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Integrating the Certainty of Response Index (CRI) with Environmental Literacy and Creative Thinking Indicators to Analyze Misconceptions in Renewable Energy Learning among Vocational High School Students

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Abstract

This study investigates vocational high school students' misconceptions about renewable energy concepts using the Certainty of Response Index (CRI) and examines their relationship with environmental literacy and creative thinking skills. A descriptive quantitative design with a diagnostic approach was employed. The instruments consisted of a three-tier multiple-choice test for environmental literacy and a two-tier essay test for creative thinking, both validated through Aiken's V (V = 0.75–1.00; valid–highly valid) and piloted prior to implementation. CRI analysis revealed substantial misconceptions, particularly in energy transition (67%) and marine energy utilization (50%). Students demonstrated stronger understanding of concrete topics (e.g., fossil energy impact, IoT integration) but struggled with abstract or unfamiliar content. Creative thinking performance was weakest in originality and elaboration, with errors linked to limited contextual exposure and insufficient inquiry-based learning opportunities. Notably, high confidence often accompanied incorrect reasoning, indicating entrenched misconceptions. Statistical analysis indicated a moderate positive correlation between environmental literacy and creative thinking ($r = 0.56$, $p < 0.05$). These findings highlight the potential of integrating CRI-based diagnostics with STEAM–SDGs-oriented, project-based, and contextual learning to address misconceptions, enhance environmental literacy, and develop students' creative capacity. Such strategies are critical to bridging the knowledge–action gap and preparing students to tackle sustainable energy challenges in the era of the green economy.

How to Cite

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INTRODUCTION

Recent flood events in various regions across Indonesia such as those in Greater Jakarta, Semarang, Kendal, and parts of Kalimantan serve as stark reminders of the intensifying climate crisis and the ongoing degradation of environmental systems. These increasingly frequent extreme weather events are widely attributed to climate change, which is driven by greenhouse gas emissions from fossil fuel combustion (Milovanovic et al., 2022; Nkoana et al., 2016). In response, there is a growing call for urgent government action to transition toward clean, sustainable, and environmentally friendly energy sources, as advocated by Sustainable Development Goal (SDG) 7 (Ellianawati et al., 2025; Puspita, 2024; Sher et al., 2021).

Achieving a sustainable energy transition requires not only policy reform but also strong educational foundations. In this regard, preparing the younger generation to understand the concepts and implications of renewable energy becomes critical. This is especially relevant for students in vocational high schools (SMK), where the curriculum emphasizes practical and technical competencies that are directly aligned with real-world environmental and energy challenges (Akinwale et al., 2014; Ewim et al., 2023).

However, previous studies have revealed that students' conceptual understanding of energy particularly renewable energy remains limited and often marked by persistent misconceptions. A study conducted by Wahyuni et al. (2023) revealead misconceptions among 11th-grade at SMA Negeri 1 Tanjung Timur regarding the topic of energy and the law of conservation of energy, with a reported rate 20.2%. Similarly, Hasran et al.(2021) found that 49% of students experienced misconceptions related to energy and its transformations. Furthermore, Ustari et al. (2024) repoted that 45% of students exhibited misconceptions across all subconcepts of effort and energy. Classroom observations conducted during learning process corroborated these findings, revealing persistent misconceptions among students regarding fundamntal energy concepts, particularly fossil energy and rebewable energy. When asked about the origin of fossil fuels, several students responded that fossils only came from animals, lacking an understanding that plants are also contribute significantly ti the formation of fossil fuels. Additionally, some students believed that fossil fuels are inexhaustible and have minimal environmental impact. Regarding renewable energy, approximately 17 out of 30 students believed that solar energy can only be utilized during daylight and assumed that all forms of renewable energy are entirely environmentally harmless. These findings underscore the urgent need for more contextualized teaching strategies and the implementation of diagnostic assessment tools to accurately identify and address students' misconceptions in energy related topics (Habiddin & Page, 2019; Mulyani et al., 2020). The development of diagnostic instruments has led to a variety of formats ranging from two-tier, there-tier, to four-tier versions that combine students' answers, justifications and confidence levels to gain a more comprehensive understanding of concept mastery and to detect misconceptions more accurately (Hasran et al., 2021; Wahyuni et al., 2023)

One of the important components of these tiered instrument is the certainty of response index (CRI). In contrast to conventional assessments that only assess correct or false answers, CRI explains the extent to which students are confident in the answers they choose. Through a combination of the answer results and the confidence level, CRI provides more in-depth diagnostic information (Jarrah et al., 2022; Ningroom et al., 2025) Instruments based on CRI offer a holistic view of students' conceptual understanding while also revealing instances of misconception, ignorance or chance success (N, AM. Hindi et al, 2020; Turmuzi et al., 2024). In addition, this technique can also reflect students' ability to think creatively and reflective of the answers given, because students are invited to metacognitively assess their own beliefs in the answers given. Thus, CRI not only serves as an evaluation tool, but also as a means of reflective learning that encourages deeper awareness of concepts.

Students' misconceptions are often intertwined with insufficient environmental literacy and underdeveloped creative thinking skills. Environmental literacy reflects students' cognitive, affective and acting abilities in dealing with environmental issues, including in terms of energy management and utilization (Khuc et al., 2023; Santillán el al, 2023). Meanwhile, creative thinking skills such as fluency, flexibility, originality and elaboration are important requirements in understanding abstract and complex scientific concepts (Habibi et al., 2020; Sakdiah et al., 2023). The non-fulfillment of these two aspects often strengthens misconceptions in learning social studies.

Although studies have addressed misconceptions in energy learning, limited attention has been paid to vocational students who are poised to enter fields directly related to energy production and environmental management. Additionally, while the CRI has been applied in general education contexts, there is a notable lack of integrated frameworks that simultaneously consider conceptual understanding, environmental literacy, and creative thinking. Addressing these interrelated aspects holistically is vital in supporting students' readiness for the demands of a green economy and sustainable development (Nurwidodo et al., 2024; Qhutra Nada Salym et al., 2022).

