



Diagnostic Instrument Test of Renewable Energy Topics: Analysis of Conceptual Change Students Using the Rasch Approach

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Abstract

The learning of students about abstract physics concepts faces multiple hurdles, which can result in misconceptions. Considering this problem, the present research intends to analyze students' misconception changes through a diagnostic tool based on the issue of renewable energy using the Rasch analysis methods. The Renewable Energy Topic Diagnostic Instrument (DITRET) was created with the ADDIE development model, which consists of five stages: analysis, design, development, implementation, and evaluation. The subjects of the study were 30 high school students aged 17 years (9 boys and 21 girls). DITRET has 20 components with four hierarchical stages for each item. During the analysis stage, students' responses are classified into categories, and conceptual scores are then computed in the Rasch framework. The results showed that DITRET has strong reliability and validity in estimating students' understanding of renewable energy. With some minor adjustments, this instrument can identify students' conceptual changes and diagnose misconceptions on other physics topics. The research findings enhance the available literature, providing valid and reliable tools to measure, detect, and resolve misconceptions in the concept of renewable energy.

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INTRODUCTION

Students' conceptions are influenced by the ideological framework (Assem et al., 2023), which plays a crucial role in enhancing their comprehension, disseminating accurate concepts for problem-solving, and ultimately advancing their knowledge and skills (Fauth et al., 2019; Fratiwi et al., 2018). However, students often have misunderstandings or incorrect beliefs when learning certain concepts, especially those related to experiences that cannot be easily observed or detected by our thinking abilities (Bitzenbauer, 2021; Cai et al., 2021; Nurdini et al., 2020). Consequently, conceptual misinterpretation poses a significant challenge for researchers, particularly novice scholars who cannot construct accurate theoretical frameworks (Park & Liu, 2021). Assessing students' understanding might be a challenging yet engaging method to address that issue (Fitri et al., 2022; Suhandi et al., 2020).

Various conventional and contemporary assessment methods, including conferences, concept maps, open-ended assessments, portfolios, and diagnostic evaluations, are employed to gauge students' comprehension of concepts and their misconceptions (Basri et al., 2024; Fratiwi et al., 2020). Many researchers have developed other techniques for the description of physics, in addition to the fundamental principles (Panergayo, 2023). Among these techniques, distinguishing a four-tier diagnostic test has become popular because of its potential to show students'

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understanding more profoundly (Suhandi et al., 2020; Misbah et al., 2022; Permadi & Tiarto, 2022). Still, very little work has been done applying this approach to the area of renewable energy, and none appear to have tried validating the tool using the Rasch method, showing a lack of focused research.

This four-tier structure comprises tier 1 as a question, tier 2 as the degree of certainty regarding the response (tier 1), tier 3 as the rationale, and tier 4 as the amount of confidence in the rationale (tier 3) (Izzati & Rochmah, 2020; Suhandi et al., 2020). Various diagnostic assessment tools are employed to determine students' understanding of physics concepts, including electricity, optics, and other topics (Pratiwi, 2024; Saregar et al., 2022). However, this has not yet been widely accepted to assess students' understanding of the topic of renewable energy. The results of the analysis related to conceptual change can be seen in Figure 1.

