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The Implementation of Lumio Interactive Learning Media to Improve Students' Conceptual Understanding of Energy and Its Transformations

Alya Zahara*, Zulirfan, and Muhammad Nor

Physics Education Study Program, Universitas Riau, Bina Widya Campus KM. 12,5, Tampan, Pekanbaru, Riau, Indonesia

* Corresponding author(s), e-mail: alya.zahara1261@student.unri.ac.id

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Abstract:

Conceptual understanding is a crucial aspect of science education in vocational schools; however, the learning process, which is still largely dominated by lecture methods and minimal use of interactive media, often renders students passive and less able to grasp the material. This study aims to describe the level of students' conceptual understanding and to evaluate the effectiveness of Lumio, a SMART interactive learning media, on the subject of energy and its transformations. The study used a quasi-experiment with a non-equivalent posttest-only control group design, involving two 10th-grade groups at SMK Dar El Hikmah Pekanbaru. The experimental group learned using Lumio by SMART, while the control group used conventional PowerPoint. Data were obtained through a concept comprehension test covering seven indicators of concept comprehension, namely interpreting, exemplifying, classifying, summarizing, concluding, comparing, and explaining. Data were analyzed descriptively and inferentially through an independent sample t-test. The descriptive analysis results showed that the average score of the experimental group was 70.11 in the Good category, higher than the control group at 59.95 in the Fair category. Inferentially, there was a significant difference between the two groups with Sig. = 0.008 < 0.05, indicating that Lumio by SMART was effective in improving students' conceptual understanding. Thus, the Lumio by SMART interactive learning media has been proven to improve the quality of natural and social sciences learning, particularly in the subject of energy and its transformations.

1. Introduction

Education plays an important role in improving the quality of human resources and determining the progress of a nation. Law Number 20 of 2003 concerning the National Education System explains that education is a planned effort to create a learning process that enables students to develop their potential, talents, and interests optimally (Rani, 2022). Schools, as formal educational institutions, serve to realize these objectives through structured learning activities (Setyosari, 2017). However, classroom learning practices are still dominated by lecture methods, with limited use of learning media. This condition causes learning, especially in physics, to be less interesting and makes students passive, which results in low learning outcomes and conceptual understanding (Winarti et al., 2021). Similar problems are also found in Vocational High Schools (SMK), where physics is often considered difficult theoretical material, even though mastery of physics concepts is important to support students' vocational competencies (Patandean et al., 2023).

The low level of scientific concept mastery among Indonesian students is reflected in the results of the 2022 Programme for International Student Assessment (PISA), which shows that only 34% of Indonesian students are at Level 2 or above in science literacy, far below the OECD average of 76% (OECD, 2023). At this level, students are only able to recognize basic scientific explanations, while almost none reach Levels 5–6, which require advanced scientific thinking skills. These findings indicate that science education, including physics in vocational schools, needs to focus on strengthening conceptual understanding rather than merely procedural memorization (Maisaroh and Mayasari, 2018).

The characteristics of learning in vocational schools require a more contextual and applied approach than in senior high schools. Government Regulation No. 29 of 1990 Article 3 emphasizes that vocational education aims to equip students with professional skills and attitudes so that they are ready to enter the workforce. In IPAS subjects, physics concepts are presented alongside other science materials, requiring learning media that can connect abstract concepts with students' real experiences (Rochaenah and Linuwih, 2024). Therefore, learning innovations that utilize technology are needed to help students understand concepts more meaningfully.

The development of digital technology provides a great opportunity to improve the quality of learning. The rapid use of mobile devices has made students more familiar with interactive and flexible digital learning resources (Marinda and Rakhmawan, 2025). Teachers are now required to be able to utilize digital media as an effective means of learning communication (Sukinarti et al., 2024). Interactive learning media has become one of the alternatives that has been widely developed because it can increase students' attention, motivation, and understanding (Astuti et al., 2017; Dasmo et al., 2020; Berasa and Desnita, 2023).

Lumio by SMART is one of the rapidly growing interactive learning media. This media is a web-based digital platform that provides interactive learning activities, videos, quizzes, exercises, and collaborative features that can be accessed through any device (Andayani et al., 2024). Several studies have reported that the use of Lumio by SMART can improve learning outcomes, motivation, and students' reasoning skills (Relawati et al., 2024; Siregar et al., 2024; Thohir et al., 2024). However, research specifically examining the effectiveness of using Lumio by SMART in improving conceptual understanding of energy and its transformations in the context of vocational schools still needs to be further explored.

Various studies in Indonesia show that students' understanding of physics concepts, especially energy and its transformations, is still relatively low. These difficulties are characterized by the emergence of misconceptions, a low ability to relate concepts to everyday phenomena, and a weak ability to explain concepts scientifically. This condition is influenced by the dominance of conventional learning and the limited use of learning media that can visualize concepts dynamically and contextually (Rochaenah and Linuwih, 2024). Most of these studies still focus on improving learning outcomes in general. Studies that specifically place interactive learning media as a means of building conceptual understanding of energy and its transformations, particularly in the context of vocational education, are still relatively limited. Thus, research is needed that not only describes learning outcomes but also tests the effectiveness of interactive learning media in meaningfully improving students' conceptual understanding.

Therefore, this study is novel in its assessment of the effectiveness of interactive learning media as a means of building students' understanding of physics concepts, particularly in the context of vocational education, with a focus on energy and its transformations. Based on this description, this study applied Lumio by SMART interactive learning media to the subject of energy and its transformations in the 10th-grade at SMK Dar El Hikmah Pekanbaru. This study aims to

1. Describing Lumio by SMART-based interactive learning media applied in teaching Energy and Its Transformations.
2. Describe the level of students' conceptual understanding after the implementation of Lumio by SMART interactive learning media on the material of energy and its transformations.

3. Test the effectiveness of using Lumio by SMART interactive learning media in improving students' conceptual understanding of the material of energy and its transformations.