This study seeks to explore the misconceptions surrounding renewable energy among students of SMK Bina Utama Kendal through the lens of the Certainty of Response Index (CRI). By examining students' confidence in their responses, alongside their environmental literacy and creative thinking skills, this research provides a multidimensional perspective that supports the design of more effective and responsive science instruction aligned with the objectives of SDG 7.

Amid Indonesia's national commitment to a green energy transition, vocational high school graduates are expected to play a strategic role as future practitioners and innovators. It is therefore essential to ensure that these students possess accurate conceptual knowledge, strong environmental awareness, and robust creative thinking skills. Accordingly, this study is theoretically and practically urgent for informing effective instructional strategies and diagnostic assessments that align with the targets of SDG 7. Based on this background, this study aims to analyze the misconception of renewable energy in students of SMK Bina Utama Kendal using the Certainty of Response Index (CRI) approach. It is hoped that the results of this research can contribute to the development of diagnostic instruments and Project-Based Learning strategies that are effective, participatory and relavan in fostering understanding of concepts, concern for the environment and the ability to think creatively in facing sustainable energy challenges.

METHOD

This study employed a descriptive quantitative method with a diagnostic approach to identify and analyze students' misconceptions related to the topic of renewable energy (Basimah Atsilah et al., 2020; Fatkhana et al., 2025). This approach was chosen to evaluate students' conceptual understanding while simultaneously assessing their confidence levels through the Certainty of Response Index (CRI) (Not et al., 2020; Pebrianto et al., 2021). The CRI framework is particularly effective in distinguishing between misconceptions and mere lack of knowledge, as it combines cognitive and metacognitive data by capturing both the correctness of students' answers and their perceived certainty. Such integration offers a more nuanced picture of learning difficulties than conventional assessments.

The primary participants of this study consisted of 30 students from Class X RPL 1 at SMK Bina Utama Kendal. Instrument testing and validation were conducted with 58 students from Class X TKJ 1 and X TKJ 2, who had received instruction on renewable energy and were assumed to have a comparable level of conceptual understanding. This sampling strategy ensured a robust preliminary evaluation before implementation with the main research group.

Two types of diagnostic instruments were developed:

1. A three-tier multiple-choice test designed to assess students' environmental literacy, and
2. A two-tier essay test aimed at evaluating creative thinking skills.

Each instrument was intentionally designed to probe students' understanding at various cognitive levels while identifying prevalent misconceptions. The three-tier structure included a content-based question, a reason for the selected answer, and a self-reported confidence level, enabling multi-layered analysis (Aas Uswatun Hasanah et al., 2023; Sari et al, 2019; Sulistyoningrum et al., 2024).

Content validation of both instruments was carried out by two experts in science education and assessment, employing Aiken's V technique to evaluate the clarity, relevance, and construct alignment of each item. Items with a V coefficient ≤ 0.75 were revised to enhance content validity and appropriateness before the trial phase (Ahmad et al., 2024).

The revised instruments were piloted with 58 validation participants to assess multiple psychometric aspects. The pilot phase focused on evaluating: (1) clarity of language and phrasing, to ensure that each item was easily understood by students; (2) difficulty level and discrimination index for each item, to determine their appropriateness and ability to differentiate between high and low performing students; (3) empirical validity, assessed using the point-biserial correlation coefficient to measure the relationship between individual item performance and the total test score; and (4) internal consistency reliability, measured using Cronbach's alpha coefficient to evaluate the instrument's overall reliability (Pfadt et al., 2022). Items that did not meet the minimum psychometric criteria were revised or removed in accordance with expert recommendations and statistical results. Data analysis was conducted using IBM SPSS Statistics version 25, ensuring rigorous and systematic estimation of reliability and validity.

After validation, the finalized instruments were administered to main participants. The responses were analyzed using a two-tier diagnostic framework for essay items targeting creative thinking and a three-tier diagnostic model for multiple-choice items targeting environmental literacy. These analyses enabled identification of specific misconceptions, levels of creative cognitive processing, and patterns of student confidence, contributing to a comprehensive diagnostic profile.

This research provides several key contributions to the field of science education. First, it presents a methodological innovation by combining CRI-based analysis with multi-tier diagnostics to assess both conceptual accuracy and confidence alignment. Second, it introduces a contextualized diagnostic instrument tailored to the renewable energy domain, a topic of global relevance in the current climate crisis. Finally, it contributes to improving pedagogical practices in vocational education, an area often underrepresented in educational research.

The findings of this study align with the goals of Sustainable Development Goal (SDG) 7 (Affordable and Clean Energy) and SDG 4 (Quality Education) by promoting environmental literacy and critical thinking on renewable energy topics. Moreover, the study supports national educational priorities in Indonesia, particularly the Merdeka Belajar initiative, which emphasizes student-centered learning and real-world problem-solving (Dey et al., 2022; Siregar et al., 2024; Trinh & Chung, 2023; Wijayarathne et al., 2023).

While the diagnostic instruments demonstrated strong validity and reliability, certain limitations must be acknowledged. The two-tier essay format, while rich in diagnostic depth, required considerable time for scoring and interpretation. Moreover, the sample size was limited to a single vocational school, which may constrain generalizability. Future studies are encouraged to expand the participant pool across multiple schools and to consider the use of digital platforms to automate diagnostic assessments.

RESULT AND DISCUSSION

The diagnostic test instruments developed in this study comprise two types: (1) a three-tier multiple-choice test designed to measure environmental literacy indicators, and (2) a two-tier essay test aimed at evaluating creative thinking skills. Prior to their deployment in the learning implementation phase, both instruments underwent a rigorous content validation and pilot testing process to ensure construct validity and practical feasibility.

Content validation was conducted by two experts specializing in science education and assessment, employing the Aiken's V technique to quantify the level of expert agreement on the quality of each item (Hidayah et al., 2023; Magara et al., 2021; Nurjanah et al., 2023). The experts assessed each question item using a Likert scale ranging from 1 to 5, after which the scores were converted into Aiken's V coefficients.