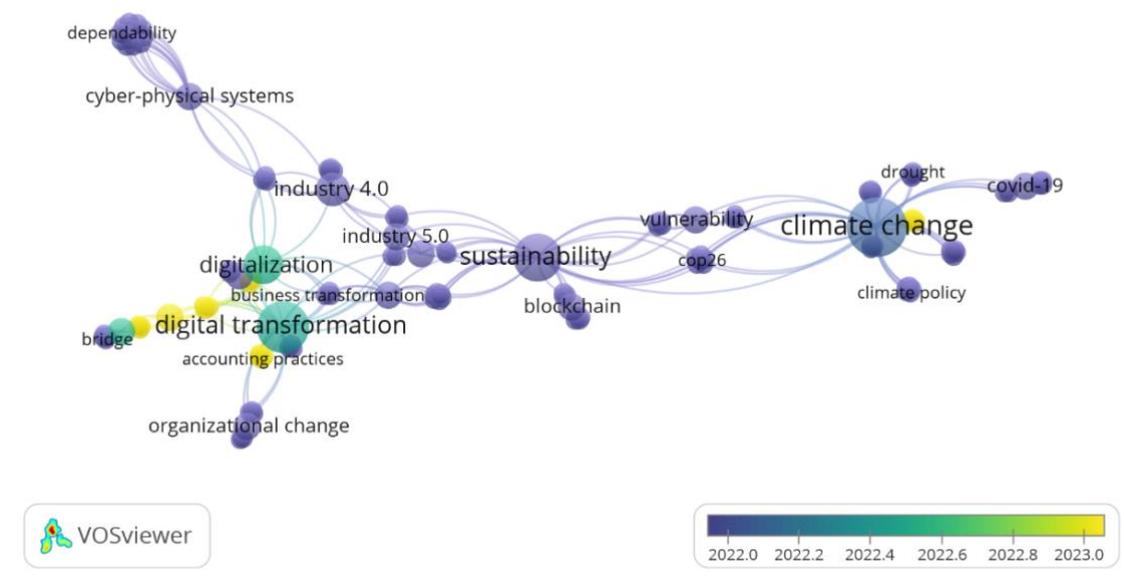


Figure 1. VOSviewer Analysis Based on Keywords

Figure 1 is a VOSviewer analysis based on keywords found in the analyzed documents (200 documents). The selection of keywords was carried out because it is the focus of this study, but the results are not yet visible as complete data, because they only help visualize the bibliometric network.

Misconception is a challenge frequently encountered by novices. The term misunderstanding denotes the disparity between a student's comprehension and the accurate concept of scientific theory (Kiray & Simsek, 2021). Even though there have been major improvements in how we understand physics education, wrong ideas still exist, showing that learning methods won't fix these misunderstandings unless they are directly focused on them (Cai et al., 2021; Tumanggor et al., 2020). Therefore, we need to conduct further analysis, especially using the Rasch analysis method.

The Rasch analysis to measure constructs in human psychology with a focus on two constraints: item difficulty and person ability (Suhandi et al., 2020; Uwamahoro et al., 2021). Rasch is an optional methodology for a degree that generates an approximation phase in line with the principles of a universal framework of elements, as a tool through the use of a specific unit of measurement, and can be thought of as an excellent classical approach (Uwamahoro et al., 2021). The Rasch model is effective in identifying the most relevant segments of rating scale collections as an alternative assessment tool for humanization (Tunç, 2023). Nevertheless, while Rasch analysis has become popular in psychometric and educational research, its application in developing four-level diagnostic instruments for physics, particularly in the field of renewable energy, seems quite limited in the literature. Furthermore, the results of the bibliometric analysis using VOSviewer on 200 documents indicate that the relationship between the keywords "diagnostic instruments,"

"renewable energy," and "Rasch analysis" is still very limited, reinforcing the novelty claim of this research. So, the aim of this research is to design and analyze the validity and reliability of a four-level diagnostic instrument titled DITRET (Diagnostic Instrument Test of Renewable Energy Topics) using Rasch analysis in an effort to assess students' conceptual changes regarding renewable energy topics more accurately and systematically. Uncorrected misconceptions will hinder pupils' comprehension of more complex subjects in the future. Research by Fuadiah et al (2019) Kahu & Nelson (2018) shows that misunderstandings negatively impact students' understanding of new concepts. Educators have employed diverse strategies to reduce student misconceptions, including the creation of assessment tools (Anam et al., 2019).

The study intends to assess students' understanding of Renewable Energy Topics. The development of DITRET (Diagnostic Instrument Test of Renewable Energy Topics) is significant due to the scarcity of diagnostic tools for assessing students' understanding. This tool is advanced and uses a four-part test that includes tier-1 (the main question), tier-2 (how confident the student is about tier-1), tier-3 (the main reason for their answer to tier-1), and tier-4 (how confident they are about their reason in tier-3). We selected this format because it was novel compared to the alternatives. The research results will be sorted according to the research design used, namely ADDIE, starting from the Analysis stage to the Evaluation stage. So, this study aims to examine student conceptual change with diagnostic instruments focused on renewable energy using the Rasch analysis approach, which is significant due to the challenges many students face in comprehending abstract physics concepts, perhaps leading to misconceptions.

METHOD

The learning technique utilizes the ADDIE framework, which has five comprehensive steps: analysis, design, development, implementation, and evaluation, and the stages can be seen in Figure 2. The analytical processes constituted the phase for examining literature by students' perceptions of renewable energy themes derived from prior research. Moreover, researchers employed this word to emphasize the physical aspects within the existing curriculum. During the design phase, researchers meticulously selected a four-tier model for implementation in this study. During the development phase, researchers formulated the DITRET using the four-tier framework that they derived from validated assessments. Furthermore, we administered the previously designed instrument to the pupils via Google Forms. Finally, we examined all students' responses based on their conceptual categories and scores using the Rasch analysis method.

