to Ennis (2011) indicators.

Based on previous research, a test instrument based on Higher Order Thinking Abilities (HOTS) has been developed to measure students' critical thinking abilities. The research produced questions that are valid and reliable, and have been tried out on a number of students. However, the developed instrument is still conventional or paper- based, and has not yet utilized digital technology as a more practical and interactive assessment medium (Jesika, 2024). This indicates the need to develop assessments that are not only capable of evaluating critical thinking abilities more comprehensively but also utilize digital technology as an assessment medium. Thus, the development of electronic assessments to evaluate students' critical thinking abilities on the topic of Rectilinear Motion becomes very important to improve the quality of learning evaluation and support a more effective and efficient learning process.

This study aims to analyze the content validity of an electronic assessment to assess students' critical thinking skills in linear motion. This research is expected to produce effective assessments and provide an accurate picture of students' critical thinking abilities. Furthermore, the results are expected to assist teachers in implementing more optimal assessments. This research can encourage students to be more active and reflective in understanding linear motion.

METHODS

This study applies a design research method aimed at producing and testing the validity of a product. The framework used refers to Plomp's (2013) development model, which theoretically consists of three phases: preliminary research, prototyping phase, and assessment phase. However, this study is limited to the prototype development and expert testing stages. The process begins with a needs analysis to identify teachers' challenges in assessing students' critical thinking abilities on rectilinear motion material, which is then followed up with a literature review to formulate an appropriate solution.

The needs analysis in this study was conducted through a qualitative approach, involving interviews with three physics teachers at SMAN 6 Padang to explore the implementation of critical thinking skills assessment. To strengthen the data, this analysis was supported by relevant literature studies. In the prototype phase, the researcher designed, evaluated, and revised the electronic assessment instruments iteratively to ensure product quality. This process included self-formative evaluation as well as the use of self- assessment sheets and expert validation. The final development stage involved validation by three expert lecturers in the fields of assessment, learning, and physics learning media to ensure the product's feasibility.

In accordance with research procedures, validation was conducted with three experts, namely three physics education lecturers from UNP. Data obtained from this stage consisted of quantitative (assessment scores) and qualitative (comments and suggestions) data using a validation instrument sheet. This instrument sheet consisted of an assessment questionnaire addressed to the three experts (dosage) to measure content validity. The questionnaire used a Likert scale of 1-5 (strongly disagree - strongly agree) to assess the product's feasibility. The

expert assessment covered key aspects: material substance, learning design, visual communication, and software utilization.

The evaluation of the validity of this electronic assessment instrument was analyzed quantitatively using the V Aiken formula. The product validation process was conducted by referring to four main elements according to the guidelines for creating ICT-based teaching materials from the Ministry of Education and Culture (2010), which include content aspects, learning design, visual communication, and software aspects (Sungkowo, 2010). The data collection instrument used was a validity questionnaire with a Likert scale model weighted from 1 to 5, where a score of 1 represents the 'strongly disagree' category and a score of 5 represents 'strongly agree'. Based on calculations using the Aiken formula, the validity test results were as follows:

$$V = \sum s \, [n(c-1)]$$

$$s = r - l_0$$

Information:
V = Validity index
lo = The lowest validity rating number (in this case = 1)
c = The highest validity rating number (in this case = 5)
r = The number given by the validator
n = Number of validators
$\sum s$ = Sum of all s scores from all validators

The category of the index value is determined when the rater agreement index has been obtained. The outcomes of the Aiken's V Index-based category determination are shown in Table 1 (Retnawati, 2016).

Table 1. Decision categories following Aiken's V scal

Interval	Valid Category
< 0,4	Low
0,4 ≤ V ≤ 0,8	Medium
> 0,8	High

RESULTS AND DISCUSSION

Results

Preliminary Research

In the preliminary research phase, a needs analysis was conducted to map the actual conditions regarding the assessment of students' critical thinking skills in physics learning, particularly on the topic of linear motion. A needs analysis aims to identify fundamental problems in school learning, thereby addressing the gap between the desired and current state. This analysis will facilitate researchers in developing products to address learning issues. The needs analysis was conducted at SMA N 6 Padang with two physics teachers.