Table 1. presents the validity category criteria according to the Aiken's V interval values

Interval Value V	Validity Category
$0.80 < V \leq 1.00$	Highly Valid
$0.60 < V \leq 0.80$	Valid
$0.40 < V \leq 0.60$	Moderately Valid
$0.20 < V \leq 0.40$	Less Valid
$0.00 \leq V \leq 0.20$	Invalid

(Adapted from Ummah, 2019)

Based on these criteria, Table 2 summarizes the content validation results for the environmental literacy instrument items. Based on the results of content validation, all items in the environmental literacy instrument obtained Aiken's V coefficients greater than 0.75, indicating that none of the items were categorized as invalid or less valid. According to Azwar's (2012) classification, 10 out of the 12 items were rated as highly valid, while the remaining 2 items were considered valid.

These findings affirm that the instrument is feasible for use as an evaluative tool in STEAM-SDGs oriented science learning contexts. The validity of both content and item construction was rigorously examined by two experts using the Aiken's V methodology, which quantitatively measures the degree of agreement among experts regarding the relevance, clarity, and representativeness of each item. The results demonstrate that the instrument meets established standards of validity and is thus appropriate for assessing students' achievement in environmental literacy and higher-order thinking skills (HOTS)(Mulyono et al., 2023; Rizkia et al., 2022).

In addition to the environmental literacy items, the instrument also includes a set of items aimed at measuring students' creative thinking skills. Table 3 presents the results of the content validation for these items, which was conducted using the same Aiken's V technique. The objec-

Table 2. Results of Validation of Environmental Literacy Items Using Aiken's V

No	Aspects/Indicators	r_1	r_2	s_1	s_2	Σs	V	Validity Category
1	Alignment with environmental literacy indicators	5	4	4	3	7	0.875	Highly Valid
2	Contextual and engaging stimuli	4	4	3	3	6	0.750	Valid
3	Measurement of higher-order thinking skills (HOTS)	5	5	4	4	8	1.000	Highly Valid
4	Homogeneity of answer options and logical consistency	5	5	4	4	8	1.000	Highly Valid
5	Presence of a single correct answer	5	4	4	3	7	0.875	Highly Valid
6	Concise, clear, and unambiguous item wording	5	4	4	3	7	0.875	Highly Valid
7	Item does not provide cues to the correct answer	4	5	3	4	7	0.875	Highly Valid
8	Free from double negatives	5	5	4	4	8	1.000	Highly Valid
9	Item is self-contained and context-independent	4	5	3	4	7	0.875	Highly Valid
10	Linguistic appropriateness	5	4	4	3	7	0.875	Highly Valid
11	Communicative sentence structure	5	5	4	4	8	1.000	Highly Valid
12	Avoidance of unnecessary word repetition	4	4	3	3	6	0.750	Valid

tive was to ensure that each item effectively captures dimensions of creative thinking within the context of IPAS (Integrated Science) learning, framed by the integration of STEAM principles and Sustainable Development Goals (SDGs) values.

Table 3. Results of Validation of Creative Thinking Skills Items Using Aiken's V

No	Aspects/Indicators	r_1	r_2	s_1	s_2	Σs	V	Validity Category
1	Alignment with creative thinking skill indicators	5	4	4	3	7	0.875	Highly Valid
2	Contextual and engaging stimuli	4	4	3	3	6	0.750	Valid
3	Measurement of reasoning and higher-order thinking skills (HOTS)	5	5	4	4	8	1.000	Highly Valid
4	Homogeneity and logical consistency of answer choices	5	5	4	4	8	1.000	Highly Valid
5	Presence of a single correct answer	5	4	4	3	7	0.875	Highly Valid
6	Concise, clear, and unambiguous item formulation	5	4	4	3	7	0.875	Highly Valid
7	Item does not provide cues to the correct answer	4	5	3	4	7	0.875	Highly Valid
8	Free from double negatives	5	5	4	4	8	1.000	Highly Valid
9	Stand-alone items (not dependent on other questions)	4	5	3	4	7	0.875	Highly Valid
10	Linguistic appropriateness	5	4	4	3	7	0.875	Highly Valid

(Azwar, 2012)

Based on results of content validation conducted by two experts in science education, all 10 items designed to assess creative thinking skills achieved Aiken's V coefficients ranging from 0.75 to 1.00. According to the validity classification proposed by Azwar (2012), 8 out of 10 items (80%) were categorized as Highly Valid ($0.80 < V \leq 1.00$), while the remaining 2 items (20%) fell within the Valid category ($0.60 < V \leq 0.80$). No items were rated as Sufficiently Valid, Less Valid, or Invalid, indicating that each item meets the theoretical standards for content feasibility.

These findings confirm that the instrument is appropriate for use in assessing creative thinking skills within the framework of STEAM-SDGs-based IPAS learning. The use of Aiken's V analysis ensured a systematic and quantitative evaluation of item relevance, clarity, and alignment with targeted competencies (Nurjanah et al., 2023). Consequently, the validated instrument offers a reliable means of capturing students' creative cognitive performance in meaningful, contextual learning environments.

The results of the content validation indicate that the instrument possesses strong psychometric quality, particularly in terms of its alignment with the indicators of creative thinking skills, clarity and precision in item formulation, and the use of communicative language that minimizes semantic bias. Therefore, the instrument is considered feasible for subsequent trial stages without requiring major revisions (Firdaus et al., 2025; Tanjung et al., 2023).

Following the content validation phase, the instrument was administered to 58 students from Class X TKJ 1 and X TKJ 2, who had previously received instruction on renewable energy topics. These trial groups were selected based on the assumption of relatively homogeneous levels of conceptual understanding to ensure the reliability and validity of the empirical findings. The primary objective of this trial was to obtain empirical evidence of the instrument's construct validity and internal consistency through comprehensive item analysis, which included evaluations of item difficulty, discrimination power, empirical validity, and internal reliability. The trial was conducted in a controlled classroom environment, where students individually completed the CRI-based diagnostic test under standardized administration procedures. The implementation process involved a pre-test briefing, distribution of the test instruments, independent completion by students, and supervised collection of responses. Figure 1 provides classroom-based documentation of this implementation, capturing the administration of CRI-based diagnostic test items in both Class X TKJ 1 and X TKJ 2.