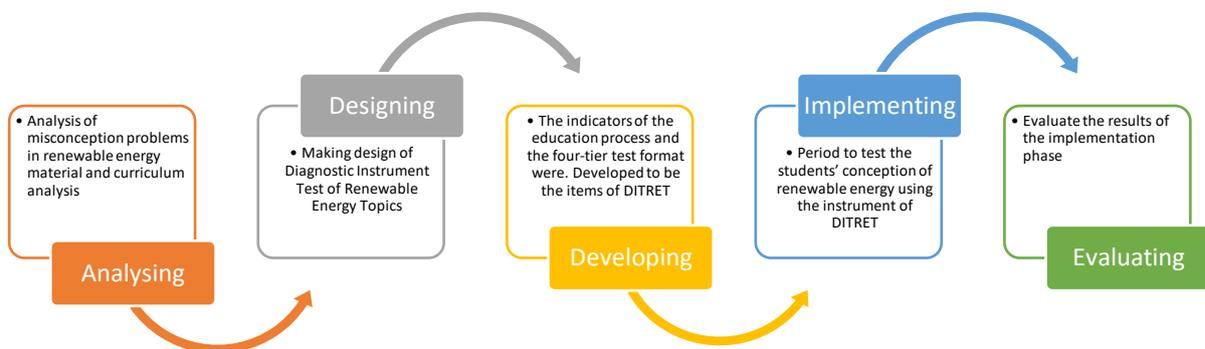


Figure 2. ADDIE Stages Used (Aldoobie, 2015)

The employed sampling approach is purposive sampling, which is a strategy predicated on specific criteria stated by the researcher. This strategy is often referred to as judgmental sampling. This investigation involved 30 students, comprising 9 males and 21 females, predominantly aged 17 years and selected from a senior high school in Bandung, West Java. Researchers undertook this action to explore the feasibility of conducting online assessments via Google Forms. The tool employed in this study is designated as the "Diagnostic Instrument Test of Renewable Energy Topics (DITRET)." The Renewable Energy Standardized Test served as its genesis. Before the development phase, this instrument consisted of a single tier, which addressed the primary inquiry

about the concept of renewable energy. We designed this instrument into a four-tier framework to assess the pupils' understanding. Figure 3 depicts the theoretical framework.

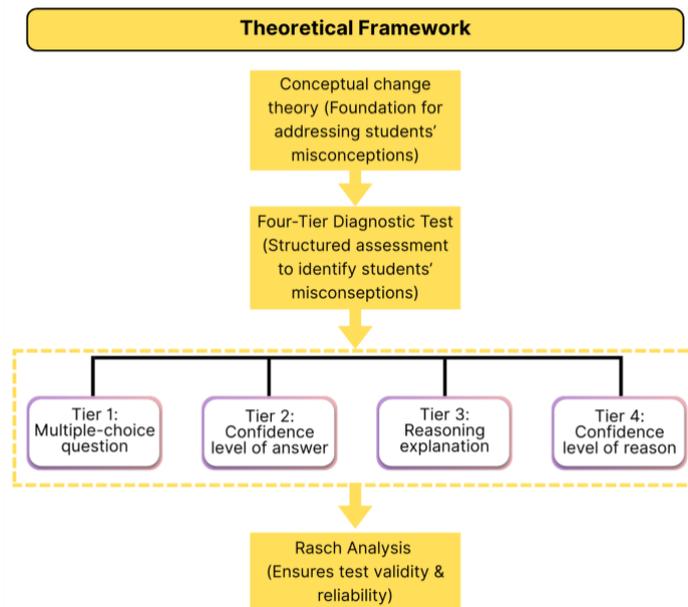


Figure 3. Theoretical Framework

We examined the data utilizing two classifications. The preliminary examination of the data concerns the defendants' responses, as outlined in Table 1, which correspond to the initial classifications. Secondly, we used the answer data to evaluate the reliability and validity of the instrument items, as well as the functioning of gender-specific items. The data documented in Microsoft Excel, which transformed the students' responses, produced binary code. WINSTEP software version 4.4.5 conducted a Rasch analysis on the binary code. We measured the validity of the instrument with WINSTEP 4.4.5 software and used item (column) output to rank the fit. We derived the information from the logit value of the Mean Square Outfit (MNSQ), Z-standard output (ZSTD), and point-measure correlation (PTMEASURE COOR). We used the Summary Statistics output from WINSTEP 4.4.5 to determine the reliability of the instrument.

RESULTS AND DISCUSSION

Analyzing

At this stage, the scholars have presented various studies on multiple prior works. What has transpired with renewable energy? Additionally, we examined the renewable energy components within *Merdeka's* curriculum in Indonesia. Ultimately, we identified a minimum of seven sub-concepts within this material: Energy, Forms of Energy, Law of Conservation of Energy, The Urgency of Energy Needs, Renewable and Non-renewable Energy Sources, Impact of Energy Exploration and Utilization, and Energy Fulfillment Initiatives. Subsequently, we formulated the objectives into 20 indicators of the learning process, as illustrated in Table 1.