2. Theoretical Framework

2.1. Conceptual Understanding

Conceptual understanding is the ability of students to master the meaning of a concept and apply it in various learning contexts and everyday life (Zaelani et al., 2023). Students who have conceptual understanding are not only able to remember information but also explain concepts in their own words, distinguish the characteristics of a concept, provide relevant examples, and apply the concept in problem solving (Aledya, 2019; Puri and Perdana, 2023). Thus, conceptual understanding occupies a higher cognitive level than simply memorizing knowledge.

In science education, especially physics, conceptual understanding is a crucial aspect because physics concepts are interrelated and used to explain various natural phenomena. However, various studies show that students still tend to memorize formulas without understanding their physical meaning, causing them to experience difficulties when faced with contextual problems (Aledya, 2019). This condition indicates that physics learning needs to be designed to encourage students to actively build conceptual understanding through meaningful learning experiences, not just through one-way delivery of information.

Conceptual understanding can be identified through several indicators. Abdi et al. (2021) propose seven indicators of conceptual understanding, namely the ability to interpret, exemplify, classify, summarize, conclude, compare, and explain. These indicators show that conceptual understanding encompasses complex cognitive abilities, ranging from understanding information to logically connecting and explaining the relationships between concepts. Therefore, learning that aims to improve conceptual understanding needs to involve activities that allow students to actively interact, explore, and reflect on concepts.

2.2. Energy and Its Transformations

Energy and its transformations are one of the fundamental concepts in physics education, covering the understanding of energy, work, the relationship between work and energy, power and its efficiency, as well as energy sources. This concept is not only theoretical but also closely related to everyday life, such as in motion events, the use of electrical energy, and the utilization of energy sources. Therefore, mastery of the concept of energy and its transformations is an important foundation for students to fully understand various physics phenomena (Puri & Perdana, 2023).

However, various studies show that abstract physics concepts, including energy and its transformations, are often considered difficult by students because they involve abstract concepts and interrelated concepts. Students often have difficulty distinguishing between types of energy, understanding transformations in energy forms, and relating the concept of energy to work and power in real-world contexts. These difficulties indicate that energy learning cannot be adequately conveyed through verbal explanations or formula memorization, but rather requires an approach that helps students build a deep conceptual understanding (Aledya, 2019; Zaelani et al., 2023).

In the context of conceptual understanding, learning about energy and its transformations requires students to interpret concepts, provide examples of energy transformations in everyday life, compare various forms of energy, and explain the relationship between work, energy, and power logically. These abilities are in line with the indicators of conceptual understanding, which include interpreting, exemplifying, classifying, summarizing, concluding, comparing, and explaining (Abdi et al., 2021). Therefore, learning about energy and its transformations needs to be designed in a contextual and interactive manner so that students can construct meaningful conceptual understanding.

2.3. Lumio by SMART

Lumio by SMART is one of the Information and Communication Technology (ICT)-based learning media developed by SMART Technologies. Lumio is a web-based interactive learning platform that can be accessed via computers or mobile phones without the need to install additional applications. The presence of Lumio makes it easier for teachers and students to carry out more dynamic, participatory, and flexible learning in line with current developments in educational technology (Sari et al., 2025).

As an interactive learning medium, Lumio has various learning support functions, including a digital presentation medium that allows the integration of text, images, videos, and the creation of game-based questions and activities. These features allow students to be actively involved in the learning process, not only as recipients of information, but also as participants who interact directly with the learning material (Andayani et al., 2024).

The advantage of Lumio over other digital learning media lies in its multifunctional and collaborative nature. Lumio provides various classroom activity templates, such as quizzes, mind maps, reflections, and educational games that can be tailored to learning needs. In addition, Lumio can be used online without installation, both in the free and paid versions, making it easy for teachers to implement in various learning conditions (Fajrianti et al., 2024). This ease of access is supported by the fact that students generally already have digital devices, so that the use of Lumio in learning can be optimized (Arifin et al., 2025).

In relation to conceptual understanding, the use of Lumio by SMART has the potential to support the strengthening of conceptual understanding through the presentation of visual, interactive, and contextual material. The multimedia content integration feature allows students to observe phenomena, simulations, and visual representations that help them interpret and explain concepts in a more meaningful way. In addition, game-based activities and interactive responses can encourage students to actively exemplify, compare, and conclude the concepts being studied. Thus, Lumio by SMART is relevant for use as a learning medium that supports the achievement of conceptual understanding indicators in physics learning, especially in the material on energy and its transformations.

3. Method

3.1 Research Design and Participants

This study used a quasi-experiment with a non-equivalent posttest-only control group design. This design was chosen because the researcher was unable to fully randomize the subjects, given that group divisions in vocational schools had already been determined by the school. The selection of the posttest-only design was based on the consideration that both groups had relatively equivalent academic characteristics. This equivalence was proven through data from previous material tests with statistical prerequisite tests showing that the initial abilities of students in the experimental group and the control group were normally distributed and were in a homogeneous condition. Thus, the differences in the posttest results obtained can be assumed to originate from the learning treatment given.

This is in line with Krishnan (2019), who states that the non-equivalent posttest only control group design is commonly used in quasi-experimental research when subject randomization is not possible, but initial equality between groups can be proven through previous academic data and homogeneity tests.

Two groups were used as samples, namely the experimental group that received learning using Lumio by SMART, and the control group that learned using conventional PowerPoint. The research design is shown in Table 1.

Table 1. *Research Design*

Group	Treatment	*Posttest*
Experimental	X	O_1
Control	-	O_2

In this study, X represents the treatment using Lumio by SMART media. O_1 refers to the posttest scores of the experimental group after receiving the treatment, while O_2 refers to the posttest scores of the control group, which did not receive the treatment.

This study was conducted at SMK Dar El Hikmah Pekanbaru in the odd semester of the 2025/2026 academic year, from September to November 2025. The research population consisted of all 55 students in grade X at SMK Dar El Hikmah. The sampling technique used was total sampling, so that all students in grade X were included in the sample. The details are shown in Table 2.

