Jurnal Teknologi Pendidikan, April 2026, 28 (1), 113-131
DOI: http://dx.doi.org/10.21009/JTP2001.6
p-ISSN: 1411-2744 e-ISSN: 2620-3081
Accredited by Directorate General of Strengthening for Research and Development
Available online at http://journal.unj.ac.id/unj/index.php/jtp

Development of a Google Forms-Based Five-Tier Diagnostic Test for Identifying Misconceptions in Modern Physics

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Received : January 28, 2026
Revised : February 3, 2026
Accepted : April 10, 2026

Abstract
Misconceptions in modern physics concepts such as X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interactions remain prevalent among students and are difficult to detect using conventional assessments. This study aims to develop and implement a Five-Tier diagnostic instrument based on Google Forms to identify students' misconceptions in modern physics learning. The study employed a Research and Development (R&D) approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The instrument was validated by subject matter and evaluation experts and tested on 14 students and two physics education lecturers. Data were collected through validation sheets, lecturer response questionnaires, instrument practicality questionnaires, and Five-Tier diagnostic tests. Data analysis was conducted descriptively and quantitatively using content validity analysis, empirical validity testing, Cronbach's Alpha reliability testing, and percentage analysis. The results indicate that the instrument has very high content validity (CVL = 1.00; IRA = 1.00), adequate empirical validity and reliability (α = 0.54–0.64), and a very high level of practicality, as reflected by lecturer responses (92.50%) and instrument practicality (90.5%). The implementation results reveal that students' misconceptions are most dominant in the Compton effect and pair production topics. Therefore, the developed Five-Tier diagnostic instrument is feasible and effective as a digital diagnostic assessment in modern physics learning and can serve as a practical reference for future development of technology-based diagnostic instruments.

Keywords: Five-Tier diagnostic test; misconceptions; modern physics; Google Forms; ADDIE model

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How to Cite: Winarni, S., Asnidar, V., Halim, A., Nurulwati, Musdar, & Ramadhan, T. M. H. (2026). Development of a Google Forms-Based Five-Tier Diagnostic Test for Identifying Misconceptions in Modern Physics. *JTP - Jurnal Teknologi Pendidikan*, *28*(1), 113–131. https://doi.org/10.21009/jtp.v28i1.66006

INTRODUCTION

Modern physics is a fundamental component of physics education that plays a crucial role in developing students' understanding of microscopic phenomena and contemporary technological advancements. Unlike classical physics, whose concepts are largely observable through everyday experiences, modern physics requires abstract reasoning, mathematical formalism, and the use of conceptual models that are not directly observable (Kaltakci-Gurel & Eryilmaz, 2017; Gurel et al., 2015; Rokhim et al., 2023; Kartal & Bakaç, 2016; Steinberg et al., 2020). Core topics such as X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interactions are grounded in principles of energy quantization and wave–particle duality, which often conflict with students' prior intuitions. As a result, students frequently experience difficulties in developing a coherent and meaningful conceptual understanding, particularly when instruction emphasizes mathematical derivations without sufficient attention to underlying physical interpretations (Berek et al., 2016; Singh & Marshman, 2018; Docktor & Mestre, 2014; Steinberg & Sabella, 2017).

These conceptual challenges contribute directly to the persistence of misconceptions among students. Numerous studies report that physics education students continue to exhibit misconceptions in modern physics despite having completed formal coursework. Such misconceptions are not isolated but are distributed across interconnected topics, including photon energy and momentum, radiation–matter interactions, and particle–antiparticle pair production processes (Mubarak et al., 2020; Nugroho et al., 2021; Friska et al., 2023; Widodo et al., 2020; Kurniawan et al., 2021). This evidence indicates that modern physics instruction in higher education still faces significant challenges in fostering scientifically accurate and conceptually integrated understanding.

Misconceptions in physics learning extend beyond incorrect answers; they involve alternative conceptions that students strongly believe to be correct and that are resistant to conventional instruction (Yusup, 2018; Kaniawati et al., 2019; Fitriani et al., 2020). When misconceptions are not identified early, they tend to persist and interfere with the acquisition of more advanced concepts. This issue is particularly critical in modern physics, where conceptual understanding is hierarchical and interdependent. Misunderstandings of fundamental concepts—such as the nature of photons or radiation–matter interactions—can hinder comprehension of advanced topics like the Compton effect, pair production, and photon–gravity relationships (Anam et al., 2019; Sari et al., 2022; Rahmawati & Subali, 2021).

Various methods have been employed to identify student misconceptions, including clinical interviews, concept mapping, and diagnostic tests. While interviews and concept maps allow for in-depth exploration of student thinking, they are time-consuming and impractical for large-scale implementation. Diagnostic tests, by contrast, offer greater efficiency and enable systematic identification of students' conceptual understanding across large populations (Widodo et al., 2020; Kaltakci-Gurel, 2018; Hasyim et al., 2021). In line with advancements in physics education research, diagnostic assessments have evolved from single-tier formats to multi-tier instruments that provide richer diagnostic information.

Among these, the Five-Tier diagnostic test represents an advanced approach designed to capture students' understanding comprehensively. Beyond assessing answer correctness, the Five-Tier structure examines conceptual reasoning, confidence levels in both answers and reasoning, and the sources of students' knowledge construction (Caleon & Subramaniam, 2010; Anam et al., 2019; Mubarak et al., 2020; Rokhim et al., 2023; Kurniawati et al., 2022). This structure enables more accurate differentiation between genuine understanding, guessing, and deeply rooted misconceptions.