Table 1. The Indicators of the Learning Process

Sub Concepts	Indicators
Energy	Identifying energy availability problems Analyze possible solutions to energy limitations in the surrounding environment
Forms of Energy	Analyzing the impact of energy limitations Identifying changes in the form of energy Understanding the forms of energy Analyzing the forms of energy involved in its application in everyday life

Sub Concepts	Indicators
Law of Conservation of Energy	Analyze the validity of the law of conservation of mechanical energy Analyzing the law of conservation of energy from an object dropped without initial velocity
The Urgency of Energy Needs Issue	Identify business relationships with potential changes Giving meaning to an idea or concept about alternative energy sources Analyzing simple energy-producing devices
Renewable and Non-renewable Energy	Explaining the concept of renewable and non-renewable energy sources Explaining renewable and non-renewable electricity generation Analyzing the differences between renewable energy and non-renewable energy
Impact of Energy Exploration and Use	Explaining alternative energy that can be used in human life Analyzing the limitations of energy sources and their impact on life Feel the emotions felt by people who experience the impacts of environmental pollution and energy shortages.
Energy fulfillment efforts	Analyzing problem-solving efforts with alternative energy Analyze the process of making alternative energy from various sources. Analyzing tools that can change energy for everyday life

Designing

Upon examining the physical and subordinate conceptions, investigators exercise caution regarding the nature of multi-tiered demands. To enhance the relevance of the penalties, we judiciously selected a four-tier exam format for implementation in this research. The primary level of the queries consists of the principal multiple-choice questions that assist in identifying the specific issue to be addressed by the defendants. The researchers have approved this tier based on their completion of standardized renewable energy. The second tier represents the degree of assurance provided by the first tier. This tier comprises two types of responses: certain or uncertain. The objective related to the central query is presented in tier 3 and includes five potential responses. The last tier provides the guarantee required to achieve the third tier. For further information, the structure is presented in Figure 4.

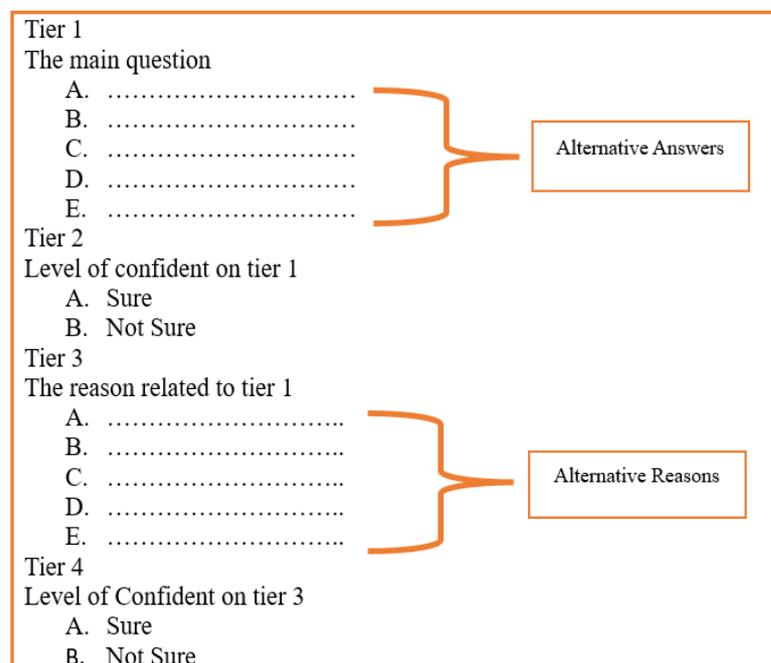


Figure 4. The Four-Tier Test Format

Figure 4 depicts the DITRET format, which will subsequently serve as a reference for formulating questions. There are four tiers: tier 1 pertains to a question regarding the concept of energy; tier 2 inquires about the participant's confidence in their answer to tier 1; tier 3 seeks reasons relating to tier 1; and tier 4 questions the certainty of the answer provided in tier 3.

Developing

At this step, the indicators of the educational process and the four-tier assessment format were established. We created these indicators to form the components of DITRET. This instrument comprises 20 items reflecting seven sub-concepts: Energy, Forms of Energy, Law of Conservation of Energy, Urgency of Energy Needs, Renewable and Non-renewable Energy Sources, Impact of Energy Exploration and Use, and Energy Fulfillment Efforts. Additionally, it encompasses supplementary concepts that require comprehension. An example of an item on an instrument is presented in Figure 5.