Table 2. *Research Population and Sample*

Group	Number of Students
X DKV	27
X AKP	28

(Source: Data from Dar El Hikmah Vocational School, Pekanbaru)

Both groups were declared eligible for sampling after the normality and homogeneity tests showed that the data had a normal distribution. Group X DKV (Sig. = 0.181 > 0.05) and group X AKP (Sig. = 0.200 > 0.05) had homogeneous variance (Sig. Levene's Test = 0.906 > 0.05).

This study has obtained permission from the school. All participants voluntarily participated in the study, and the data obtained were used solely for academic purposes. Student identities were kept confidential in accordance with the principles of educational research ethics.

3.2 Research Procedures, Instruments, and Data Analysis

Research Procedures. The research flow was designed systematically through several stages, namely the design of Lumio by SMART-based learning, the development of instruments for understanding energy concepts and their transformations, the implementation of learning in experimental and control groups, data collection through posttests, and data analysis to determine the effectiveness of learning. The conceptual framework of this study positions the use of Lumio by SMART as a treatment variable that is expected to facilitate interactive learning activities in accordance with conceptual understanding indicators, thereby impacting the improvement of students' understanding of concepts related to energy and its transformations.

In practice, both the experimental and control groups conducted learning using a scientific approach and the same Student Worksheets (LKPD), so that the differences in learning outcomes that emerged were not influenced by differences in approach or teaching materials. In the experimental group, learning was conducted using Lumio by SMART media. Teachers presented material on energy and its transformations through the integration of visual and multimedia content, followed by interactive activities such as quizzes, response activities, and shout it out-based discussions. Each activity was designed to support concept comprehension indicators, such as interpreting energy phenomena, providing examples of energy transformations in everyday life, comparing various forms of energy, and explaining the relationship between work, energy, and power. Meanwhile, the control group followed the learning process using conventional PowerPoint media without the use of technology-based interactive activities.

Research Instrument. The research instrument consists of a test of understanding of energy concepts and their transformations, which is compiled based on the indicators of conceptual understanding according to Abdi et al. (2021), namely, interpreting, exemplifying, classifying, summarizing, concluding, comparing, and explaining. The instrument was developed contextually in accordance with the material on energy and its transformations, so that it was confirmatory of the conceptual understanding indicator framework. The test consisted of 14 multiple-choice questions, each representing a conceptual understanding indicator. The instrument underwent expert validation by physics education lecturers to ensure the suitability of the material, construction, and language. Each conceptual understanding indicator was then mapped specifically to the material on energy and its transformations.

Table 3. *Concept Comprehension Indicators and Aspects*

No.	Indicators	Aspects
1	Conclude	• Determine the value of work done when the direction of force is perpendicular to the direction of displacement from the information provided. • Determine the relationship between the work done on an object and the transformations in its kinetic energy based on the physics concepts from the information provided.
2	Interpret	• Present force and displacement data from the table in the appropriate graphical form. • Interpreting the correct statement regarding the potential energy value of an object based on the graph provided.
3	Exemplify	• Showing examples of kinetic energy events in everyday life. • Showing examples of spring potential energy events.
4	Summarize	• Convey the essence of the information provided about the energy of an object in a concise manner. • Summarize the essence of information about power efficiency values in a concise manner.
5	Explain	• Explain the conversion of energy forms in everyday life according to the law of conservation of energy. • Explain the importance of reducing the use of fossil fuels and switching to renewable energy.
6	Classify	• Classify events in everyday life based on whether or not there is a transformations in energy. • Classify renewable and non-renewable energy sources.
7	Compare	• Determine the comparison of electrical power between two devices based on the effort and time required. • Determine the differences in the characteristics of renewable geothermal and biomass energy.

This study did not develop learning media; instead, it applied the existing interactive learning media, Lumio by SMART. Therefore, the validation process in this study focused on the research instrument, namely the posttest questions on conceptual understanding, to ensure the feasibility and accuracy of measuring students' conceptual understanding. The content validity of the instrument was analyzed using Aiken's V coefficient based on expert assessment. The item validity criteria were determined based on conventions commonly used in educational research, where Aiken's V value of ≥ 0.60 indicates a valid category and a value of ≥ 0.80 indicates a highly valid category (Azwar, 2015; Retnawati, 2016). The concept comprehension instrument and the results of the instrument validation are presented in full in Appendix A and Appendix B. The indicators and aspects of the instruments used in this study are shown in Table 3.

Research Data Analysis. Data were collected through a concept comprehension test in the form of a posttest given to both groups after the treatment. The question format, number of items, and completion time were the same for both groups. Data analysis techniques were performed using descriptive and inferential analysis. In the descriptive analysis, equation 1 was used to calculate the students' posttest mean scores.

$$\text{Score} = \frac{\text{Score obtained by the student}}{\text{Maximum score}} \, x\, 100 \qquad (1)$$

Students' conceptual understanding scores were then classified into categories of conceptual understanding in physics, adapted from Arikunto (2013) as cited by Puri and Perdana (2023). This classification consists of five categories, namely very good with a score interval of $85 \leq x < 100$, good with an interval of $70 \leq x < 85$, fair with an interval of $55 \leq x < 70$, poor with an interval of $40 \leq x < 55$, and very poor for scores $x < 40$.

Inferential analysis was used to test the effectiveness of Lumio by SMART on students' conceptual understanding. The prerequisite tests conducted included a normality test using Kolmogorov-Smirnov and a homogeneity test using Levene's Test. After the data met the prerequisite tests, a hypothesis test was conducted using an independent sample t-test at a significance level of 0.05 to see the difference in posttest results between the experimental group and the control group.

Research hypothesis

H_0: There is no significant difference between the two groups.

H_a: There is a significant difference between the two groups.

Lumio by SMART is declared effective if there is a significant difference between the two groups in the t-test, and the average concept comprehension score in the experimental group is descriptively higher than that of the control group.