Interview results revealed the importance of critical thinking skills. The instruments used by teachers to assess students' critical thinking skills did not fully meet the critical thinking indicators. The questions given to students by teachers to assess their critical thinking skills consisted of calculation problems, direct questions, and questionnaires that

focused more on student perceptions. Teachers faced challenges in developing critical thinking assessments. An analysis of the assessment questions provided by teachers to students was conducted by comparing them with the critical thinking indicators. Based on the analysis, it was found that the questions used by teachers at school did not include critical thinking indicators. The results of this analysis were used as considerations in the development of electronic assessments to assess students' critical thinking skills.

This stage is carried out after identifying the problem that needs to be solved, then a product is designed to determine the appropriate solution. A literature review was conducted on electronic assessments, critical thinking skills, and linear motion material. Various references were used in designing the electronic assessment to assess students' critical thinking skills in the linear motion material. The literature review demonstrated the importance of students' critical thinking skills. Critical thinking skills can be measured using a critical thinking skills assessment. Assessments given to students should keep up with current developments, so electronic assessments are suitable for use in creating critical thinking skills assessments.

Development/Prototyping Phase

Based on the analysis in the previous stage, a product prototype was created in the form of a comprehensive electronic assessment package to evaluate students' critical thinking skills on the topic of Linear Motion. Substantially, this assessment is designed based on Ennis' (2011) critical thinking ability theory, with a focus on summative assessment. The implementation of the product in electronic format through software files, Google Sites, and Wizer.me also supports efficiency and flexibility in use, in line with findings on the benefits of technology in assessment (Handayani, 2024). All product components are integrated into a single main portal based on Google Sites to facilitate access for teachers and students. The display of the cover page of the developed assessment portal is presented below.

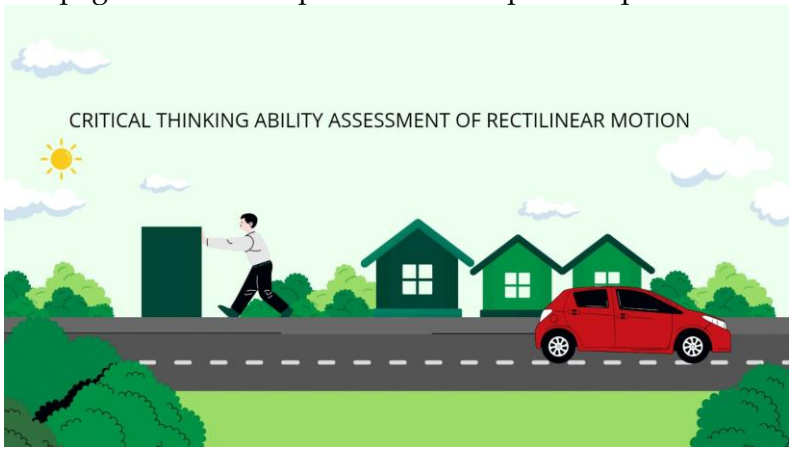

Figure 1. Cover Page of the Assessment Google Site

From the cover page, users are then directed to the main page, which serves as a navigation hub to access the summative assessments and their components. This system integrates all summative assessment components into a Google Sites portal to facilitate teacher access. The portal includes a Wizer.me icon to access interactive summative tests, as well as a document icon linking to complete assessment instruments. The summative assessment consists of 20 questions divided into 4 contexts on the topic of Linear Motion, with each context containing 5 questions representing specific critical thinking indicators. This test is conducted through the Wizer.me platform, which includes visual elements such as images. Here is a preview view of the summative assessments on the Wizer.me platform.