An object has a potential of E when it is at a height of h. When the object falls freely due to the influence of conservative forces, what is the condition of its mechanical energy at a height of 1/4 h? A. increased by 1/4 mgh B. increased by 3/4 mgh C. reduced by 1/4 E D. reduced by 3/4 E E. the value remains the same
Your level of confidence regarding the answer choices for the question: A. Sure B. not sure
What is the appropriate reason to answer the question regarding mechanical energy in an object? A. Mechanical energy remains constant because the path of the conservative force is independent of the object's path. B. Mechanical energy remains constant because the path of the conservative force depends on the path of the object. C. Mechanical energy is affected by height, where the higher the height, the greater the kinetic energy. D. Mechanical energy is not affected by height, but the higher the height, the greater the kinetic energy E. The law of conservation of mechanical energy does not apply to conservative force work, because mechanical energy is influenced by potential energy and kinetic energy.
Your level of confidence regarding the answer choices for reasons: A. Sure B. Not Sure

Figure 5. The Example of Items on DITRET

Implementing

The implementation phase is the time to evaluate students' understanding of renewable energy via the DITRET instrument. Due to the prevailing circumstances in Indonesia, the researchers could not administer the instrument directly to the students; therefore, in this study, they distributed the tool via online testing using Google Forms, an example of which is shown in Table 2.

Table 2. DITRET Sample Questions Based on Four Levels (Mechanical Energy Topic – Question 1)

Tier	Question Components
	Conceptual Question: An object has a potential of E when it is at a height of h. when the object falls freely due to the influence of conservative forces, what is the condition of its mechanical energy at a height of 1/4 h?
Tier 1	Answer Choices: A. increased by 1/4 mgh increased by 3/4 mgh B. reduced by 1/4 E C. reduced by 3/4 E D. the value remains the same

Tier	Question Components
Tier 2	Your level of confidence regarding the answer choices for the question: A. Sure B. Not Sure The reason for the answer to the question in Tier 1: What is the appropriate reason to answer the question regarding mechanical energy in an object? A. Mechanical energy remains constant because the path of the conservative force is independent of the object's path Mechanical energy remains constant because the path of the conservative force depends on the path of the object B. Mechanical energy is affected by height, where the higher the height, the greater the kinetic energy C. Mechanical energy is not affected by height, but the higher the height, the greater the kinetic energy D. The law of conservation of mechanical energy does not apply to conservative force work, because mechanical energy is influenced by potential energy and kinetic energy
Tier 3	
Tier 4	Your level of confidence regarding the answer choices for the question: A. Sure B. Not Sure

Table 2 demonstrates a sample of a four-tier DITRET item designed to evaluate students' understanding of mechanical energy. The first part of the table contains the initial multiple-choice question (tier 1), alongside a question asking students to rate their confidence in the selection they made (tier 2), responding with either "Sure" or "Not Sure" as options. This two-tier system is designed to capture a student's answer together with their confidence in the accuracy of that response. The last section of Table 2 contains the reasoning options for the first question, which enables the students to select justifications for the answer that they gave in tier 2 (that is, tier 3). The last section (tier 4) documents their confidence in the reasoning they articulated.

This structure brought a lot of benefits for the researchers involved. The instrument was effectively shared online, allowing it to connect with participants from a variety of schools, each with their own unique cultural and educational experiences. The students' responses were then sorted according to specific criteria for conceptual understanding, as shown in Table 3. For instance, if a student answers correctly in Tier 1, shows confidence in Tier 2, picks the right reasoning in Tier 3, and feels sure about their answer in Tier 4, they're classified as having Sound Understanding. Conversely, if a student gets the answer right in Tier 1, feels unsure in Tier 2, gives incorrect reasoning in Tier 3, and lacks confidence in Tier 4, they're placed in the Partial Negative category. To systematically evaluate the DITRET framework, Table 3 outlines the specific criteria used in the analysis, detailing key dimensions and indicators relevant to assessing its components.

Table 3. Criteria for Analysing DITRET

Level of Conception	Coding	Tier 1	Tier 2	Tier 3	Tier 4
No Coding	NC	Incomplete Answer			
No Understanding	NU	Incorrect	Not Sure	Incorrect	Sure
		Incorrect	Sure	Incorrect	Not Sure
		Incorrect	Not Sure	Incorrect	Not Sure
		Incorrect	Sure	Incorrect	Sure
Misconception	MC	Incorrect	Sure	Incorrect	Sure
		Partial Negative	PN	Correct	Sure
Partial Negative	PN	Correct	Not Sure	Incorrect	Sure
		Correct	Sure	Incorrect	Not Sure
		Incorrect	Not Sure	Incorrect	Not Sure
		Incorrect	Sure	Correct	Sure
		Incorrect	Not Sure	Correct	Sure
		Incorrect	Sure	Correct	Not Sure