4. Result

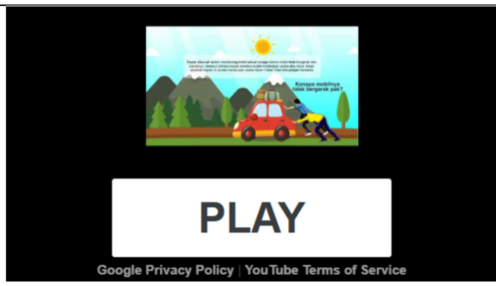
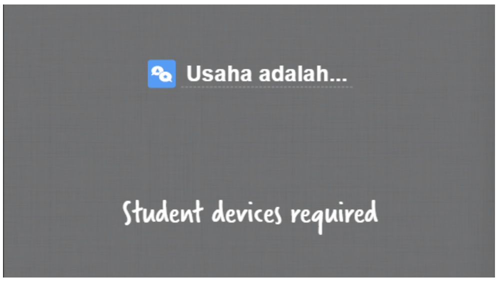
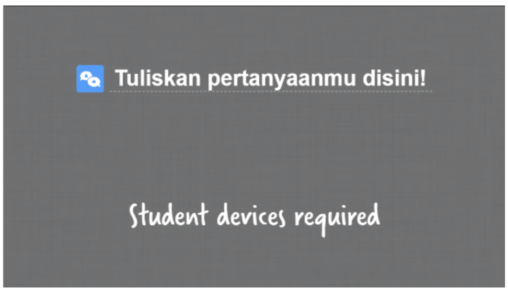
4.1. Application of Lumio interactive media by SMART

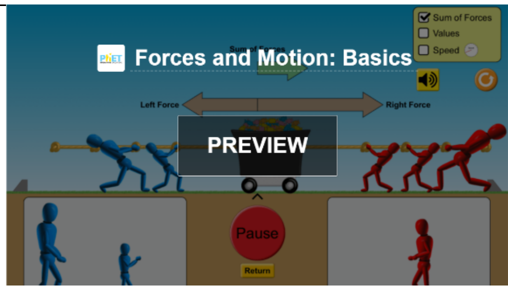
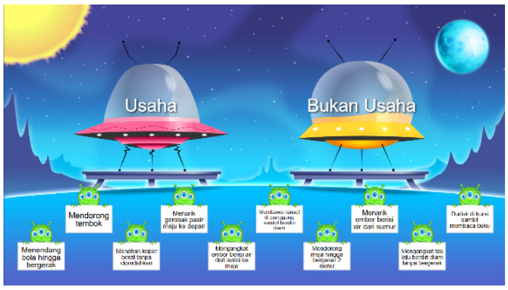
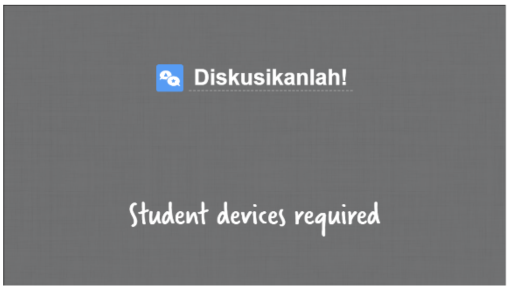
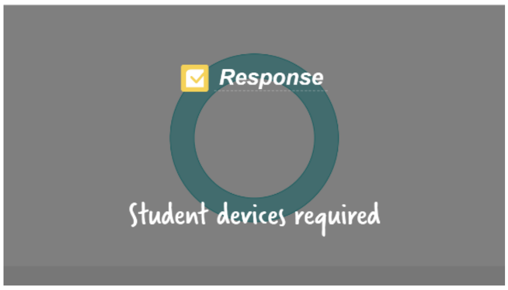
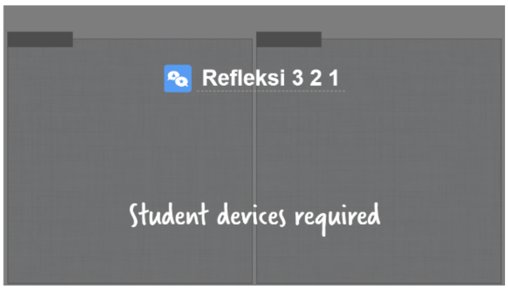
Lumio by SMART interactive learning media is used as a learning support medium for energy and its transformations material in experimental classes. In practice, both experimental and control classes apply the scientific approach and use the same Student Worksheets (LKPD), ensuring that any differences in learning are not caused by the approach or teaching materials, but rather by the characteristics of the media used.

The use of Lumio by SMART is integrated into the scientific learning stages through the presentation of visual and multimedia content, as well as interactive activities. Features such as quizzes, response activities, and shout-it-out-based discussions are used to encourage active student participation and support concept comprehension indicators. In addition, Lumio by SMART allows teachers to set the slides to be displayed and the duration of each slide, so that all activities and materials that appear on students' devices can be controlled by the teacher in accordance with the learning flow. In terms of the design flow, Lumio by SMART learning media is systematically arranged in the form of a sequence of learning slides in accordance with the scientific approach, as shown in Table 4.

In comparison, the control class used conventional Microsoft PowerPoint media without technology-based interactive activities. This media tends to be one-way, so student engagement in the learning process is relatively limited. This difference confirms that Lumio by SMART has more prominent interactive features that support student engagement.

Table 4. *Lumio by SMART learning slide sequence*

Slide	Content	Display
1	Present videos or images as initial stimuli for students to observe	
2	Include provoking questions based on the videos or images that students have observed	
3	Use the shout it out feature as a platform for students to answer the provoking questions on the previous slide	
4	Present videos or images that describe events or phenomena related to the learning material for that session	
5	Using the shout it out feature to facilitate students in asking questions related to the video or image that has been observed	

Slide	Content	Display
6	Contains a simulation experiment carried out by students in accordance with the instructions and directions listed in the Student Worksheet	
7	Present educational games that aim to strengthen students' understanding of concepts	
8	Use the shout it out feature as a means for students to discuss after gathering information from the simulation experiment results	
9	Use the response feature to evaluate learning in that session	
10	Use the shout it out feature to collect learning reflections from all students	

4.2. Descriptive Analysis

The descriptive analysis in this study also aims to describe the profile of students' conceptual understanding of energy and its transformations, both overall and based on conceptual understanding indicators. This profile includes student achievement on each indicator and the distribution of conceptual understanding categories in the experimental and control groups. The posttest results for both groups can be seen in Tables 5 and 6.

