

Received : 30 June 2023
Revised : 18 December 2023
Accepted : 26 December 2023
Online : 30 December 2023
Published: 31 December 2023

DOI: doi.org/10.21009/1.09206

Development of a Two-Tier Diagnostic Test for The Analysis of Momentum and Impulse Learning Difficulties in Students

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Abstract

This study aimed to develop a formation test that also serves as a diagnostic test. The purpose of this product is to determine students' learning difficulty levels. We used a two-step multiple-choice assessment tool to develop this diagnostic test. Because two-step multiple-choice tests help teachers identify learning difficulties that arise in students. The research method used is research and development. This test was developed using the Moodle platform and takes the form of a closed multiple-choice test consisting of 20 questions. Media and materials experts validate diagnostic tests. Based on validation, this developed product can be used as a physics learning assessment tool to measure student learning outcomes and learning difficulties. The aspects of media learning expert is usability, navigation, visuals, product, effectiveness, and content. While, the aspects of material expert are compliance with curriculum, construction, and language. We tested high school students and found that 2 of the 20 questions about the concepts of momentum and impulse were mastered and the remaining 18 were at the level of instrumental understanding and misunderstanding. Therefore, teachers should look for strategies to expand students' conceptual knowledge of dynamics and momentum. Thus, the mastery of the student's concept is whole and thorough.

Keywords: diagnostic test, formative test, impulse and momentum, two tier

INTRODUCTION

Teachers can detect students' learning difficulties through diagnostic tests (Timothy et al. 2023). Diagnostic test execution can also be used as a formative test. However, diagnostic test results can map students' understanding of various concepts. This mapping is useful for teachers to improve their learning so that concepts that have not been understood can be immediately followed up (Bezanilla et al. 2019). Including difficulties in understanding the concepts of momentum and impulse. Students who were hesitant in answering questions about momentum and impulse even answered with signs and emojis (Klieger and Goldsmith 2019). The consistent findings of the research indicate that students

face difficulties in understanding momentum, particularly the relationship between total force, time, and change in momentum (Xu et al. 2020). These difficulties signify signs of fragmented knowledge structure and poor knowledge integration. Some students even "feel capable of doing questions or memorizing questions" (Xu et al. 2020), especially those related to real and everyday life but still answer incorrectly. This is because students see problems preceded by doubt (Swensen et al. 2021).

An alternative assessment that can be developed to measure how confident students are in answering questions is not to use the usual multiple-choice, but to modify the form of multiple-choice questions in a Two-Level Multiple-Choice Test (TTMCT) (Rintayati et al. 2021). It can be concluded that TTMCT is a development of the two tier test. TTMCT can help teachers recognize learning issues in their students. TTMCT is a variant of the multiple-choice form that is included in the objective test type. The developed TTMCT has two levels of questions: the first is the content of the main questions or items with two answer choices, and the second is the reasoning behind the answers given based on the first level (Permana et al. 2022). The existence of reasoning at the second level aims to improve thinking skills and see students' reasoning abilities. TTMCT can be applied as an alternative formative assessment, to assess student understanding, ask students to use higher-order thinking skills in giving reasons at the second level, and identify misconceptions students may have. TTMCT can be used as an insight to create a form of assessment that challenges student knowledge, and provides techniques for assessing student concepts, especially in classroom learning.

The implementation of a two-tier test has proven to be a valuable assessment strategy in gauging students' understanding of complex scientific concepts (Fadzil, Saat and Rafi 2022). This test structure, comprising a question followed by two tiers of responses, allows for a more in-depth examination of students' grasp on both fundamental principles and higher-order thinking skills. The first tier assesses basic knowledge, while the second tier delves into application, analysis, and synthesis. The effectiveness of the two-tier test in providing a comprehensive evaluation aligns with the overarching goal of formative assessment, fostering continual learning improvement. Moreover, the correlation observed between the outcomes of the two-tier test and formative assessments underscores the test's utility as a diagnostic tool, offering valuable insights into students' conceptual understanding and learning progress (Ivanjek et al. 2021).