Level of Conception	Coding	Tier 1	Tier 2	Tier 3	Tier 4
Partial Positive	PP	Incorrect	Not Sure	Correct	Not Sure
		Correct	Not Sure	Correct	Sure
		Correct	Sure	Correct	Not Sure
		Correct	Not Sure	Correct	Not Sure
Sound Understanding	SU	Correct	Sure	Correct	Sure

A 2017 study (Favale & Bondani, 2013) provided the basis for this grading. Due to potential missing information in one of the tiers, Coding received no score. The data is relevant and accessible for examination by the Rasch methodology.

Evaluating

At this stage, the categories listed in Table 1 guide the evaluation of students' test responses. Table 2 converted the pupils' initial category into a manageable score. This scoring was examined using many methods, including person dependability, item reliability, instrument validity, and gender differential item functioning (DIF). Presentation of the Student Conception can be seen in Figure 6.

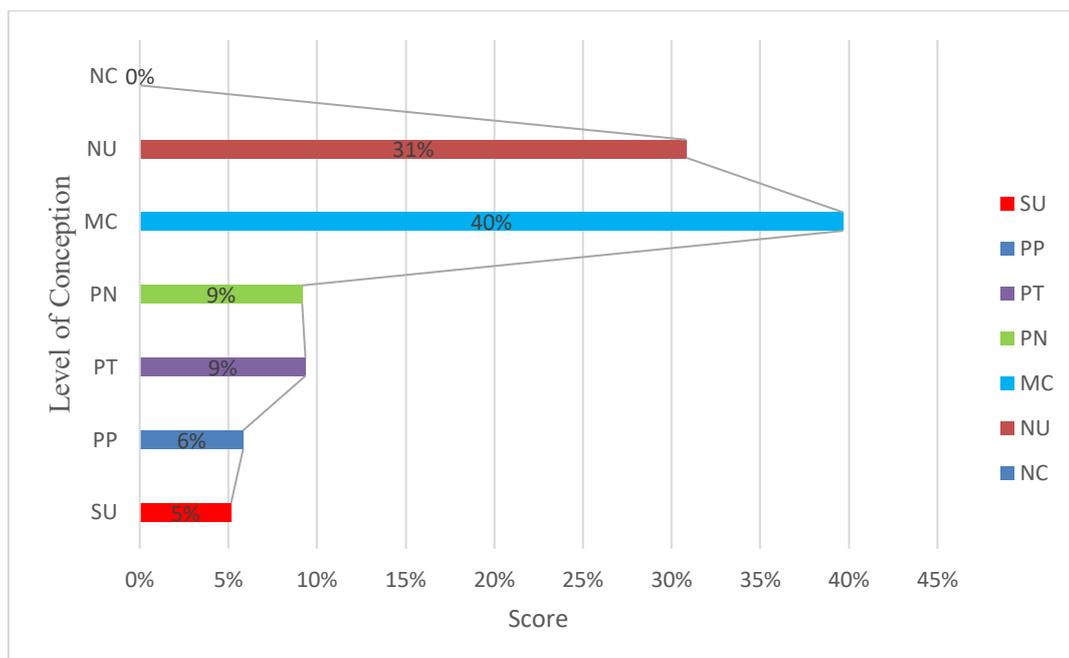


Figure 6. Presentation of Student Conception

From Figure 6, student understanding distribution in the Sound Understanding (SU) type is 5%, Partial Positive (PP) is 6%, Partial Neutral (PT) is 11%, Partial Negative (PN) is 10%, Misconception (MC) is 40%, No Understanding (NU) is 31%, and No Coding (NC) is 0%. Misconception type has the highest percentage of 40% and also shows gigantic challenges in students' understanding, especially in the work and energy concepts. Previous studies have found several reasons for misconceptions, such as students not being mentally ready (Potvin et al., 2020), a lack of interest in the subject (Prodjosantoso et al., 2019), incorrect information given by teachers (Fauth et al., 2019), inappropriate learning materials (Yang & Chen, 2023), and teaching that is too abstract (Resbiantoro, G., & Setiani, 2022).

Erroneous notions lacking rectification will impede pupils' ability to comprehend more intricate content in the future. Misconceptions will impede students' comprehension of new topics (Liu & Fang, 2016). Misconceptions can affect an individual's cognitive processes and actions, leading to suboptimal learning results (Resbiantoro, G., & Setiani, 2022; Rupp, 2013). In addition, misconceptions have both short-term and long-term effects, rendering them trending issues that require immediate attention.