Item analysis is a critical phase in the development of valid and reliable assessment instruments, particularly within the context of evaluating environmental literacy. In this study, three core psychometric parameters were analyzed: item difficulty index (P), discrimination index (D), and empirical validity, calculated using the point-biserial correlation coefficient (r_pb)(Fiore et al., 2024; Yasaroh et al., 2023). These parameters serve to determine how effectively each item measures students' cognitive abilities, discriminates between high- and low-performing students, and reflects the strength of association between item responses and total test scores.

The item difficulty index (P) indicates the proportion of students who correctly answered a particular item relative to the total number of test-takers (Yan et al., 2023). This value provides insight into whether an item is classified as easy, moderate, or difficult. The classification criteria for item difficulty levels are presented in Table 4.

Table 4. Question Difficulty Level Categories

P Value	Category
$P < 0.30$	Difficult
$0.30 \leq P \leq 0.70$	Moderate
$P > 0.70$	Easy

Ideally, question items should fall within the moderate category, as these items are considered most effective in providing diagnostic information regarding students' overall abilities. The discrimination index (D) reflects the capacity of an item to differentiate between students with high and low levels of competence. This index is calculated based on the difference in the proportion of students in the upper and lower groups who answered the item correctly. The interpretation of D values is presented in Table 5.

Table 5. Discrimination Index Categories

D Value (Discrimination Index)	Category
$D \geq 0.40$	Excellent
$0.30 \leq D < 0.40$	Good
$0.20 \leq D < 0.30$	Fair
$0.00 \leq D < 0.20$	Poor
$D < 0.00$	Worst

In the context of higher-order thinking skills (HOTS) assessments, items with a discrimination index of at least fair ($D \geq 0.20$) are considered sufficiently effective for use as evaluative instruments.

Furthermore, empirical validity was assessed using the point-biserial correlation coefficient (r_pb), which quantifies the relationship between students' correct responses to an item and their total test scores. A high correlation suggests that the item contributes meaningfully to measuring the intended construct. The interpretation of r_pb values is shown in Table 6.

Table 6. Empirical Validity Criteria (Point-Biserial Correlation)

r_pb Value	Interpretation
≥ 0.40	Excellent
0.30 – 0.39	Good
0.20 – 0.29	Fair
0.00 – 0.19	Weak
< 0.00	Invalid

Based on these parameters, item analysis was conducted on 10 multiple-choice questions designed to assess environmental literacy. The objective of this analysis was to evaluate the overall quality of the instrument in terms of difficulty, discrimination, and empirical validity, ensuring its suitability for implementation in STEAM-SDGs-based science learning assessments.

Results of the Environmental Literacy Question Analysis

Item analysis was conducted on ten multiple-choice questions aimed at assessing students' environmental literacy, focusing on three psychometric properties: difficulty level (P), discrimination index (DP), and empirical validity measured through the point-biserial correlation coefficient (r_pb). The results of this analysis are summarized in Table 7.

The analysis of essay question items aims to assess the quality of evaluation instruments based on the ability to measure students' creative thinking skills. The creative thinking skills analyzed include four main indicators, namely: fluency, flexibility, originality, and elaboration. To assess the quality of the questions, three main parameters were used, namely difficulty level (P), differentiating power (DP), and empirical validity through biserial point correlation (r-calculus).

The level of difficulty indicates how easy or difficult a question is answered by the learner. Differentiating power reflects the ability of questions to distinguish between high and low ability students. Meanwhile, empirical validity based on biserial point correlation provides an idea of extent to which the score in each question item correlates with the total score, which is an indicator of the validity of the construct of the question.

Table 7. Item Analysis Results of Environmental Literacy Multiple-Choice Questions

No	Item Code	Difficulty Level (P)	Difficulty Category	Discrimination Index (DP)	Discrimination Category	r_pb	Empirical Validity Category	Decision
1	S1	0.52	Moderate	0.42	Good	0.47	Good	Accepted
2	S2	0.67	Moderate	0.36	Good	0.41	Good	Accepted
3	S3	0.47	Moderate	0.31	Good	0.36	Fair	Accepted
4	S4	0.40	Moderate	0.18	Poor	0.28	Fair	Revised
5	S5	0.35	Moderate	0.21	Fair	0.29	Fair	Revised
6	S6	0.62	Moderate	0.38	Good	0.45	Good	Accepted
7	S7	0.55	Moderate	0.44	Good	0.50	Excellent	Accepted
8	S8	0.58	Moderate	0.32	Good	0.40	Good	Accepted
9	S9	0.70	Easy	0.26	Fair	0.39	Fair	Accepted
10	S10	0.62	Moderate	0.48	Excellent	0.51	Excellent	Accepted

The following Table 8 presents analysis of the results of creative thinking skills essay questions based on three parameters, namely level of difficulty, differentiation, and empirical validity.

Table 8. Analysis of Creative Thinking Skills Essay Questions

No	Question Code	Dominant Indicator	Difficulty Index (P)	Difficulty Category	Discriminating Power (DP)	Discriminating Category	r-count	Empirical Validity Category	Decision
1	E1	Fluency	0.58	Moderate	0.41	Good	0.49	Good	Accepted
2	E2	Flexibility	0.44	Moderate	0.39	Good	0.42	Good	Accepted
3	E3	Originality	0.37	Moderate	0.26	Fair	0.34	Fair	Accepted
4	E4	Elaboration	0.32	Moderate	0.18	Poor	0.25	Fair	Revision
5	E5	Flexibility	0.71	Easy	0.33	Good	0.38	Fair	Accepted

The analysis results indicated that all essay questions fell within the moderate to easy difficulty range, which is considered optimal for assessment purposes. Among the five items, three (E1, E2, and E5) demonstrated good discriminating power, while one item (E3) showed fair discriminative ability. Item E4 exhibited poor discriminating power, indicating the need for revision to enhance its capacity to distinguish between varying levels of student performance.

In terms of empirical validity, all items recorded biserial point correlation values (r-count) ≥ 0.25, suggesting a positive association with the total test score. Nonetheless, items E3 through E5 were categorized as having only fair validity, highlighting the need for refinement in their formulation to improve alignment with the intended constructs. Overall, four out of five essay questions were deemed acceptable, while item E4 is recommended for revision to improve the overall quality and diagnostic value of the instrument.