However, conventional paper-based diagnostic tests present several limitations, including inefficient data processing, susceptibility to scoring errors, and limited feedback speed for both lecturers and students (Putri & Suparman, 2021; Yulianti & Hartono, 2022; Fatonah, 2022; Pratiwi et al., 2020). These constraints reduce the effectiveness of diagnostic assessments as tools for improving instruction. Advances in digital technology provide opportunities to address these limitations through online assessment platforms that facilitate efficient data collection, automated analysis, and rapid feedback (Susanti et al., 2021; Handayani et al., 2022).

The use of Google Forms for developing diagnostic instruments aligns with the Technological Pedagogical and Content Knowledge (TPACK) framework, which emphasizes the integration of content knowledge, pedagogy, and technology in science education (Chai et al., 2019; Valtonen et al., 2020; Yusop & Sumintono, 2021). Technology-enhanced assessments not only improve efficiency but also enhance the depth and quality of diagnostic information obtained from student responses. Nevertheless, studies focusing on Google Forms–based Five-Tier diagnostic instruments specifically designed for modern physics topics at the higher education level remain limited, highlighting a clear research gap.

Despite the recognized effectiveness of Five-Tier diagnostic tests in identifying misconceptions, there is a lack of technology-based Five-Tier instruments specifically developed for modern physics learning in higher education that are valid, practical, and empirically tested.

This study aims to develop, validate, and implement a Google Forms–based Five-Tier diagnostic instrument to identify students' misconceptions in modern physics and to evaluate its validity, reliability, and practicality in higher education contexts.

The novelty of this research lies in: (1) the integration of the Five-Tier diagnostic structure with the Google Forms platform, which has not been widely implemented; (2) a specific focus on modern physics topics in higher education; (3) comprehensive expert validation and empirical testing; and (4) the ability of the multi-tier structure to visualize students' intellectual reasoning processes and sources of misconceptions.

METHODS

Type and Design of Research

This study employed a Research and Development (R&D) approach aimed at developing a Five-Tier diagnostic instrument based on Google Form to identify university students' misconceptions in modern physics concepts. The development model used in this study was the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The ADDIE model was selected because it provides a systematic and structured development process suitable for educational assessment instruments, allowing the product to be validated, tested, and revised before implementation (Aldoobie, 2015; Molenda, 2015; McKenney & Reeves, 2019).

Time and Place of Research

This research was conducted during the odd semester of the 2025/2026 academic year, specifically from November 26 to December 15, 2025**.** The research was carried out at the Physics Education Study Program, Universitas Syiah Kuala, Banda Aceh**.**

Research Subjects and Sampling Technique

The research subjects consisted of lecturers and university students. Two Physics Education lecturers were involved in this study with dual roles: as expert validators to evaluate the instrument in terms of content validity, construct validity, and language clarity, and as respondents to the practicality questionnaire to assess the usability and practicality of the developed instrument from an expert user perspective.

The subjects of the limited trial were 14 students of the Physics Education Study Program who had completed the Modern Physics course. The subjects in the implementation stage consisted of 23 Physics Education students selected using a purposive sampling technique, with the criterion that the students had studied modern physics topics relevant to the developed instrument. Purposive sampling was applied to ensure that the selected participants were appropriate for diagnosing conceptual understanding and misconceptions (Creswell & Creswell, 2018; Anam et al., 2019).

All participants voluntarily took part in this study after being informed about the research objectives and procedures. Informed consent was obtained prior to participation. Participants' identities were anonymized, and all data were kept confidential and used solely for research purposes. Participants were informed that they could withdraw from the study at any time without any academic consequences.

Research Ethics

This study adhered to ethical research principles involving human participants. Prior to data collection, all participants were informed about the purpose of the study, research procedures, and their voluntary participation. Informed consent was obtained from all participants before they completed the diagnostic test and questionnaires. Participants' identities were kept anonymous, and all collected data were treated confidentially and used solely for research purposes. Participants were also informed that they could withdraw from the study at any time without any academic consequences.

Research Procedure

The research procedure followed the stages of the ADDIE development model as described below.

Analysis stage

At this stage, a needs analysis was conducted through a literature review, analysis of the Modern Physics course learning outcomes, and interviews with course lecturers. This stage aimed to identify modern physics concepts that are prone to students' misconceptions, including X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interaction (Kaltakci-Gurel, 2018; Mubarak et al., 2020).

Design stage

The design stage involved constructing a test blueprint and indicators of conceptual understanding based on the identified modern physics concepts. At this stage, the Five-Tier diagnostic test structure was designed, consisting of conceptual answers, confidence levels, conceptual reasoning, confidence in reasoning, and sources of understanding. This multi-tier structure enables a more comprehensive diagnosis of students' understanding compared to single-tier tests (Caleon & Subramaniam, 2016; Anam et al., 2019).

Development stage

During the development stage, the Five-Tier diagnostic instrument was developed in the form of a Google Form. The instrument was then validated by expert lecturers to evaluate content appropriateness, construct accuracy, and clarity of language. Expert validation is essential to ensure the content validity of assessment instruments (Taherdoost, 2016). Revisions were made based on the validators' feedback. The revised instrument was subsequently tested in a limited trial involving 14 students to obtain empirical validity, reliability, and practicality data (Rusilowati, 2015).

Implementation stage

In the implementation stage, the revised Five-Tier diagnostic instrument was administered to 23 Physics Education students using Google Form. The use of Google Form facilitated efficient online assessment, ease of access, and automatic data recording (Putri & Suparman, 2021; Yulianti & Hartono, 2022).

Evaluation stage

The evaluation stage involved analyzing all collected data to assess the quality of the developed instrument in terms of validity, reliability, practicality, and effectiveness in identifying students' misconceptions (McKenney & Reeves, 2019).