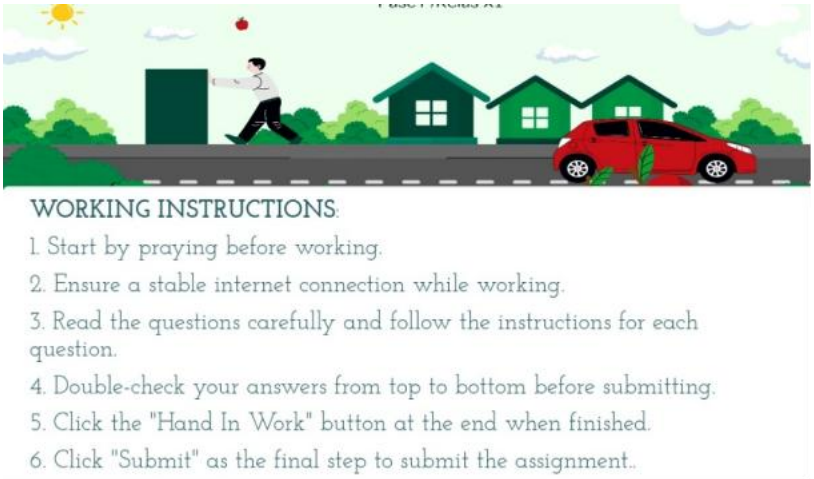

Figure 2. Display of the Summative Assessment on Wizer.me

As we can see, the wizer.me platform is designed to be user-friendly, allowing students to easily complete and submit their answers to each question. These assessments are evaluated through direct observation and final product, and the detailed instrument is provided to teachers as a complete document, not as an interactive platform for students. To provide a more visual illustration, below is the cover page of the developed summative assessment instrument document. Before being submitted to expert validators, the completed prototype first underwent a self-evaluation phase, which involved a thorough review of all assessment components. Once deemed feasible based on the self-evaluation, the prototype proceeded to the expert review phase to test its feasibility through content validity testing. The results of the quantitative analysis for the summative assessment are presented in the following Table 2.

Table 2. Results of the Summative Assessment Validity Analysis

Aspects	V	Category
Content Substance	0.84	High
Learning Design	0.82	High
Visual Communication	0.84	High
Software Utilization	0.86	High
Average	0.85	High

The summative assessment obtained the highest average validity score of 0.85, which falls into the "High" category, confirming its eligibility as an assessment instrument. With the highest average validity score of 0.85, this summative assessment is highly suitable for use. This underscores its strong alignment with the conceptual foundation of critical thinking and its effectiveness in measuring higher-order thinking skills in the context of Linear Motion. This achievement is consistent with previous instrument development research, which also produced valid products, both for assessing conceptual understanding and critical thinking skills.

In addition to providing assessments, validators also provided feedback in the form of input and suggestions. This was done to improve the electronic assessment for assessing critical thinking skills in the Linear Motion material being developed. Details of the responses provided by validators during the validation process can be seen in the following Table 3.

Table 3. Validator's Feedback on the Assessment

Validator	Feedback
Validator 1	1. The instrument display uses too many words and sentences and no formulas are visible in it.
Validator 2	1. The use of software in interactivity (feedback) should be clarified further
Validator 3	1. There are still some typos in the document 2. The operational verbs in the question indicators often do not match the verbs in the learning objectives. 3. Some sentences were found to be less effective

The table above details the responses provided by the validators during the validation process. The validators provided feedback in the form of input and suggestions for improving the electronic assessment for assessing critical thinking skills in the Linear Motion material being developed. This validity is based on the substance of the material, learning design, visual communication, and software utilization. Based on qualitative input from experts presented in the table above, the researchers conducted a series of revisions to refine the prototype.

Discussion

The electronic test in this study was created to evaluate students' critical thinking skills regarding the topic of linear motion. The development of this test involved several stages, including design, validation, and implementation, to ensure that the test accurately measures students' analytical and reasoning abilities (Plomp & Nieveen, 2013; Dirman & Mufit, 2022). This discussion will cover the research findings obtained from each stage of the study, highlighting strengths and areas that need improvement identified during the process. The following is a description of the discussion explaining how electronic assessment contributes to effective learning evaluation.

In the preliminary research phase, a needs analysis was conducted to map the actual conditions regarding the assessment of students' critical thinking skills in physics learning, particularly on the topic of linear motion. This identification process includes three crucial components: a literature review, in-depth interviews with educational practitioners (teachers), and an analysis of the assessment documents used in schools. This step aims to measure the extent to which critical thinking skills have been integrated into assessments, while also exploring the availability of electronic-based assessment instruments in the school environment.