Table 5. *Student Achievement on Each Indicator*

No	Indicator	Experimental group		Control group	
		Average	Category	Average	Category
1	Exemplifying	88.89	very good	75.00	good
2	Concluding	55.56	fair	50.00	poor
3	Summarizing	64.81	fair	62.50	fair
4	Interpreting	55.56	fair	50.00	poor
5	Comparing	74.07	good	53.57	poor
6	Explaining	66.67	fair	57.14	fair
7	Classifying	85.19	very good	67.86	fair
Average		70.1	good	59.96	fair

In Table 5, the experimental group obtained an average score of 70.11 in the good category, while the control group obtained 59.96 in the fair category. The indicators with the highest achievement in the experimental group were exemplifying and classifying, while the indicators of concluding and interpreting were the lowest achievements in both groups.

Table 6. *Distribution of Conceptual understanding Categories*

Interval	Category	Experimental group		Control group	
		Number	Percentage (%)	Number	Percentage (%)
$85 \le x < 100$	very good	5	18.52	1	3.57
$70 \le x < 85$	good	11	40.74	8	28.57
$55 \le x < 70$	fair	7	25.93	10	35.71
$40 \le x < 55$	poor	4	14.81	7	25.00
$0 \le x < 40$	very poor	0	0.00	2	7.14
Average		70.11		59.95	
Category		Good		Fair	

The distribution of conceptual understanding categories in Table 6 also shows clear differences. In the excellent category, the experimental group achieved 18.52% compared to the control group, which only achieved 3.57%. In the good category, the experimental group scored 40.74%, higher than the control group at 28.57%. The average score of the experimental group was higher, at 70.11, compared to the control group at 59.95. This shows that the use of Lumio by SMART has a positive effect on students' conceptual understanding.

Student response to learning using Lumio media shows that most students respond positively to the use of Lumio interactive learning media by SMART. Students find that learning becomes more interesting, easier to understand, and encourages active engagement during the learning process. Interactive features such as quizzes, discussions through shout it out, as well as visualizations and simulations, help students understand the concepts of energy and its transformations more concretely. Through the shout it out feature, students feel more confident and less shy about asking questions or expressing their opinions because they can participate in writing, making classroom interaction more lively. In addition, interactive activities make the learning atmosphere more enjoyable. This positive response reinforces the learning outcome findings that active engagement and technology-based learning experiences contribute to an increase in students' conceptual understanding.

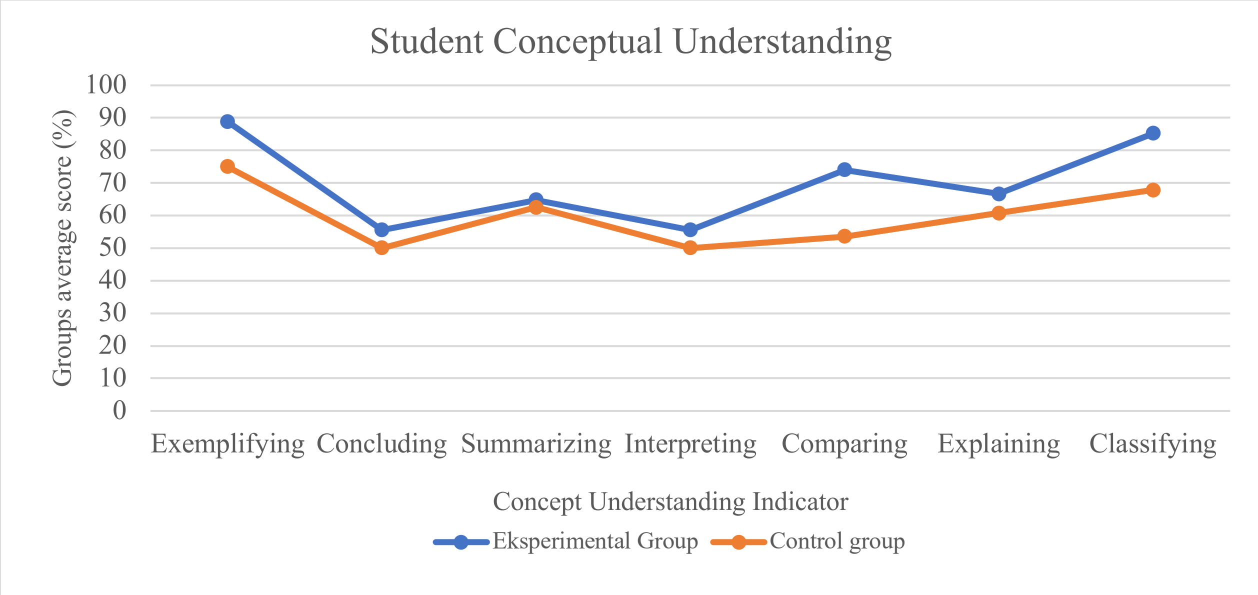


Figure 1. *Graph showing the conceptual understanding of students in the control group and the experimental group*

Student conceptual understanding profiles, analyzed based on conceptual understanding indicators. Improvements in each of these indicators can be observed in the comparison chart of results per indicator, which shows that the experimental class consistently scored higher than the control class. Improvements in each student conceptual understanding indicator can be seen in Figure 1. Based on Figure 1, the experimental class showed higher achievements than the control class in all conceptual understanding indicators. The largest difference was in the comparing indicator, which was 20.51 points, followed by the exemplifying indicator, which was 13.89 points, and the classifying indicator, which was 8.40 points. Meanwhile, the concluding and interpreting indicators each showed a difference of 5.56 points, the explaining indicator showed a difference of 5.95 points, and the summarizing indicator had the lowest difference of 2.32 points. Overall, these results indicate that the use of Lumio by SMART has a positive impact on students' conceptual understanding, especially on indicators that require analytical and applied skills.

4.3. Effectiveness of Lumio by SMART

The inferential analysis in this study aims to determine the difference in conceptual understanding between the experimental group that uses Lumio by SMART interactive learning media and the control group that uses PowerPoint learning media as usual. Before testing the hypothesis, prerequisite tests were conducted in the form of normality and homogeneity tests to ensure that the data met the requirements for parametric analysis (Usmadi, 2020).