Research Instruments

The primary instrument used in this study was a Five-Tier diagnostic test developed for modern physics topics, including X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interaction. The Five-Tier structure consists of five levels: (1) conceptual answer, (2) confidence in the answer, (3) conceptual reasoning, (4) confidence in the reasoning, and (5) source of understanding. This structure allows for detailed identification of students' conceptual understanding and misconceptions (Anam et al., 2019; Rokhim et al., 2023). In addition to the diagnostic test**,** lecturer and student response questionnaires were used to evaluate the practicality of the developed instrument.

Data Collection Techniques

Data were collected through expert validation sheets, students' responses to the Five-Tier diagnostic test, and practicality questionnaires completed by two lecturers and students**.** All data were collected online using Google Form and automatically recorded in spreadsheet format to facilitate data management and analysis (Putri & Suparman, 20Data Analysis Techniques Data analysis was conducted using descriptive quantitative techniques, as described below.

Validity analysis

Instrument validity was analyzed through two stages: content validity and empirical item validity. Content validity was determined based on expert judgment using percentage analysis (Rusilowati, 2015).

Empirical item validity was analyzed using the point biserial correlation r_{pbis} to determine the discrimination power of each test item (Arikunto, 2018), using the following formula:

$$r_{pbis} = \frac{M_p - M_t}{S_t} \; x \; \sqrt{\frac{p \; x \; q}{1}}$$

Table 1. Instrument validity criteria **(**Rusilowati, 2015)

Percentage (%)	Category
81–100	Very valid
61–80	Valid
41–60	Moderately valid
21–40	Less valid
0–20	Invalid

Reliability analysis

`Instrument reliability was analyzed using Cronbach's Alpha coefficient to determine internal consistency (Hair et al., 2019), calculated using the following formula:

$$\propto = \frac{k}{k-1}\left(1 - \frac{\Sigma\sigma_i^2}{\sigma_i^2}\right)$$

Table 2. Instrument reliability criteria (Hair et al., 2019)

Alpha (α)	Category
≥ 0.80	Very high
0.60–0.79	High
0.40–0.59	Moderate
0.20–0.39	Low
< 0.20	Very low

Practicality analysis

The practicality of the instrument was analyzed based on lecturer and student response questionnaires using a single percentage calculation method for both groups. The practicality percentage was calculated using the following formula (Salsabila & Ermawati, 2020):

$$\text{Practicality}(\%) = \frac{\text{Score obtained}}{\text{Maximum score}} x\ 100\%$$

Table 3. Instrument practicality criteria (Salsabila & Ermawati, 2020)

Percentage (%)	Category
81–100	Very practical
61–80	Practical
41–60	Moderately practical
21–40	Less practical
0–20	Not practical

Misconception analysis

Students' misconceptions were identified based on the combination of answers, reasoning, and confidence levels in the Five-Tier diagnostic test. The percentage of students experiencing misconceptions was calculated using the following formula (Mubarak et al., 2020):

$$\text{Percentage of misconceptions} = \frac{\text{Percentage of misconceptions}}{\text{Total Number Of Students}} x\ 100\%$$

Table 4. Misconception level criteria (Mubarak et al., 2020)

Percentage (%)	Level
0–20	Very low
21–40	Low
41–60	Moderate
61–80	High
81–100	Very high

RESULTS & DISCUSSION

Analysis

The analysis stage was conducted to identify the need for developing a diagnostic instrument in modern physics learning. This stage involved a literature review, analysis of the learning outcomes of the Modern Physics course, and interviews with course lecturers. The results of the analysis indicated that students still experienced difficulties in understanding modern physics concepts that are abstract and microscopic in nature, particularly in topics such as X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interaction.

Students' difficulties were reflected in conceptual errors accompanied by a high level of confidence in incorrect answers, indicating the presence of strong misconceptions. This condition is consistent with the findings of Gurel et al. (2015) and Mubarak et al. (2020), who stated that misconceptions are alternative conceptions that are strongly believed to be correct and tend to persist despite instructional interventions. The analysis also revealed that previously used evaluation instruments were predominantly single-tier tests that only measured correct or incorrect answers. As a result, these instruments were not able to comprehensively reveal students' conceptual reasoning, confidence levels, and sources of understanding (Anam et al., 2019; Rokhim et al., 2023).

Based on these findings, it is necessary to develop a diagnostic instrument that can identify students' misconceptions in a more comprehensive manner. The Five-Tier Diagnostic Test is considered relevant because it is capable of revealing students' conceptual answers, reasoning, confidence levels, and sources of understanding within a single assessment instrument (Anam et al., 2019; Mubarak et al., 2020; Rokhim et al., 2023). In addition, the use of Google Form was selected to support the efficiency of assessment implementation and digital data processing (Putri & Suparman, 2021; Yulianti & Hartono, 2022).

Design

The design stage aimed to develop a Five-Tier diagnostic instrument based on the results of the needs analysis in modern physics learning. At this stage, an instrument blueprint was constructed, and indicators of conceptual understanding were formulated based on the learning outcomes of the Modern Physics course. The designed indicators of conceptual understanding covered topics including X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interaction. These indicators served as the basis for developing diagnostic test items to ensure that each item represented the essential concepts being measured.

The instrument was designed using the Five-Tier Diagnostic Test structure, which consists of five levels: conceptual answer choices, confidence in the answer, conceptual reasoning, confidence in the reasoning, and the source of information used by students. This Five-Tier structure was designed to reveal students' conceptual understanding in greater depth and to distinguish between students who possess scientific understanding, students who answer by guessing, and students who hold misconceptions with high confidence. Compared to single-tier tests, this instrument design enables the collection of more comprehensive diagnostic information (Anam et al., 2019).

In addition to designing the instrument blueprint and structure, the design stage also established the development workflow based on the ADDIE model as the research framework. The adoption of the ADDIE framework aimed to ensure that the instrument development process was conducted systematically and in an integrated manner across the analysis, development, implementation, and evaluation stages. Consequently, the instrument designed at this stage was adequately prepared for further development and testing in subsequent stages (Mayfield, 2016; Peterson, 2018).