The preliminary research phase is the initial stage of this study, aimed at identifying problems and needs in the field as a basis for product development. The results of the preliminary research systematically reveal a significant gap between the importance of critical thinking skills emphasized by the curriculum and the assessment practices in the field. The preliminary research began with an analysis of the curriculum and materials to identify the policy and conceptual foundation for assessment development. This analysis shows a strong alignment between the general goals of the curriculum and specific learning outcomes, which explicitly require students to develop critical thinking skills, especially in the context of linear motion for design and engineering. In addition, it is also confirmed that linear motion is a highly relevant and strategic topic, as it provides a rich context for application in authentic problems and serves as an ideal space for applying critical thinking.

These findings provide a strong basis for the assessment. The research then proceeded with an analysis of interviews with three physics teachers from SMAN 6 Padang. They emphasized the importance of critical thinking but admitted that they did not have specific tools to evaluate it. They noted that the digital and paper-based assessments they currently use fail to incorporate critical thinking indicators, with time constraints and the complexity of developing instruments as the main challenges. The next step was a document analysis of exam questions on linear motion used in the school. This analysis showed that none of the reviewed questions provided students with the opportunity to demonstrate critical thinking skills. These questions do not meet the five indicators according to Ennis (2011): Providing simple explanations, building basic skills, drawing conclusions, providing further explanations, and Organizing strategies and tactics. The final stage involves a literature study, which provides a strong conceptual basis for product design. This review emphasizes that critical thinking can be systematically measured using the indicators identified by Ennis (2011). The review also supports the use of electronic assessments due to their efficiency and flexibility, as well as providing the necessary theoretical foundation regarding Linear Motion.

The development phase (prototype phase), there are several stages of research. This assessment has been designed based on the latest CP of the independent curriculum phase F SMA / MA (Kemendikbudristek, 2023) and critical thinking indicators (Ennis, 2011). After designing the electronic assessment of critical thinking on momentum and impulse material, it is continued at the self-evaluation stage. This self-evaluation stage is important in the development stage of electronic assessments such as research conducted by Gunawan & Mufit (2024) which also uses self-evaluation in developing electronic assessments. The results obtained from the self-evaluation were in the good category. Researchers found several errors in the assessment such as typing errors and discourse sentences that were too long and ambiguous. Each error contained in the self- evaluation assessment has been revised and then tested for validity.

The content validity test stage by experts (expert review) for electronic assessment of critical thinking on momentum and impulse material is in the valid category. The summative assessment obtained the highest average validity score of 0.85, which falls into the "High" category, confirming its eligibility as an assessment instrument. With the highest average validity score of 0.85, this summative assessment is highly suitable for use. This underscores its strong alignment with the conceptual foundation of critical thinking and its effectiveness in measuring higher-order thinking skills in the context of Linear Motion. This achievement is consistent with previous instrument development research, which also produced valid products, both for assessing conceptual understanding and critical thinking skills.

The electronic assessment is considered valid for evaluating students' critical thinking skills in terms of material substance, learning design, visual communication, and software use based on validation test findings conducted by three validators. This is because the developed electronic assessment has fulfilled all the necessary aspects in question creation (Gunawan & Mufit, 2024). Developing an electronic assessment to evaluate students' critical thinking skills on the topic of linear motion requires a considerable amount of time to complete the product until it is feasible to use. This study is limited to only one physics topic, namely linear motion. Therefore, it is necessary to develop electronic assessments to evaluate students' critical thinking skills on other topics in physics learning.

CONCLUSION

The electronic assessment of critical thinking on the topic of linear motion is an assessment that consists of five aspects of critical thinking within a single discourse, with each aspect represented by a critical thinking indicator. This electronic assessment was developed using Wizer Me media with the aid of Google Sites, accessible via smartphone in HTML format. The purpose of this electronic test is to evaluate the critical thinking abilities of 11th-grade students regarding the topic of linear motion. The electronic assessment of critical thinking on the topic of linear motion is considered valid in terms of content, instructional design, visual communication, and software utilization, based on expert content validation results. The average score on this assessment is 0.85. This indicates that the developed electronic assessment is suitable for evaluating students' critical thinking skills on the topic of linear motion. Therefore, further research on the practicality and effectiveness of this electronic assessment is highly anticipated. This electronic assessment can also be developed for other physics topics to evaluate students' critical thinking skills.

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