Items that did not meet the criteria for validity or reliability were either revised or eliminated based on the results of the pilot testing. Revisions were applied to items with potential for improvement, particularly in terms of wording clarity and the precision of distractors, while items with persistently poor psychometric properties were excluded. This process adhered to the principles of content validation and internal consistency, and involved expert review from both subject matter and educational evaluation specialists. Their input ensured that each item accurately and representatively measured indicators of environmental literacy and creative thinking skills (Al-Muhdhar et al., 2021; Napitupulu et al., 2025; Qhutra Nada Salym et al., 2022).

Following validation and reliability confirmation, the final instrument was administered to the main study participants, consisting of 30 students from Class X RPL 1. The resulting data served as the primary source for analyzing students' conceptual understanding using a two-tier diagnostic approach for assessing creative thinking skills, and a three-tier diagnostic framework for evaluating environmental literacy. These diagnostic models were selected for their capacity to assess not only the level of conceptual mastery but also to identify misconceptions and gauge the students' confidence in their responses, thereby providing deeper insight into student learning within STEAM-SDGs-based instructional context.

Analysis of Student Comprehension Profile

The analysis of students' conceptual comprehension in this study adopts the three-tier diagnostic model developed by Subakti et al., 2020 and Rosyada et al., 2021, which integrates three essential components: response accuracy (Tier 1), reasoning quality (Tier 2), and the level of confidence as measured by the Certainty of Response Index (CRI) (Tier 3). This comprehensive framework enables the classification of students' conceptual understanding into five diagnostic categories: Conceptual Understanding, Misconception, Correct Guessing, Lack of Understanding, and Discomprehension, as outlined in Table 9.

Table 9. Classification Matrix of Conceptual Understanding Based on Three-Tier

Tier 1 (Answer)	Tier 2 (Reason)	Tier 3 (CRI)	Classification of Student Understanding
True	True	Sure	Conceptual Understanding
True	False	Sure	Misconception
False	True	Sure	Misconception
False	False	Sure	Misconception
True	True	Not Sure	Correct Guessing
True	False	Not Sure	Lack of Understanding
False	True	Not Sure	Lack of Understanding
False	False	Not Sure	Discomprehension

This classification illustrates how the intersection of answer correctness, reasoning alignment, and confidence level (CRI) can be used to holistically categorize students' conceptual understanding (Al-Shanfari et al., 2020; Preheim et al., 2023). Unlike conventional assessments that only capture the correctness of answers, the three-tier diagnostic approach delves into students' cognitive processes by also revealing the rationale behind their choices and their confidence in those choices.

Such a nuanced framework is particularly useful for diagnosing common misconceptions, assessing conceptual depth, and identifying uncertainty in learning. The resulting data can inform evidence-based instructional strategies and targeted remedial actions, thereby enhancing the effectiveness of science learning, particularly within STEAM-SDGs-oriented curricula.

Data collection was conducted using a three-tier diagnostic test instrument administered via Google Form. The instrument consisted of: (1) selection of an answer option (Tier 1), (2) justification for the selected answer (Tier 2), and (3) confidence rating using the Certainty of Response Index (CRI) (Tier 3). The use of Google Form was strategically chosen for its efficiency in test administration, its accessibility for students, and its capability to streamline data classification through automated processing.

To better illustrate the procedure, Figure 2 replaces the previous activity image with a more informative schematic diagram showing the sequential stages of the diagnostic assessment for both the three-tier and two-tier test formats. The three-tier format was used to assess environmental literacy, while the two-tier format was designed to measure creative thinking skills. This visualization facilitates a clear understanding of the assessment workflow, from test preparation to data acquisition and classification.

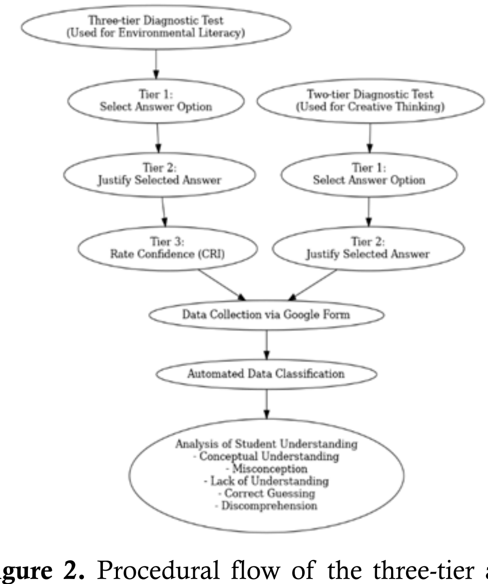

Figure 2. Procedural flow of the three-tier and two-tier diagnostic test implementation

The collected data were subsequently analyzed to determine students' conceptual comprehension profiles regarding environmental literacy in the context of renewable energy. Following the classification framework of Safriana et al. (2021), student responses were categorized into five diagnostic types: Conceptual Understanding, Misconception, Lack of Understanding, Correct Guessing, and Discomprehension.

This diagnostic framework facilitates the identification of prevalent misconceptions and conceptual gaps that require instructional reinforcement (Laeli et al., 2023). For instance, items predominantly categorized under Misconception suggest a fundamental misunderstanding that necessitates targeted instructional strategies such as the use of analogies, formative feedback, or inquiry-based learning interventions.

Conversely, high frequency of Correct Guessing or Discomprehension responses reveals issues related to students' cognitive uncertainty and confidence levels. Such patterns highlight importance of incorporating motivational scaffolding, reflective metacognitive activities, and improved conceptual clarity within instructional design.

The three-tier diagnostic test provided a comprehensive profile of students' conceptual understanding in environmental literacy within the context of renewable energy. By integrating three dimensions answer accuracy (Tier 1), reasoning quality (Tier 2), and confidence level (Tier 3) student responses were classified into five diagnostic categories: Conceptual Understanding, Misconception, Lack of Understanding, Correct Guessing, and Discomprehension. This multidimensional classification offers valuable insights into both cognitive accuracy and students' epistemic beliefs and reasoning strategies.