The results of the normality test using Kolmogorov–Smirnov showed that the posttest data on students' understanding of concepts in the experimental group and control group were normally distributed. In the experimental group, a significance value of 0.155 (> 0.05) was obtained, while in the control group, a significance value of 0.067 (> 0.05) was obtained. The results of the homogeneity test using Levene's Test showed that the posttest data on students' conceptual understanding in the experimental group and control group had homogeneous variance with a significance value of 0.376 (> 0.05). Thus, both groups met the requirements for parametric analysis.

After the data met the prerequisite test, hypothesis testing was carried out using an independent samples t-test with SPSS 26 version. The results of the independent sample t-test showed a significance value of 0.008 (< 0.05), indicating a significant difference between the conceptual understanding of students in the experimental group and the control group. The experimental group achieved a higher mean score (70.11) compared to the control group (59.95). These findings demonstrate that the implementation of Lumio by SMART interactive learning media has a significant positive effect on students' understanding of energy concepts and their transformations.

5. Discussion

5.1 Interpretation of Findings

Interactive learning media based on Lumio by SMART, which is applied to the learning of Energy and Its Transformations, is used as a supporting medium that is integrated with a scientific approach. The application of this media does not stand alone, but is combined with the use of the same worksheets between the experimental and control classes, so that the differences in learning outcomes better reflect the characteristics of the media used. Lumio by SMART is used to present visual and multimedia content as well as interactive activities that are systematically arranged following the stages of scientific learning, starting from providing stimuli, asking questions, collecting information through simulations, to evaluating and reflecting on learning. Interactive features such as shout it out, response activities, quizzes, and educational games allow students to actively participate in each stage of learning, whether in expressing opinions, discussing, or reflecting on learning outcomes.

Teachers have full control over the flow and duration of slide displays on student devices, making the learning process more structured and focused. This feature distinguishes Lumio by SMART from conventional presentation media used in control classes, which tend to be one-way and do not facilitate active student interaction. Thus, Lumio by SMART not only functions as a medium for presenting material, but also as an interactive learning tool that supports students' cognitive and participatory engagement in understanding the concepts of energy and its transformations. In addition, the results of student response analysis show that the use of Lumio by SMART makes learning more enjoyable and encourages students to be more courageous in asking questions and expressing their opinions, especially through the shout it out feature that allows students to interact without fear or embarrassment.

Based on Figure 1, the difference in conceptual understanding achievement between the experimental class and the control class on each indicator shows that the use of Lumio by SMART has a consistent impact on improving the quality of student understanding. The more prominent improvement in indicators that require analytical skills, such as comparing and giving examples, indicates that interactive media-based learning can help students process information more deeply and relate concepts to relevant contexts. These findings are in line with the view that visual presentations and interactive activities can help students connect concepts to real-world examples more accurately (Alifah et al., 2023) and that interactive media can reinforce concept representation through visualization and technology-based activities that actively engage students cognitively (Dasmo et al., 2020).

In addition, better achievements on the classification indicator show that interactive features such as quizzes and visual exercises on Lumio play a role in helping students organize and group information systematically, so that conceptual understanding becomes more structured. On the indicators of summarizing, interpreting, and explaining, the difference in achievement that remained in favor of the experimental class shows that interaction- and visualization-based learning has the potential to support students' reasoning processes in a sustainable manner. Meanwhile, on the summarizing indicator, the achievements of both classes show relatively similar trends, indicating that both Lumio-based and conventional learning support the ability to summarize information, although Lumio still provides advantages in enriching students' learning experiences. These results are consistent with previous findings showing that the use of Lumio can significantly improve learning outcomes compared to conventional learning (Alifah et al., 2023; Thohir et al., 2024).

The comparison indicator shows the largest difference between the two classes. Lumio's interactivity through visualization, simulation, and drag-and-drop activities provides strong support for students' ability to identify similarities and differences between concepts (Andayani et al., 2024). On the other hand, the indicators for summarizing and interpreting were the lowest-scoring indicators in both classes. This indicates that students still need to strengthen their higher-order thinking skills. However, the experimental class still showed higher achievements, indicating that Lumio helps students visualize the relationships between concepts so that the interpretation and conclusion processes become more focused. In general, these achievements show that the level of students' conceptual understanding in the experimental class was in a better category than the control class after the application of Lumio by SMART interactive learning media.

The results of the study indicate that the use of Lumio by SMART has a significant effect on students' understanding of concepts related to energy and its transformations. Descriptive analysis and media effectiveness analysis show that the experimental class that consistently used Lumio obtained higher average scores than the control class that used conventional PowerPoint. The results of the independent sample t-test support these findings, with a significance value of 0.008 (< 0.05), indicating a significant difference between the two classes.

The results of the research analysis confirm that the application of Lumio by SMART is effective in improving students' conceptual understanding of energy and its transformations. This effectiveness is supported by the integration of all learning activities, such as the use of PhET, practice questions, interactive bulletin boards, and educational games into one platform (Relawati et al., 2024). This integration makes learning access easier, learning more efficient, and allows teachers to monitor student activities directly. Unlike conventional PowerPoint, which requires switching media for simulations or quizzes, learning using Lumio is faster, more interactive, and more structured. This study focuses on the application of the existing Lumio by SMART interactive learning media, not on the development of learning media, so the validation process in this study focuses on the research instruments used to measure students' conceptual understanding.

5.2 Impact

The implementation of Lumio by SMART has had a significant impact on improving students' cognitive abilities and skills. Based on their concept comprehension profiles, students in the experimental group showed improvement in indicators that require analytical and applied skills. This indicates that the use of Lumio encourages students to think critically and connect concepts with real-life examples. In addition to cognitive aspects, Lumio supports the development of creativity and collaboration. Interactive features such as quizzes, drag-and-drop exercises, and simulations enable students to learn actively, discuss, and work together to solve problems. These collaborative activities implicitly improve communication, teamwork, and problem-solving skills, which are important competencies in 21st-century science education.