Formative assessment in tests that serve as diagnostic tests can be developed online (Choi and McClenen 2020), commonly known as electronic formative diagnostic tests. Much of the research on formative diagnostic test assessment focuses on developing statistical models that estimate individual student learning difficulties. The developed formative test refers to a set of cognitive-based diagnostic procedures that demonstrate students' strengths and weaknesses in their knowledge structure and process skills (Xu et al. 2023). There have only been paper and pencil formative tests used as diagnostic tools for learning difficulties so far. Paper Based Test (PBT) correction and classification procedures take longer, especially if only one student completes them. Utilizing Computer Based Tests (CBT) in the administration of formative assessments and diagnostic exams for learning difficulties is one solution to this issue (Dawati et al. 2019). The speed and simplicity of the assessment process are just a couple of the benefits of using computer-integrated assessment. Finally, the teacher stopped examining each answer sheet individually before calculating the grades. However, the software can offer grades, and students can instantly see the grades received along with an answer key so that the exact location of the error can be ascertained (Xu et al. 2023). This test also has the potential to decrease student cheating and the use of paper in assessment activities. Students find it challenging to ask other students because the questions on computer-based tests can be randomly and arbitrarily arranged. Additionally, the use of computerized formative assessment in the classroom enables teachers to continuously and more frequently evaluate students' learning (Shin et al. 2022).

Moodle is one piece of software that is openly usable. Based on user experience, Moodle is rated as one of the top 20 LMS (Learning Management Systems) (Poondej and Lerdpornkulrat 2020). An online platform called Moodle can offer exam facilities. Among other features offered by Moodle, this platform allows for the creation of multiple exam question packages, allowing teachers to pick and choose which questions to grade. Randomization of questions and the provision of answer keys to student statistical data are tools that teachers can use to analyze what content students have mastered or not, allowing them to target remedial or enrichment programs (Mutoharoh and Ambarwulan 2021).

We will create diagnostic tests for Moodle-based learning challenges using the Momentum and Impulse material in the first year of high school based on the explanation of the aforementioned issues.

METHODS

The Four-D model (Thiagarajan 1974) is the development research model that is employed, but it only covers the stages of defining, designing, and development, not dissemination. field trials, media learning, and expert validation of materials during the development stage. The three steps are described in the following way:

Define

Analyzing potential and issues is the first step in creating a formative and diagnostic test based on Moodle. Using techniques for interviewing physics teachers and pertinent research, analyze potential issues. A literature review was also conducted at this time to evaluate the proficiency of first-grade high school students. The acquired competencies examine how forces interact and how mass, force, and motion of objects moving straight ahead are related. Learning outcomes in the form of created tests, question formats, answer categories, question count, and scoring methods.

Design

We will determine from the data gathered related to the problem analysis what form is required in developing products to aid teachers in the assessment process. Making a test instrument that generates question indicators is the first step. The Moodle learning platform is utilized in the second stage of media selection. The third step is to use Moodle to create a storyboard test design.

Develop

The creation of test instrument products is the goal of the development stage. Twenty questions with five answer options were created using the question indicator. The development of question indicators takes the form of closed multiple choice. The cognitive levels and the indicators in TABLE 1 are based on Bloom's revised taxonomy (Anderson and Krathwohl 2021). The levels of taxonomy that are used are C1: remember, C2: understand, C3: apply, C4: analyze, and C5: evaluate.

TABLE 1. The indicator of question and cognitive level

No.	Indicator of Competency Achievement	Number Question	Cognitive Level (Question Number)
1.	Understand the concepts of impulse and momentum	4	C1 (1, 2), C2 (3), C4 (4)
2.	Determine the magnitude of the impulse and momentum of an object	4	C3 (5, 7, 8), C4 (6)
3.	Determine the magnitude of the coefficient of restitution on the object	3	C2 (9), C4 (10), C5 (11)
4.	Solving problems related to the relationship between impulse and momentum	3	C4 (12), C5 (13, 14)
5.	Integrate the law of conservation of energy and conservation of momentum for events collision	3	C2 (15), C3 (16), C4 (17)
6.	Analyze the concept of momentum and impulse to solve problems in life.	3	C2 (18), C4 (19), C3 (20)

The product will go through the assessment stage of learning media experts and material experts. While expert validation of content includes aspects of conformity with curriculum, construction, and language use, expert validation of learning media includes aspects of usability, visuals, and content. These professional validation tests also involve product revisions. Additionally, only teachers and students will be allowed to test the revised product in the field. These products are rated from one to five, with one denoting very low viability, two denoting low viability, three denoting sufficient

viability, four denoting viability, and five denoting high viability. After grouping the interpretation classes listed in TABLE 2, the results of this assessment will be interpreted using Equation 1's calculation. The results of the TTMCT are displayed in TABLE 3.