Accordingly, the diagnostic outcomes not only info Accordingly, the diagnostic outcomes derived from the three-tier test not only provide a nuanced understanding of students' conceptual mastery but also serve as a robust evidence base for designing adaptive, targeted, and contextually relevant pedagogical interventions within STEAM–SDGs-based science education. Building upon the earlier analysis of misconception patterns and cognitive confidence levels, these results underscore the need for instructional designs that strategically address both content-related misunderstandings and the underlying metacognitive factors influencing student learning. To further contextualize these findings, the distribution of responses across the five diagnostic categories Conceptual Understanding, Misconception, Lack of Understanding, Correct Guessing, and Discomprehension is summarized in Table 10, offering a concise yet informative snapshot of prevailing learning outcomes while simultaneously identifying critical areas that warrant focused instructional reinforcement. This empirical mapping strengthens the linkage between diagnostic assessment and evidence-based curriculum refinement, ensuring that targeted interventions directly address the most pressing conceptual and cognitive gaps identified in the cohort.

Following global patterns observed in Table 10, more granular analysis was conducted to explore students' understanding across specific sub-concepts embedded within assessment items. Each item was first mapped to a corresponding sub-concept, after which student responses were analyzed and categorized based on same five-tier diagnostic scheme. The percentage students falling into each category was calculated per item and subsequently aggregated subconcept domain.

Table 10. Recapitulation of Conceptual Understanding Categories Based on Three-Tier Diagnostic Analysis

Question 1			Interpretasi	Question 2			Interpretasi	Question 3			Interpretasi	Question 4			Interpretasi
Tier 1	Tier 2	Tier 3		Tier 1	Tier 2	Tier 3		Tier 1	Tier 2	Tier 3		Tier 1	Tier 2	Tier 3	
B	S	Sure	Misconceptions	S	S	sure	Misconceptions	B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding
B	S	Sure	Misconceptions	S	S	Not Sure	Discomprehension	S	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	S	Sure	Misconceptions	S	S	Not Sure	Discomprehension	B	B	Not Sure	Correct Guessing
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding	S	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding
B	S	Not Sure	Lack of understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Not Sure	Correct Guessing
B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding
B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Sure	Conceptual Understanding	B	B	Yakin	Paham konsep
B	S	Sure	Misconceptions	B	S	Not Sure	Lack of understanding	B	S	Tidak Yakin	Kurang Paham	B	S	Yakin	Miskonsepsi
B	S	Sure	Misconceptions	B	B	Sure	Conceptual Understanding	B	B	Yakin	Paham konsep	B	B	Yakin	Paham konsep

This sub concept level analysis enables educators and researchers to identify which areas of content have been well internalized by learners and which remain problematic. Moreover, it provides an empirical foundation for designing differentiated instructional strategies aimed at addressing specific misconceptions or reinforcing fragile conceptual frameworks. The detailed mapping of students' conceptual understanding by sub-concept is presented in Figure 3.

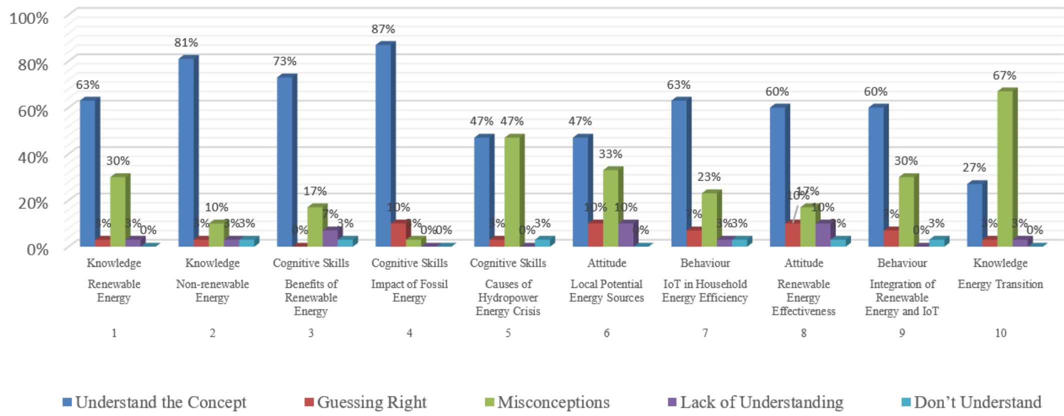

Figure 3. Distribution of Students' Conceptual Understanding across Ten Energy-Related Sub-Concepts Aligned with Environmental Literacy Indicators

Figure 3 illustrates the distribution of students' conceptual understanding across ten energy-related sub-concepts, as assessed using a three-tier diagnostic test aligned with environmental literacy indicators. The analysis refers to the four core components of the Middle School Environmental Literacy Survey (MSELS): knowledge, cognitive skills, attitudes, and behavior.

Each sub-concept is categorized into five diagnostic outcomes: (1) Understand the Concept, (2) Guessing Right, (3) Misconceptions, (4) Lack of Understanding, and (5) Don't Understand. These categories enable a nuanced classification of student cognition, distinguishing between accurate conceptual grasp, probabilistic guessing, and cognitive inconsistencies or gaps.

The results show that students exhibit a relatively high level of conceptual understanding in domains such as impact of fossil energy (87%), non-renewable energy (81%), and benefits of renewable energy (73%). Conversely, substantial conceptual difficulties observed in energy transition (67% misconceptions, only 27% understanding) and causes of hydropower energy crisis (47% misconceptions), indicating critical area targeted instructional intervention is warranted.

Behavioral and attitudinal sub-concepts such as local potential energy sources, IoT energy applications in households, and renewable energy effectiveness display moderate understanding (47–63%) but are accompanied by notable misconceptions (17–33%), revealing an incomplete internalization of energy-related actions and values. These findings emphasize the importance of integrating contextualized learning, systems thinking, and socio-scientific reasoning to enhance environmental literacy beyond factual recall.

The diagnostic patterns highlight that while declarative knowledge is relatively well-developed, interpretive reasoning and behavior-oriented literacy remain fragile. These results have implications for curriculum design, suggesting the need to scaffold not only content knowledge but also cognitive engagement and real-world application through interdisciplinary and inquiry-based pedagogies.