This confirms that renewable energy is a subject prone to misconceptions in physics education. Students' misconceptions may arise from both external and internal reasons (Resbiantoro, G., & Setiani, 2022). External variables include the insufficient utilization of suitable educational resources to assist pupils in comprehending complex concepts. The educational medium frequently fails to offer sufficient visualization of a concept's application in a real-world situation. This complicates students' ability to connect physics concepts to their everyday experiences, resulting in prevalent misconceptions (Qian, 2019). Alongside external variables, misconceptions are also influenced by internal ones, notably student interest (Resbiantoro, G., & Setiani, 2022; Surya et al., 2022). A lack of enthusiasm in physics lectures sometimes undermines students' academic performance in the subject. Numerous research studies indicate that learning interest positively correlates with achievement in specific areas, such as physics (Mešić et al., 2019).

Based on Table 4, it is clear that nearly all of the substances are valid to use, except items quantities 5, 7, 13, 16, and 19, which require minor revision. Therefore, this item necessitates a slight evaluation, as the MNSQ value is rather close to the requirement. The division level displays anticipated results by validity. All chemicals fall within the classifications of 'very good' and 'good', while one item is categorized as 'satisfactory' but remains acceptable (Permana & Widodo, 2022).

Table 4. The Interpretation of Item Validity and Distinction Level

Question Number	Outfit		PT Measure All Corr.	Interpretation (Item Validity)	Interpretation (Distinction Level)
	MNSQ	ZSTD			
1	.56	-1.20	.54	Valid	Very Good
2	.52	-1.12	.48	Valid	Very Good
3	1.16	.44	.32	Valid	Good
4	1.06	.33	.44	Valid	Very Good
5	1.87	1.78	.20	Valid with revision	Enough
6	.86	-.03	.34	Valid	Good
7	1.96	1.72	.23	Valid with revision	Enough
8	1.08	.34	.57	Valid	Very Good
9	1.07	.32	.44	Valid	Very Good
10	1.06	.33	.55	Valid	Very Good
11	.76	-.25	.40	Valid	Good
12	1.32	.87	.32	Valid	Good
13	1.90	1.73	.25	Valid with revision	Enough
14	1.06	.33	.44	Valid	Very Good
15	.61	-.27	.34	Valid	Good
16	1.92	1.70	.23	Valid with revision	Enough
17	1.06	.33	.44	Valid	Very Good
18	.55	-1.14	.47	Valid	Very Good
19	1.94	1.71	.21	Valid with revision	Enough
20	1.04	.30	.52	Valid	Very Good

Questions about instruments that are considered valid but need changes indicate that, while they do measure what they are supposed to, some parts need improvement to make the measurements more accurate and relevant. This change may involve incorporating additional questions to expand the breadth of the knowledge assessed, altering the difficulty level, or enhancing the formulation of the questions.

One prerequisite for the tool's validity is that the instrument and materials employed are devoid of bias. If an instrument determines that one individual with specific characteristics is more advantageous than others, it is considered biased. For example, male students respond to things more readily than female students, indicating that the instrument exhibits gender bias. The researchers have performed analyses to see how different genders respond to test items using DIF results from WINSTEP 4.4.5 software (Susongko et al., 2019). The results of the bias analysis are illustrated in Figure 7.