Development

The development stage focused on transforming the designed Five-Tier diagnostic instrument into a ready-to-use assessment tool. At this stage, the instrument blueprint and indicators of conceptual understanding in modern physics were developed into Five-Tier diagnostic test items covering topics such as X-rays, the photoelectric effect, the Compton effect, pair production, and photon–gravity interaction. Each test item was constructed in a multiple-choice format accompanied by conceptual reasoning options, confidence levels for both answers and reasoning, and sources of information used by students. This structure enabled the collection of in-depth diagnostic data in accordance with the characteristics of multi-tier diagnostic tests (Dick et al., 2015).

The developed instrument was then transformed into a digital assessment using Google Form. The outcome of this stage was a Five-Tier diagnostic instrument based on Google Form that included all components of the multi-tier test and could be accessed online by students. The use of digital platforms in assessment instrument development facilitates the presentation of test items, the collection of student responses, and automatic data recording, thereby improving the efficiency of assessment implementation (Putri & Suparman, 2021).

Furthermore, Google Form allows Five-Tier test items to be presented in a systematic and sequential manner, enabling students to respond to each tier according to the intended diagnostic thinking process. The use of Google Form in this study offers several advantages, including ease of access for students, flexibility in designing multi-tier test items, automatic recording of response data in spreadsheet format, and ease of integration with statistical analysis. These features make Google Form an effective and efficient medium for implementing a Five-Tier diagnostic assessment.

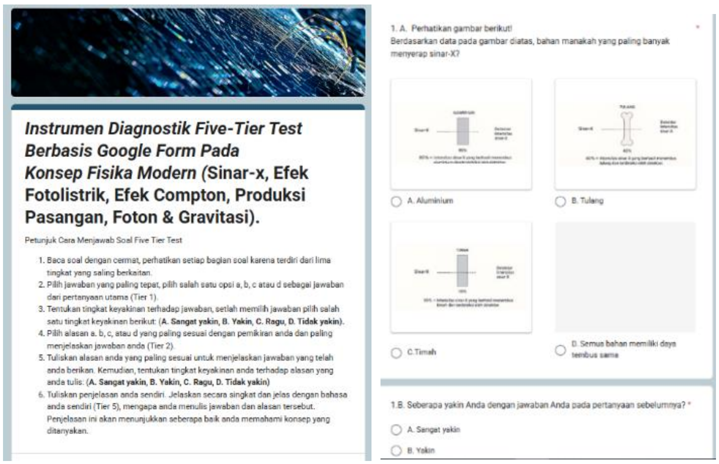


Figure 1. Display of the Google Form–based Five-Tier diagnostic instrument

The developed Five-Tier diagnostic instrument was subsequently validated by two expert lecturers in Physics Education. The validation was conducted to evaluate the alignment of the instrument content with modern physics concepts, the appropriateness of the Five-Tier item construction, and the clarity of language. The validation results indicated that all test items obtained a Content Validity Lawshe (CVL) value of 1.00, demonstrating that all items were considered essential by the validators. In addition, the Inter-Rater Agreement (IRA) analysis yielded a value of 1.00 with a 100% agreement level, which falls into the very high category. These results indicate a very strong level of agreement between the two validators in assessing the feasibility of the developed diagnostic instrument.

Based on the validation results, revisions were made to several test items, particularly in improving the wording and the clarity of conceptual reasoning, resulting in an instrument that was suitable for use in the trial stage. After completing the validation and revision processes, the instrument was subjected to a limited trial involving 14 students of the Physics Education Study Program.

The limited trial aimed to determine the empirical validity, reliability, and practicality of the instrument. Empirical validity testing was conducted using Pearson item–total correlation with the criterion $r_{calculated} \geq r_{tabler}$ at a significance level of $\alpha=0.05$ and a sample size of n=14n = 14n=14, resulting in an r_{tabler} value of 0.532. The analysis showed that under the Tier 1 scoring scheme, six items were valid; under the Tier 1 and Tier 3 scoring scheme, five items were valid; and under the Five-Tier scoring scheme (0–1), five items were valid. Several invalid items were influenced by homogeneous student responses, which served as a basis for item revision during the evaluation stage of development.

Instrument reliability was examined using Cronbach's Alpha coefficient. The results indicated reliability values of 0.6398 for Tier 1, 0.5417 for the Tier 1 and Tier 3 scoring scheme, and 0.5417 for the Five-Tier scoring scheme. These values fall into the moderate category, indicating that the instrument has adequate internal consistency for diagnostic purposes.

Furthermore, during the limited trial stage, student response data were collected through a questionnaire to determine the practicality of the developed instrument. The response questionnaire was administered to 14 students and consisted of 19 statements using a five-point Likert scale. Data analysis was conducted using a percentage formula, calculated as the ratio of the actual score to the maximum possible score multiplied by 100%. The results of the limited trial of the Google Form–based Five-Tier diagnostic instrument indicated that the instrument received very positive responses from both students and lecturers. Student responses regarding the use of the instrument, as presented in Table 5, showed a percentage of 89.13%, which falls into the "strongly agree" category.

Table 5. Student Responses to the Five-Tier Diagnostic Instrument (Limited Trial)

No.	Assessment Aspect	Percentage (%)	Category
1	Ease of use of the instrument	88.39	Strongly agree
2	Clarity of display and instructions	89.73	Strongly agree
3	Readability and clarity of language	89.29	Strongly agree
4	Relevance of the instrument to the learning material	89.11	Strongly agree
5	Helps reveal conceptual understanding	89.14	Strongly agree
	Average	89.13	Strongly agree

These results indicate that students perceived the instrument as easy to use, having a clear display and instructions that were easy to understand. In addition, the multi-tier structure of the Five-Tier instrument was considered helpful in enabling students to express their conceptual understanding, scientific reasoning, and confidence levels in a more systematic manner.