Another positive impact is related to ease of access to technology. The integration of various learning activities, simulations, practice questions, interactive bulletin boards, and educational games in one platform makes it easier for students to learn independently or in groups. Students can apply the concepts they have learned in their daily lives, for example, understanding energy in everyday events or relating theory to practical experiments. This also improves students' digital literacy and practical skills. This research contributes to the development of physics education, both in Indonesia and globally, by demonstrating that interactive learning media can significantly improve conceptual understanding, foster critical, creative, and collaborative thinking skills, and increase student motivation and engagement. Lumio by SMART shows potential as a modern learning model that is adaptable to the needs of 21st-century education.

The main advantage of Lumio by SMART lies in its interactive features. The Shout It Out! feature allows students to express their ideas and opinions more freely, thereby increasing participation, including for students who tend to be passive. In addition, interactive quizzes and games increase student engagement and enthusiasm during learning. The automatic grading system also helps teachers monitor student learning progress in a more accountable manner. These features provide a richer and more meaningful learning experience, contributing to an overall improvement in students' understanding of concepts. These findings are in line with research (Ahmed et al., 2021) showing that gamified virtual labs can improve students' innovation skills and positive perceptions of learning, as well as research (Hunsu et al., 2016) confirming that interactive response systems increase motivation and conceptual understanding.

5.3 Limitation

Several limitations should be acknowledged in this study, particularly the limited sample size and the fact that the research was conducted in only one school. In addition, the use of Lumio by SMART is highly dependent on the availability of devices and the stability of the internet connection. Suboptimal network conditions have the potential to affect the smoothness of learning and the effectiveness of media use. Therefore, further research is recommended to involve a broader sample and combine quantitative data with qualitative data, such as questionnaires or interviews, in order to obtain a more comprehensive picture of the effectiveness of Lumio by SMART.

6. Conclusion

Based on the findings of this study on students' understanding of the concept of energy and its transformations, it can be concluded that the Lumio by SMART-based interactive learning media applied in learning is designed in an integrated manner with a scientific approach and facilitates visual, interactive, and participatory learning activities. The implementation of this media has a positive impact on students' conceptual understanding, where descriptively, students' conceptual understanding in the experimental class is in a better category than the control class. In addition, the results of the inferential test show a significant difference between the experimental class and the control class, with higher conceptual understanding achievements in the experimental class. These findings indicate that the use of Lumio by SMART interactive learning media is effective in improving students' conceptual understanding of energy and its transformations.

Authors Contribution

Alya Zahara: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, review & editing. **Zulirfan:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Muhammad Nor:** Methodology, Writing – review & editing, Supervision.

Ethical statement

This study was conducted in a regular classroom learning environment and classified as educational research with minimal risk. Therefore, this study did not require approval from an institutional ethics committee. Permission to conduct the study and collect data was officially obtained from the school, SMK Dar El Hikmah Pekanbaru, prior to the study.

This study involved human participants, namely 10th-grade students. Participation in the study was voluntary. All participants were given an explanation of the purpose of the study, the procedures involved, and their right to withdraw at any time without any consequences. Informed consent was obtained prior to data collection. For students under the age of 18, consent was obtained through the school, which serves as the responsible institutional authority. This study complies with the relevant principles of educational research ethics. No personal or sensitive data was collected. All data was anonymized and used solely for academic and research purposes.

Declaration of AI use

In preparing this manuscript, the authors used a generative artificial intelligence tool, ChatGPT (OpenAI), to a limited extent to help improve sentence clarity, readability, and language editing in the initial draft of the manuscript. The use of AI did not include the creation of primary scientific content, data analysis, interpretation of results, or research conclusions. All AI-assisted outputs have been critically reviewed, edited, and verified by the authors. The authors are solely responsible for the accuracy, originality, scientific integrity, and final content of this manuscript. No AI system is listed as an author. Furthermore, this research does not use images, illustrations, or videos generated by generative AI.

Conflict of Interest

The authors declare that there are no conflicts of interest, either financial or non-financial, that could influence the conduct of the research, analysis of data, or interpretation of results reported in this manuscript. All authors have reviewed and approved this conflict of interest statement.

Supplementary Materials and Data Availability

The research instruments used in this study, including the concept comprehension test instruments and the results of instrument validation, are presented in full in Appendix A and Appendix B. The dataset generated and analyzed in this study is not stored in a public repository because it contains student educational data. However, summary data and relevant supporting materials can be obtained from the corresponding author upon reasonable request. Any data shared will be anonymized and provided in accordance with research ethics approval and applicable institutional regulations.

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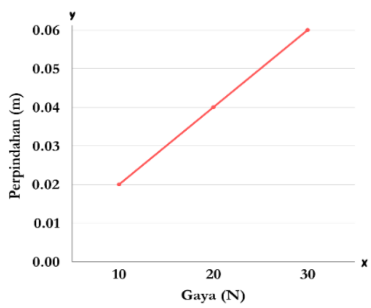
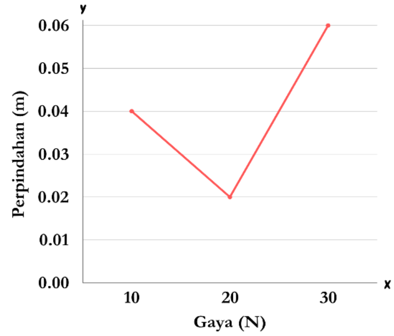
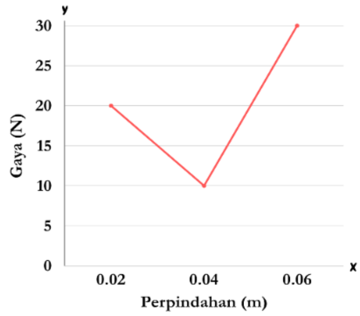
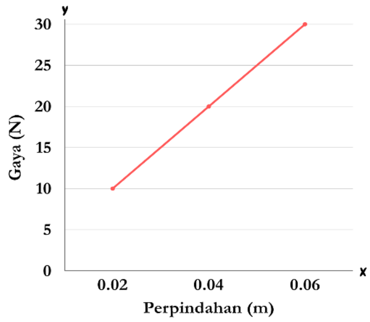
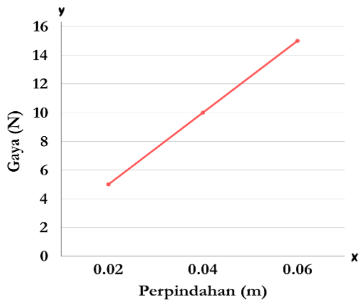
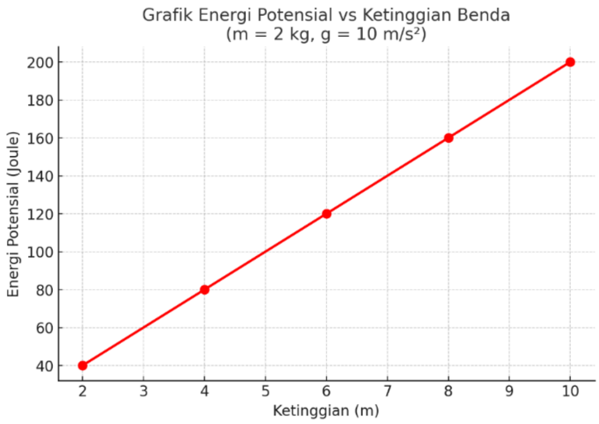
Appendix A. Research Instruments