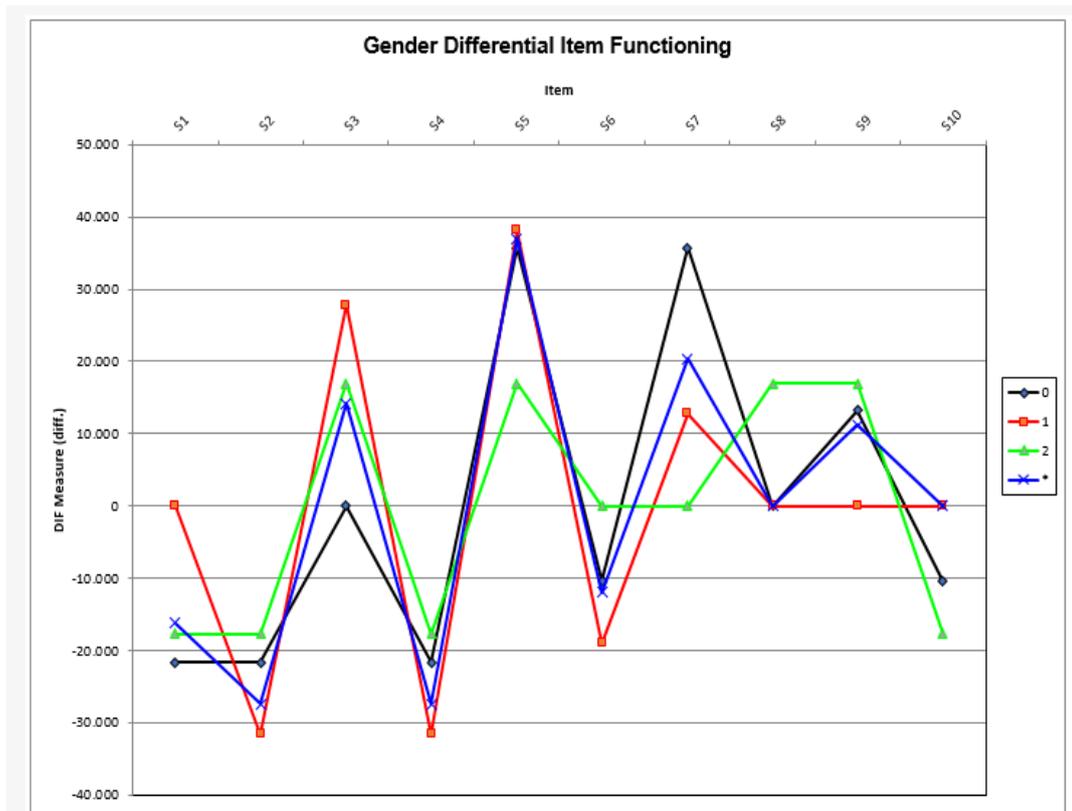


Figure 7. Gender Differential Functioning

As illustrated in the plot of Figure 7, the curve is gravitating towards the upper limit, which is item number 5 with a high level of difficulty, whereas the lower one, with item number 4, illustrates an easy level of complexity. In conclusion, we can assert that most of the questions are not gender biased, except question 5, which possesses a large gap between the two samples, female and male, though it is acceptable. The question requires minor re-evaluation, and for illustration, utilize ten data points to examine gender differential item performance.

Previous research has also shown the effectiveness of multi-level diagnostic instruments in identifying students' misconceptions regarding various physics concepts such as optics, force, and thermodynamics (Izzati & Rochmah, 2020; Suhandi et al., 2020). However, none of these papers employed the four-tier diagnostic instrument specifically for renewable energy and incorporated Rasch analysis as a psychometric process of validation. Further, while Potvin et al., (2020) discussed conceptual change models of learning science, their paper did not develop or validate a diagnostic instrument from these models.

This study, therefore, contributes to the existing literature in that it offers a new addition: the development and validation of a four-level diagnostic instrument (DITRET) on renewable energy problems using Rasch analysis. The integration of conceptual diagnosis with psychometric accuracy represents an original move in the field of physics education measurement.

LIMITATIONS

We must acknowledge the limitations of this study, despite its valuable insights into the tool of conceptual change. The findings of this study may lack generalizability due to the limited sample size, comprising just a small group of high school students from a single school in Bandung. Future studies should include expanding the sample size and incorporating individuals from diverse educational backgrounds to explore broader applications. Secondly, the intervention's length was notably short, and there was no assessment of the long-term retention of the conceptual change. Longitudinal studies may provide further insights into the long-term impacts of technology-integrated therapy. This study may exhibit bias due to its reliance on self-reported confidence levels in a four-tier diagnostic assessment.

CONCLUSION

The Diagnostic Instrument Test Renewable Energy Topics (DITRET) was systematically developed using the ADDIE framework, encompassing the stages of analysis, design, development, implementation, and evaluation. In the analysis phase, researchers identified relevant concepts and student uncertainties within the *Merdeka* curriculum, emphasizing the physical aspects of renewable energy. A four-tier diagnostic test was then designed—comprising a primary question, confidence level, reasoning, and justification confidence—and administered via Google Forms. Rasch analysis was applied to validate the instrument, confirming that the majority of items fell within acceptable statistical parameters (MNSQ: 0.5–1.5; ZSTD: -2.0–+2.0). Five items (5, 7, 13, 16, and 19) required minor revisions due to marginal deviations. Additionally, a Differential Item Functioning (DIF) analysis was conducted to detect potential gender bias, and the results indicated that the instrument was generally fair and unbiased. Overall, the DITRET instrument demonstrated strong validity and reliability, making it suitable for evaluating students' conceptual understanding in renewable energy contexts. Future studies may adapt this instrument to explore conceptual change across different science topics.

AUTHOR CONTRIBUTIONS

AZZ controlled the study design, implementation, data collection, statistical analysis, and recruiting of the manuscript. ASM and LKH donated to the conceptualization of the study, managed the research progression, on condition that critical modifications of the manuscript were made, providing organizational intuitions donated to the discussion segment, and facilitated refining the manuscript description to confirm consistency and current.

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