The lecturers' evaluation of the instrument quality, as presented in Table 6**,** yielded a percentage of 92.50%, which falls into the very good category. This result indicates that the developed instrument met the criteria of content relevance, clarity of construction, and alignment with learning objectives.

Table 6. Lecturer Responses to the Quality of the Five-Tier Diagnostic Instrument (Limited Trial)

No.	Assessment Aspect	Percentage (%)	Category
1	Alignment of the instrument with course learning outcomes	93.75	Very good
2	Clarity of instrument construction	92.50	Very good
3	Accuracy of content material	91.25	Very good
	Average	92.50	Very good

Furthermore, the lecturers' evaluation of the instrument practicality, as shown in Table 7**,** resulted in a percentage of 92.50 %**,** which is categorized as very practical. This finding suggests that the instrument is easy to use, well-constructed, and suitable for achieving learning objectives.

Table 7. Lecturer Responses to the Practicality of the Five-Tier Diagnostic Instrument (Limited Trial)

No.	Assessment Aspect	Percentage (%)	Category
1	Ease of use	92.50	Very practical
2	Clarity of instrument construction	93.75	Very practical
3	Alignment with learning objectives	91.25	Very practical
	Average	92.50	Very practical

These findings indicate that the developed instrument is not only conceptually and constructively sound, but also practical for use as a digital diagnostic assessment in modern physics learning. The trial results also show that students were able to complete each tier of the test according to the provided instructions and did not encounter technical difficulties during the Google Form–based administration. Therefore, the developed Five-Tier diagnostic instrument was deemed suitable for use at the implementation stage.

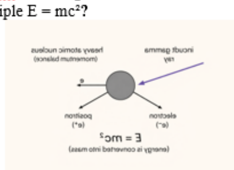
Each Five-Tier test item in the instrument was designed as an intellectual visualization of students' thinking processes**,** systematically mapping conceptual understanding, scientific reasoning, confidence levels, and conceptual synthesis. This multi-tier approach allows for a deeper identification of scientific understanding and misconceptions compared to conventional diagnostic tests (Caleon & Subramaniam, 2010; Kaltakci-Gurel, 2018; Hasyim et al., 2021).

In the X-ray items (material penetration, frequency, and tube voltage), the intellectual visualization was designed to examine how students associate photon energy with material penetration ability. The inter-tier structure was used to evaluate the consistency of students' understanding of the energy–frequency relationship and radiation–matter interactions (Bushberg et al., 2017; Podgorsak, 2016).

In the photoelectric effect and Compton scattering items, the intellectual visualization highlighted the paradigm shift from classical physics to quantum physics, particularly in understanding the role of frequency, work function, and energy and momentum transfer in light–matter interactions. This approach is consistent with studies showing that multi-tier diagnostic tests are effective in revealing misconceptions related to the quantum nature of light and wave–particle duality (Singh & Marshman, 2018; Steinberg & Sabella, 2017).

In the pair production and photon–gravity interaction items, the intellectual visualization was directed at evaluating students' ability to integrate concepts of mass–energy equivalence and general relativity. These items require advanced conceptual understanding, as they connect experimental phenomena with the theoretical framework of modern physics (Carroll, 2019; Schutz, 2015).

1A. The figure below shows an event in which a beam of gamma rays strikes a heavy atomic nucleus and produces two tracks of charged particles moving in opposite directions.Based on the figure, which conclusion best represents the application of the principle $E = mc^2$?



A. The energy of gamma rays is converted into the mass of an electron and a positron
B. The mass of an electron is converted into gamma-ray energy
C. The energy of the atomic nucleus is converted into heat
D. The electron loses energy due to magnetic force

1B. How confident are you in your answer to the previous question?
A. Very confident B. Confident C. Uncertain D. Not confident

1C. What is the best reason that supports your answer in Tier 1?
A. Because the equation $E = mc^2$ shows that the energy of gamma rays can be converted into the mass of two new particles
B. Because gamma rays are only reflected without any change in energy
C. Because electrons and positrons originate directly from the atomic nucleus
D. Because energy and mass are not related to each other

1D. How confident are you in the reason you selected?
A. Very confident B. Confident C. Uncertain D. Not confident

1E. Evaluate how the experimental result supports the theory of mass–energy equivalence.

Figure 2. Example of a Five-Tier diagnostic test item on modern physics topics

Through this intellectual visualization, the instrument is able to comprehensively distinguish between scientific understanding, strong misconceptions, weak misconceptions, and guessing responses. This capability represents the main advantage of the developed Five-Tier instrument.

The results of the development stage indicate that the Google Form–based Five-Tier diagnostic instrument has fulfilled the aspects of content validity, empirical validity, and reliability. Unlike previous studies that generally used Five-Tier tests solely to identify misconceptions, this study emphasizes a systematic instrument development process through expert validation and empirical trials. Consequently, the instrument employed in this study is a validated and tested instrument that is ready to be implemented in modern physics learning.

Implementation

The implementation stage involved the application of the Five-Tier diagnostic instrument that had been declared feasible during the development stage. At this stage, the instrument was used under actual research conditions to obtain empirical data regarding its ability to identify students' misconceptions, as well as its practicality and acceptance in modern physics learning (McKenney & Reeves, 2019; Rokhim et al., 2023).