Causes of Misconceptions in Understanding Renewable Energy Concepts in Relation to Environmental Literacy Indicators

Figure 3 illustrates that students' misconceptions regarding renewable energy are not merely the result of individual misunderstanding, but rather reflect broader challenges within the instructional process. These causes can be interpreted through four key components of environmental literacy: knowledge, cognitive skills, attitudes, and behavior.

From the knowledge perspective, misconceptions often emerge due to the abstract nature of instruction and the lack of contextual relevance. Concepts such as renewable energy and energy transition are frequently presented without clear linkage to students' everyday experiences or local environments, making them difficult to internalize. This condition underscores the importance of employing more concrete, localized, and visually supported teaching strategies to enhance conceptual clarity.

In terms of cognitive skills, students tend to memorize facts in isolation, lacking the ability to connect them within a broader, systemic framework. The limited development of critical and reflective thinking further inhibits students from integrating energy related knowledge with environmental and societal dimensions. As a result, their conceptual understanding remains fragmented and superficial.

Regarding attitudes, the low level of awareness about local and global environmental issues contributes to a weak sense of relevance and urgency concerning sustainable energy (Anas Bassam Barnawi et al., 2025).This indicates a shortfall in value-oriented education, which ideally nurtures empathy for the environment and a sense of personal and collective responsibility.

From the behavioral standpoint, students may possess theoretical knowledge about smart energy technologies, such as Internet of Things (IoT) or smart homes, but often struggle to apply these concepts in real-life contexts (Laporte et al., 2024). This gap is largely attributed to limited opportunities for experiential, hands-on, or project-based learning enables meaningful application.

In summary, the persistence of misconceptions in renewable energy concepts signals the need for a more holistic, contextual, and participatory pedagogical approach (Lucas et al., 2021). Integrating STEAM (Science, Technology, Engineering, Arts, and Mathematics) with the Sustainable Development Goals (SDGs) offers a strategic pathway to enhance environmental literacy by fostering deeper understanding, critical thinking, and real-world engagement.

General Analysis and Pedagogical Implications

The findings indicate that students' knowledge and cognitive skills outperform their attitudes and behaviors, revealing a persistent knowledge–action gap in environmental literacy. Misconceptions are not only rooted in misinformation but also in decontextualized learning, lack of hands-on experience, and weak integration of energy concepts with sustainability issues.

To address this gap, more transformative strategies are required, including:

1. Implementation of the STEAM-SDGs model to connect science with real-world contexts;
2. Use of visual media, simulations, and local case studies to enhance understanding and engagement;
3. Project-based learning focused on real actions to build pro-environmental behaviors.

Environmental literacy was measured using MSELS based instruments, while creative thinking was assessed through two-tier diagnostic essays incorporating the Certainty of Response Index (CRI). This dual approach allows for simultaneous evaluation of conceptual understanding, creative reasoning, and confidence levels, offering a holistic view of students' competencies on renewable energy issues.

Classification of Concept Understanding

The analysis of students' conceptual understanding in this study is grounded in the two-tier diagnostic test model originally developed by Treagust (1988), which consists of two components: a multiple-choice question (response) and a corresponding justification (reasoning). This model was subsequently adapted and refined by Arifah et al. (2022) through the integration of a Certainty of Response Index (CRI), enabling the assessment of students' confidence in their responses.By combining answer accuracy with confidence levels, this approach offers a more robust diagnostic framework to differentiate between conceptual understanding, misconceptions, and uncertain or guessed responses.

In the context of essay-based diagnostics, this model was further enriched by including an open justification component, allowing for deeper insights into students' reasoning processes and the originality of their conceptual frameworks. The classification criteria used in this study are summarized in Table 11.

Table 11. Classification of Concept Understanding Based on Two-Tier Model

Question 1			Intepretasi	Question 2			Intepretasi	Question 3			Intepretasi	Question 4			Intepretasi	Que	
tier 1		tier 2		tier 1		tier 2		tier 1		tier 2		tier 1		tier 2		tier 1	
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S
2	S	Sure	Misconceptions	2	S	Sure	Misconceptions	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	2	S
4	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	4	B
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	2	S	Sure	Misconceptions	3	B
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	1	S	Sure	Misconceptions	2	S
2	S	Sure	Misconceptions	4	B	Sure	Conceptual Understanding	2	S	Not Sure	Lack of Understanding	3	B	Sure	Conceptual Understanding	1	S
3	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	2	S
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	2	S
4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B
4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B	Not Sure	Correct Guessing	3	B
3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	1	S	Not Sure	Tidak Paham Konsep	2	S	Sure	Misconceptions	2	S
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	1	S	Sure	Misconceptions	2	S
3	B	Not Sure	Correct Guessing	1	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S
3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	1	S
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	1	S
4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	4	B
1	S	Not Sure	Lack of Understanding	2	S	Sure	Misconceptions	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B
4	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B
2	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B	Sure	Conceptual Understanding	3	B
3	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	2	S	Sure	Misconceptions	3	B	Sure	Conceptual Understanding	3	B
3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Not Sure	Lack of Understanding	4	B	Sure	Conceptual Understanding	4	B
3	B	Not Sure	Correct Guessing	2	S	Not sure	Lack of Understanding	3	B	Not Sure	Correct Guessing	4	B	Not Sure	Correct Guessing	2	S
2	S	Not Sure	Lack of Understanding	3	B	Sure	Conceptual Understanding	4	B	Sure	Conceptual Understanding	2	S	Sure	Misconceptions	1	S

Essay Analysis Based on Creative Thinking Skills and Conceptual Understanding

This study employed a CRI-based two-tier diagnostic model to simultaneously assess students' conceptual understanding of renewable energy and their creative thinking skills, aligned with Torrance's indicators: fluency, flexibility, originality, and elaboration.

Each item required open-ended responses, confidence ratings, and conceptual justification. This design enabled nuanced identification of understanding, misconceptions, and reasoning patterns. Figure 4 presents the proportion of student responses in four categories understands concept, correct guess, misconception, and does not understand across the creative thinking indicators.