$$\bar{X} = \frac{\sum \text{question score}}{\sum \text{max score}} \times 100\% \tag{1}$$

TABLE 2. Interpretation of Likert scale

Percentage	Interpretation
$\bar{X} > 84\%$	Very Feasible
$68\% < \bar{X} \leq 84\%$	Feasible
$52\% < \bar{X} \leq 68\%$	Enough
$36\% < \bar{X} \leq 52\%$	Not Feasible
$\bar{X} \leq 36\%$	Very Not Feasible

Note : \bar{X} = interpreted score average

TABLE 3. Scoring TTMCT (Rintayati et al. 2021)

First-tier (answer)	Second-tier (Reason)	Score
Correct	Correct	3
Correct	Incorrect	2
Incorrect	Correct	1
Incorrect	Incorrect	0

RESULTS AND DISCUSSION

The product created in this study is a formative assessment that serves as a diagnostic tool for learning disabilities based on Moodle. It can be used to gauge students' learning capacities and identify areas where they may struggle. The Electronic Formative-Diagnostic Test, or E-FDTEST, is the name given to this Moodle test. FIGURE 1 depicts the registration page for E-FDTEST.

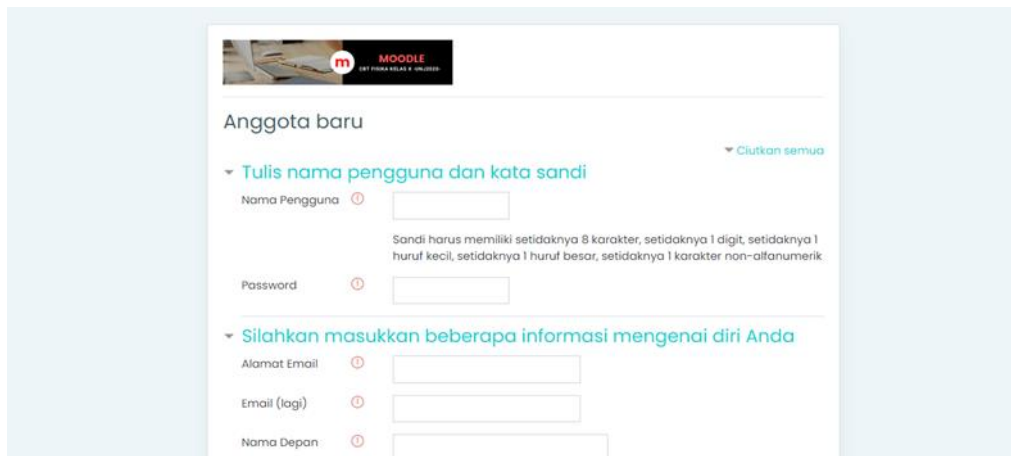


FIGURE 1. Registration page of the E-FDTEST

The position of the formative test functions as a diagnostic test comparable to a daily test. However, this research focuses on creating assessment tools to identify students' learning challenges. The scope of TTMCT material includes:

1. The concept of impulse and momentum on an object
2. Coefficient of restitution on objects
3. Problems related to the relationship between impulse and momentum
4. Energy Conservation Law and Momentum Conservation Law
5. Various collision

TTMCT, a diagnostic test based on Moodle, can be used on desktops, laptops, and mobile devices with internet access. This tool can be randomized and can present multiple questions in one package. Participants receive technical instructions on how to carry out TTMCT before beginning (FIGURE 2). Additionally, after passing TTMCT, feedback in the form of discussion for each item will be displayed on the test's final page in an effort to help students comprehend the concepts examined.