The implementation was carried out by administering the instrument to 23 students of the Physics Education Study Program who had completed the Modern Physics course. The Five-Tier diagnostic instrument was implemented online using

Google Form. The Google Form link was distributed to students through online class communication media (WhatsApp), allowing students to access and complete the instrument independently using their own devices. In addition, to obtain lecturers' responses regarding the practicality of the instrument, the researchers conducted direct communication on campus to explain the purpose of the instrument and to request lecturers' willingness to provide evaluations.

During implementation, the Google Form was configured with a two-hour time limit**.** This time restriction was intended to maintain students' seriousness in completing the instrument, minimize the possibility of discussion among respondents, and ensure that the responses reflected individual conceptual understanding. Students were instructed to answer the questions sequentially according to the Five-Tier structure, starting from the selection of conceptual answers to open-ended explanations. All student responses were automatically recorded and stored in spreadsheet format to facilitate data processing and analysis.

Throughout the implementation process, the researchers also provided limited technical and academic support for students who experienced difficulties in understanding the instructions or item wording. Students were allowed to contact the researchers via online communication media to obtain clarification regarding the procedure for completing the instrument. This assistance was limited to instructional clarification and did not include hints or guidance related to answers or conceptual reasoning, so as not to influence the independence of students' responses. This approach was employed to ensure that the collected data authentically represented students' conceptual understanding and were not affected by misunderstandings of the instrument instructions.

Based on the data obtained from the implementation stage, information regarding students' misconceptions in each modern physics topic was identified. The percentage of students experiencing misconceptions in each topic is presented in Table 8**.**

Table 8. Percentage of Students Experiencing Misconceptions in Each Modern Physics Topic

No.	Modern Physics Topic	Misconception Percentage (%)	Category
1	X-rays	39.13	Moderate
2	Photoelectric Effect	43.48	Moderate
3	Compton Effect	47.83	Moderate
4	Pair Production	43.48	Moderate
5	Photon–Gravity Interaction	30.43	Moderate
	Average	40.87	Moderate

In addition to percentage analysis, descriptive statistics were calculated to summarize the distribution of students' misconceptions across modern physics topics. The analysis showed that the mean misconception percentage was $M = 40.87\%$ with a standard deviation of $SD = 6.60\%$**.** This result indicates that, on average, students experienced a moderate level of misconceptions, with noticeable variation across different modern physics concepts. The relatively higher dispersion suggests that certain topics, particularly those involving quantum interactions such as the Compton effect and pair production, posed greater conceptual challenges compared to others.

The descriptive statistics further indicate that students' conceptual understanding was uneven across topics, confirming the diagnostic function of the Five-Tier instrument in identifying concept-specific misconceptions.

Based on Table 8, it can be observed that the level of student misconceptions varies across different topics. The highest level of misconception was found in the Compton effect topic, while the lowest level occurred in the photon–gravity interaction topic. This variation indicates that modern physics concepts that are abstract in nature and involve energy–particle interactions at the quantum scale tend to be more difficult for students to understand (Gurel et al., 2015; Kaltakci-Gurel & Eryilmaz, 2017; Rokhim et al., 2023). To clarify the comparison of misconception levels across topics, the data presented in Table 5 are visualized in the form of a bar chart in Figure 3**.**

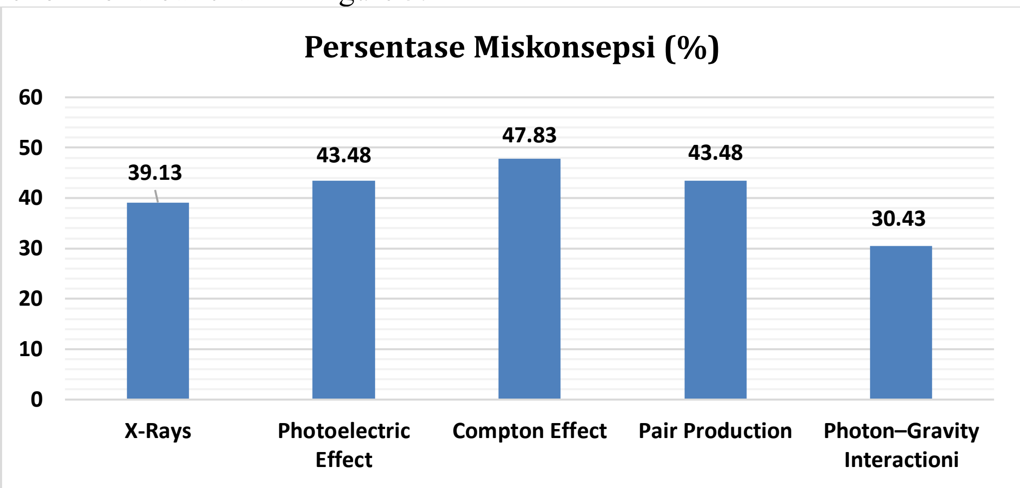


Figure 3. Bar Chart of the Percentage of Student Misconceptions in Each Modern Physics Topic

In addition to identifying students' misconceptions, the implementation stage was also used to evaluate the practicality of the Five-Tier diagnostic instrument through an analysis of student responses. Student responses were collected using a questionnaire administered after the diagnostic test during the implementation stage. The analysis results showed that the instrument obtained an average "strongly agree" percentage of 89.13%**,** which falls into the very practical category. The detailed results of student responses regarding the practicality of the instrument are presented in Table 9**.**

Table 9. Student Responses to the Five-Tier Diagnostic Instrument

No.	Assessment Aspect	Percentage (%)	Category
1	Ease of use	88.70	Strongly agree
2	Clarity of display	90.43	Strongly agree
3	Clarity of instructions	89.13	Strongly agree
4	Instrument implementability	88.26	Strongly agree
	Average	89.13	Strongly agree

These results indicate that students perceived the instrument as easy to use, having a clear interface and instructions that were easy to understand, thereby supporting the implementation of online diagnostic assessment (McKenney & Reeves, 2019; Putri & Suparman, 2021).