Figure 4 presents an analysis of five essay questions designed to assess students' creative thinking skills: fluency, flexibility, originality, and elaboration alongside their conceptual understanding in the context of energy and sustainable technology. Each question was evaluated based on the percentage of students who: (1) understood the concept, (2) guessed correctly, (3) demonstrated misconceptions, and (4) did not understand the concept.

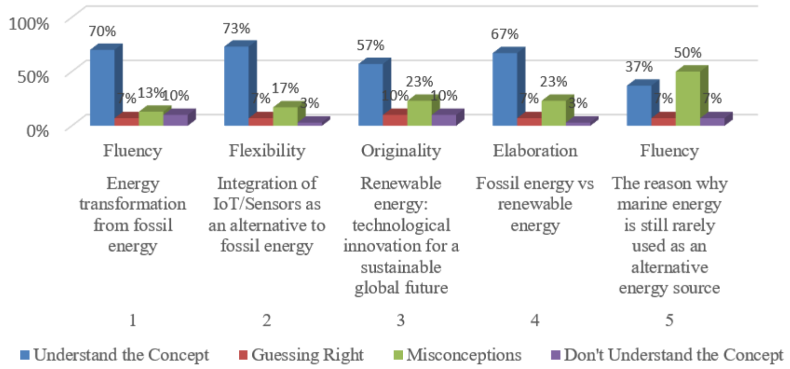

Figure 4. Presents an analysis of five essay questions designed to assess students' creative thinking skills

The results indicate that the highest level of conceptual understanding (73%) was observed in questions targeting flexibility (IoT/sensors integration), whereas the lowest (37%) was in questions related to fluency on marine energy utilization, which also had the highest rate of misconceptions (50%). Questions emphasizing originality and elaboration showed moderate conceptual grasp but revealed significant misconceptions (23% each), especially when students were asked to compare fossil and renewable energy or to reflect on global energy innovation. These findings highlight the need for more contextual and inquiry-based learning approaches to support bothcreative skill development and conceptual clarity, particularly in emerging and complex energy topics.

Causes of Student Misconceptions Based on Creative Thinking Skill Indicators

An analysis of student misconceptions across five essay questions revealed distinct patterns linked to specific creative thinking skill indicators. In Question 1 (Fluency), which addressed energy transformation from fossil fuels, misconceptions primarily stemmed from a lack of visual and contextual learning aids. Without interactive simulations or integrated explanations connecting physical and chemical energy processes, students struggled to generate multiple relevant ideas, leading to fragmented understanding.

In Question 2 (Flexibility), involving the integration of IoT and sensors as alternatives to fossil energy, misconceptions emerged due to limited exposure to real-world technological applications. Students were unable to adapt their knowledge across contexts, as learning was heavily theoretical and disconnected from practical examples restricting their ability to shift perspectives, a key component of cognitive flexibility.

Question 3 (Originality), which required students to think creatively about innovations in renewable energy, showed a higher rate of conceptual errors. The cause was largely instructional: learning environments lacked opportunities for idea exploration and originality. As a result, students defaulted to recalling known facts rather than proposing novel solutions or demonstrating divergent thinking.

In Question 4 (Elaboration), which compared fossil and renewable energy, misconceptions were linked to underdeveloped elaborative skills. Students tended to give generic, descriptive answers rather than deep, evidence-based analyses. This was due to insufficient use of support tools such as comparative data, case studies, or visual representations that could have enabled them to expand and justify their reasoning.

Finally, Question 5 (Fluency), on the topic of marine energy, had the highest rate of misconception. Students' unfamiliarity with marine-based technologies and the absence of contextualized learning materials significantly limited their ability to fluently express ideas. The lack of foundational knowledge made it difficult for them to even begin forming accurate conceptual responses.

Collectively, these findings point to the critical role of pedagogical design in shaping conceptual understanding. Misconceptions across all questions were not merely due to content difficulty but were exacerbated by the absence of contextual, visual, and project-based learning strategies that support creative thinking. Integrating STEAM–SDG frameworks with real-world applications and digital media tools appears essential for addressing these gaps and fostering both conceptual accuracy and creative capacity in science education.

General Conclusions and Learning Implications

The diagnostic analysis reveals that students show stronger understanding in concrete, application-based energy topics (e.g., fossil energy transformation, IoT integration), but struggle with abstract and less familiar themes such as future innovations and marine energy. High levels of misconception in these areas highlight limitations in students' originality and elaboration core aspects of creative thinking.

These findings emphasize the need for learning approaches that are not only conceptually diagnostic but also creativity driven. To address this, educators should implement project-based learning, contextualized content, and visual digital tools, while embedding STEAM–SDGs frameworks consistently. Such strategies are essential to enhance both conceptual mastery and students' creative capacity to engage with sustainability challenges in the green economy era.

CONCLUSION

This study demonstrated that the use of a three-tier multiple-choice instrument incorporating the Certainty of Response Index (CRI) was effective in diagnosing students' levels of understanding, misconceptions, and confidence regarding renewable energy concepts, aligned with environmental literacy indicators. The results indicate that vocational school students exhibit solid comprehension of concrete subconcepts, such as energy transformation and IoT-based energy efficiency. However, substantial misconceptions reaching up to 50% were identified in more abstract subconcepts, such as the hydropower energy crisis and the transition toward renewables. Complementary analysis using a two-tier essay instrument revealed that students' creative thinking skills, particularly in originality and elaboration, remain underdeveloped. This is attributed to limited exposure to contextual learning environments that stimulate idea generation, and to insufficient integration of STEAM principles and Sustainable Development Goals (SDGs) in science instruction. Content validation and empirical testing confirmed that both instruments possess strong validity and reliability, making them suitable for accurately profiling students' conceptual understanding and creative thinking capacities. In particular, the CRI model effectively distinguishes between genuine understanding, misconceptions, and guesswork. These findings underscore the critical need for learning innovations that combine concept-diagnostic assessment with project-based learning, scientific visualization, and the systematic integration of STEAM–SDG frameworks. Such approaches are essential to addressing persistent misconceptions, enhancing environmental literacy, and fostering the creative competencies of vocational students in a contextually relevant and sustainability-oriented educational setting.

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