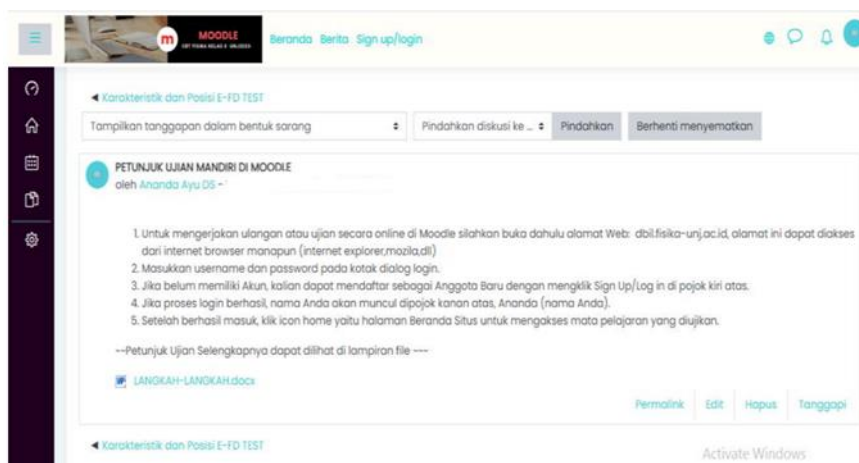


FIGURE 2. Technical instructions for students before starting TTMCT

Learning media and material experts have verified the developed products. The very feasible category is represented by the average score of 92.11% from learning experts. Regarding media, it can be said that it is practical as a tool for formative assessment and a diagnostic of academic difficulties in students. While the category of "very feasible" is included in the material experts' average score of 95.86%. There are some expert recommendations, many concepts are still missing, and the image illustrations are improved. TABLE 4 summarizes the verification of learning and content experts. The TTMCT product was altered by team after consulting with experts. Additionally, a small field trial of the updated product with teachers and students was conducted.

TABLE 4. Validation Result

No.	Validation	Aspect	Percentage	Interpretation
1.	Media experts	Usability	90	Very Feasible
2.		Navigation	100	Very Feasible
3.		Visuals	95.58	Very Feasible
4.		Product Effectiveness	75	Feasible
5.		Content	100	Very Feasible
Average			92.11	Very Feasible
1.	Material Experts	Compliance with curriculum	100	Very Feasible
2.		Construction	87.79	Very Feasible
3.		Language	100	Very Feasible
Average			95.86	Very Feasible

The results of the analysis of cross-material student learning difficulties show that students with this type of learning difficulty are divided into three categories: understanding, instrumental understanding, and not understanding concepts. indicates that it is classified as See the three-level assessment format shown in TABLE 4. At the time students were tested, two of the 20 questions represented a level of understanding of the concept with a level understanding of concepts of momentum and impulse. The other 18 questions demonstrate students' comprehension at the level of misunderstanding and instrumental understanding.

This learning difficulty is caused by difficulty understanding momentum and impulse concepts. Based on other studies, solutions to overcome difficulties in understanding the concepts of momentum and impulse can be done by developing appropriate learning media such as developing interactive handouts (Pahlawan 2021) or e-modules with problem-solving strategies (Syarlisjswan and Wahyuningsih 2021) that will be able to improve science literacy and higher-order thinking skills (Putranta 2019). However, because this research has not yet reached the dissemination stage, it is hoped

that the developed TTMCT can be disseminated and continued to test the effectiveness of products developed for physics students and teachers at the high school level.

In moving forward, the widespread utilization of this product warrants future studies to assess its effectiveness among high school students and physics teachers. Additionally, teachers are encouraged to employ effective communication strategies to address and rectify misunderstood concepts, ensuring a comprehensive understanding among students who encounter difficulties. This follow-up process is crucial for reinforcing conceptual knowledge and promoting thorough mastery among students.

CONCLUSION

In conclusion, the developed product, a dual-purpose formation and diagnostic test, stands validated for its utility as a physics learning assessment tool to evaluate both student learning outcomes and challenges. The assessment tool, employing the Two-Step Multiple-Choice Test (TTMCT) on the Moodle platform, underwent meticulous validation by experts in learning media and materials. Learning media experts focused on usability, navigation, visuals, product effectiveness, and content, while material experts scrutinized compliance with the curriculum, construction, and language. Validation results indicated a high feasibility, with learning media experts scoring an average of 92.11% and material experts achieving an average of 95.86%, both falling within the very feasible category. The assessment tool identified specific learning difficulties related to the concepts of momentum and impulse, revealing that 2 out of the 20 questions were mastered, while the remaining 18 reflected instrumental understanding and misunderstanding among 10th-grade students.

ACKNOWLEDGMENT

The author would like to thank Universitas Negeri Jakarta for funding this research with contract number: 61/SPK RESEARCH/5.FMIPA/2023.

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