Overall, the results of the implementation stage demonstrate that the developed Google Form–based Five-Tier diagnostic instrument is effective in identifying students' misconceptions and exhibits a very high level of practicality from both student and lecturer perspectives. The Five-Tier structure enables the identification of strong misconceptions, defined as conditions in which students provide incorrect answers and reasoning accompanied by a high level of confidence. These findings reinforce previous studies emphasizing the importance of multi-tier diagnostic assessment in modern physics learning (Mubarak et al., 2020; Nugroho et al., 2021; Friska et al., 2023).

Evaluation

The evaluation stage represents the final phase of the ADDIE model and aims to assess the quality of the Five-Tier diagnostic instrument implemented during the implementation stage. The evaluation focused on examining the empirical characteristics of the instrument, including empirical item validity, instrument reliability, practicality of use, and the effectiveness of the instrument in identifying students' misconceptions in modern physics learning. This stage was conducted to ensure that the developed instrument is not only conceptually valid but also functions optimally as a diagnostic tool for misconceptions under authentic learning conditions.

The evaluation of empirical item validity was conducted to determine each item's ability to measure the intended construct, namely students' conceptual understanding and misconceptions in modern physics topics. The validity analysis was based on data obtained from the implementation stage involving 23 respondents **and** 20 test items**.** The results revealed substantial variation in students' responses across items. In the context of diagnostic instruments, this variation reflects the sensitivity of the instrument in distinguishing between levels of conceptual understanding, lack of understanding, and misconceptions. Therefore, this instrument is more appropriately used as a conceptual diagnostic tool rather than as a summative evaluation test.

The evaluation of instrument effectiveness was examined based on its ability to identify students' misconceptions in each modern physics concept. The implementation results indicated that several test items exhibited very high levels of misconceptions. Table 10 presents students' responses for each modern physics concept that demonstrated misconceptions.

Table 10. Patterns of Student Responses for Each Modern Physics Concept Based on the Implementation Results of the Five-Tier Instrument

No	Modern Physics Concept	Concept Indicator	Scientific (Correct) Answer	Misconception Answer Selected by Students	Number of Students	Percentage (%)
1	X-rays	Relationship between photon energy/frequency and penetration power	The penetration power of X-rays depends on photon energy/frequency	The penetration power of X-rays is not influenced by	23	100

				photon energy or frequency		
2	X-rays	Relationship between frequency and X-ray energy	X-ray energy is directly proportional to frequency	Frequency does not affect X-ray energy	23	100
3	Photoelectric Effect	Factors causing electron emission	Electron emission is determined by the frequency of light	Light intensity determines the occurrence of electron emission	23	100
4	Compton Effect	Change in photon wavelength	Photon wavelength changes due to energy and momentum transfer	Photon wavelength does not change after scattering	23	100

In the item assessing the concept of X-ray penetration power, all students (100 %) experienced misconceptions, indicating that students had not yet understood the relationship between photon energy or frequency and the penetration ability of radiation. A similar result was found in the item examining the relationship between X-ray frequency and energy, which also showed a 100 % misconception rate, suggesting weak student understanding of the frequency–energy relationship in X-rays.

In the photoelectric effect concept, the item revealed a 100 % misconception rate, where all students believed that light intensity was the primary factor causing electron emission. This misconception was reinforced by incorrect conceptual reasoning accompanied by a high level of confidence, classifying it as a strong misconception. This finding indicates that students still rely on a classical physics framework when interpreting quantum phenomena.

Furthermore, in the Compton scattering concept, the item also demonstrated a 100 % misconception rate. Students did not understand that photons undergo a change in wavelength due to energy and momentum transfer during interactions with electrons. This result reflects students' weak understanding of the particle nature of light and the concept of wave–particle duality.

The high percentage of misconceptions across all four items indicates that the Five-Tier diagnostic instrument is not only capable of identifying incorrect answers but also effective in revealing deep-seated misconceptions accompanied by high confidence levels. Therefore, the instrument is effective in identifying critical concepts that constitute the primary sources of students' difficulties in learning Modern Physics.

The evaluation of instrument practicality was conducted based on student and lecturer responses collected during the implementation stage. The response results indicated that the instrument demonstrated a very high level of practicality, from both student and lecturer perspectives. This confirms that although the instrument reveals high levels of misconceptions in several concepts, it remains easy to use and can be effectively implemented in authentic learning contexts.

Based on the overall evaluation results, it can be concluded that the developed Google Form–based Five-Tier diagnostic instrument possesses adequate empirical validity, reliability characteristics appropriate for diagnostic purposes, a high level of practicality, and strong effectiveness in identifying students' misconceptions in Modern Physics topics. The instrument is therefore suitable for use as a basis for designing follow-up instructional strategies and misconception remediation programs.

CONCLUSION

This study developed a Google Forms–based Five-Tier diagnostic instrument designed to systematically and in depth identify students' conceptual understanding and misconceptions in modern physics topics. Developed using the ADDIE model, the instrument integrates conceptual answers, scientific reasoning, confidence levels, and sources of understanding, enabling a more comprehensive mapping of students' cognitive structures compared to conventional assessment approaches. The integration of the Five-Tier structure with a digital platform represents a methodological contribution to the development of diagnostic assessments that are practical, flexible, and informative, thereby supporting lecturers in designing follow-up instructional strategies and misconception remediation programs. Overall, the developed instrument is relevant to modern physics learning in higher education and demonstrates strong potential for broader application.

Despite its contributions, this study has several limitations. First, the sample size involved in the implementation stage was relatively small and limited to a single physics education program, which may restrict the generalizability of the findings. Second, the instrument was applied specifically to selected modern physics topics, and the results may not fully represent students' misconceptions in other physics domains. Third, the study focused on diagnostic identification rather than examining the effectiveness of subsequent instructional interventions based on the diagnostic results.

Future research is recommended to involve larger and more diverse samples across different institutions to enhance the generalizability of the findings. Further studies may also extend the application of the Google Forms–based Five-Tier diagnostic instrument to other physics topics or different scientific disciplines. In addition, future research should explore the integration of the diagnostic instrument with targeted instructional interventions to examine its effectiveness in reducing students' misconceptions over time. The development of automated data analysis and feedback features within digital diagnostic platforms also represents a promising direction for further investigation.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the lecturers of the Physics Education Study Program, Universitas Syiah Kuala, for their valuable suggestions, expert validation, and constructive feedback during the development of the Five-Tier diagnostic instrument. The authors also thank the students who participated in the trial and implementation stages of this study and contributed meaningful data. In addition, appreciation is extended to the Faculty of Teacher Training and Education, Universitas Syiah Kuala, for providing academic facilities and a supportive research environment. Finally, the authors acknowledge all colleagues and parties who offered assistance and encouragement throughout the research process.

REFERENCES

Aldoobie, N. (2015). ADDIE model. *American International Journal of Contemporary Research, 5*(6), 68–72.

Anam, R. S., Widodo, A., Sopandi, W., & Wu, H. K. (2019). Developing a five-tier diagnostic test to identify students' misconceptions in science. *Journal of Baltic Science Education, 18*(4), 570–583. https://doi.org/10.33225/jbse/19.18.570

Arikunto, S. (2018). *Dasar-dasar evaluasi pendidikan* (Edisi revisi). Bumi Aksara.

Berek, F. X., Sutopo, S., & Wartono, W. (2016). Conceptual change text to improve student understanding of modern physics concepts. *Jurnal Pendidikan IPA Indonesia, 5*(2), 247–255. https://doi.org/10.15294/jpii.v5i2.7688

ushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2017). *The essential physics of medical imaging* (3rd ed.). Lippincott Williams & Wilkins.

Caleon, I. S., & Subramaniam, R. (2010). Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves. *International Journal of Science Education, 32*(7), 939–961. https://doi.org/10.1080/09500690902890130

Carroll, S. (2019). *Spacetime and geometry: An introduction to general relativity* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/9781108770385

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage Publications.

Dick, W., Carey, L., & Carey, J. O. (2015). *The systematic design of instruction* (8th ed.). Pearson.

Friska, D., Widodo, A., & Nugroho, S. E. (2023). Identifying misconceptions in modern physics using multi-tier diagnostic tests. *Journal of Physics: Conference Series, 2468*, 012015. https://doi.org/10.1088/1742-6596/2468/1/012015

Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage Learning.

Hasyim, A., Widodo, A., & Sopandi, W. (2021). Multi-tier diagnostic tests in physics education. *Journal of Physics: Conference Series, 1806*, 012024. https://doi.org/10.1088/1742-6596/1806/1/012024

Kaltakci-Gurel, D. (2018). Development of diagnostic tests to assess misconceptions. *Education and Science, 43*(195), 1–24. https://doi.org/10.15390/EB.2018.7290

Kaltakci-Gurel, D., & Eryilmaz, A. (2017). Students' misconceptions in modern physics. *European Journal of Physics Education, 8*(2), 1–16.

McKenney, S., & Reeves, T. C. (2019). *Conducting educational design research* (2nd ed.). Routledge.

Mubarak, S., Susantini, E., & Isnawati. (2020). Identification of students' misconceptions using a five-tier diagnostic test. *Journal of Physics: Conference Series, 1467*, 012037. https://doi.org/10.1088/1742-6596/1467/1/012037

Nugroho, S. E., Wiyanto, & Hidayah, I. (2021). Diagnostic assessment to identify misconceptions in physics. *Jurnal Pendidikan IPA Indonesia, 10*(3), 402–410. https://doi.org/10.15294/jpii.v10i3.29012

Peterson, C. (2018). Bringing ADDIE to life. *Journal of Educational Multimedia and Hypermedia, 27*(2), 197–213.

Podgorsak, E. B. (2016). *Radiation physics for medical physicists* (2nd ed.). Springer. https://doi.org/10.1007/978-3-319-25382-1

Putri, R. A., & Suparman. (2021). Development of online assessment using Google Form. *Journal of Educational Technology, 15*(3), 211–220.

Rokhim, D. A., Widodo, A., & Sopandi, W. (2023). Five-tier diagnostic test to identify misconceptions. *Journal of Physics: Conference Series, 2476*, 012018. https://doi.org/10.1088/1742-6596/2476/1/012018

Rusilowati, A. (2015). Pengembangan instrumen asesmen pembelajaran sains. *Jurnal Penelitian Pendidikan IPA, 1*(1), 1–10.

Schutz, B. F. (2015). *A first course in general relativity* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511984181

Singh, C., & Marshman, E. (2018). Student difficulties in quantum mechanics. *Physical Review Physics Education Research, 14*(1), 010117. https://doi.org/10.1103/PhysRevPhysEducRes.14.010117

Steinberg, R. N., & Sabella, M. S. (2017). Understanding student reasoning in quantum physics. *American Journal of Physics, 85*(12), 965–974. https://doi.org/10.1119/1.5000807

Taherdoost, H. (2016). Validity and reliability of the research instrument. *International Journal of Academic Research in Management, 5*(3), 28–36. https://doi.org/10.2139/ssrn.3205040Yulianti, D., & Hartono, H. (2022). Online assessment using Google Form in higher education. *Journal of Physics: Conference Series, 2214*, 012012. https://doi.org/10.1088/1742-6596/2214/1/012012