Table 7. *Instruments For Assessing Understanding of Concepts*

<table>
<tr><th>No.</th><th>Indicators</th><th>Question Indicators</th><th>Questions</th><th>Answer Key</th></tr>
<tr><td>1</td><td>Summarizing (the ability of students to extract the main idea or draw conclusions from various available information)</td><td>Determining the value of the force exerted when the direction of the force is perpendicular to the direction of displacement from the information provided</td><td>
Look at the picture on the side! A student helps the teacher tidy up the library. He carries a stack of books while walking horizontally for 2 meters. Based on this information, which conclusion is correct regarding the value of the work done by the student on the displacement of the books?
A. Maximum work
B. Negative work
C. Zero work
D. Positive work
E. Work cannot be determined</td><td>C</td></tr>
<tr><td>2</td><td>Interpreting (students' ability to connect or transform information from one form to another)</td><td>Presenting force and displacement data from a table in the appropriate graphical form.</td><td>A student conducts an experiment to determine the relationship between force and displacement on a flat surface. The experiment is conducted three times by applying different forces to the same object. The results of the observations are shown in the following table.
<table>
<tr><th>No</th><th>Force (N)</th><th>Displacement (m)</th></tr>
<tr><td>1</td><td>10</td><td>0.02</td></tr>
<tr><td>2</td><td>20</td><td>0.04</td></tr>
<tr><td>3</td><td>30</td><td>0.06</td></tr>
</table>
Based on this data, which graph best shows therelationship between force (N) on the X-axis and displacement (cm) on the Y-axis ?
A. 
</td><td>A</td></tr>
</table>

No.	Indicators	Question Indicators	Questions	Answer Key
			B.  C.  D.  E. 	
3	Demonstrating (students' ability to provide concrete examples of a concept)	Providing examples of kinetic energy in daily life.	Consider the following events! (1) A ball rolling on the floor (2) A ball resting on a table (3) A book stored in a cabinet (4) A car driving (5) A coconut still on the tree Which event is an example of kinetic energy? (1) dan (4) (1) dan (5) (2) dan (5)	A

No.	Indicators	Question Indicators	Questions	Answer Key
			(3) dan (5) (3) dan (4)	
4	Interpreting (students' ability to connect or transform information from one form to another)	Interpreting correct statements about the potential energy of an object based on the given graph.	Consider the following graph.  From the graph, which statement is correct? Ep at a height of 4 m is twice Ep at a height of 2 m Ep at a height of 6 m is half of Ep at a height of 10 m As height increases, the potential energy of the object decreases Ep at a height of 4 m is equal to Ep at a height of 6 m Ep at a height of 8 m is the smallest value of Ep	A
5	Providing examples (students' ability to present concrete examples of a concept).	Providing examples of elastic potential energy phenomena.	From the statements below, which event is an example of elastic potential energy? A. Lili plays with a slingshot with her friends B. Hani reads a book in the library C. Raya pushes a broken-down car D. Lili drops a ball from the second floor E. Hani helps her mother carry groceries	A
6	Summarizing (students' ability to convey the main ideas of information concisely and clearly).	Summarizing the main information about the energy of an object concisely.	Naya places a book on a table that is 1 meter high from the floor. The book remains on the table throughout the day without being moved by anyone. There are also several other objects on the table, such as a flower vase, a glass, and a pencil. Despite the presence of many objects on the table, the position of the book does not change and it does not move at all. Based on the event above, which statement is correct? The book has no energy because it does not move throughout the day. All objects on the table transfer energy to one another. The book has no energy because it has not moved throughout the day. The book has kinetic energy because it is on the table. The book has potential energy because of its position on the table.	E
7	Explaining (students' ability to present a logical and	Explaining energy transformations in everyday life based on the law	Auntie is baking a cake using an oven in the kitchen. The oven Auntie is using is an electric oven. Based on the law of conservation of energy, why can Auntie's oven produce heat that can bake a cake?	D

No.	Indicators	Question Indicators	Questions	Answer Key
	coherent explanation of a concept).	of conservation of energy.	Because electrical energy disappears and is replaced by heat energy when the oven is turned on. Because the heat comes from the surrounding air that is heated by the fan inside the oven. Because heat energy appears suddenly when an electronic device is turned on. Because electrical energy is converted into heat energy in the oven. Because electrical energy creates heat energy in the oven.	
8	Classifying (students' ability to group objects, events, or information based on shared characteristics in accordance with a concept).	Categorizing daily-life events according to whether energy transformation occurs.	Consider the following events! Storing books in a cupboard Turning on a lamp A bicycle becomes damaged due to frequent use Using a mixer when making a cake Turning on the television A book getting wet when exposed to water A bicycle becoming damaged due to rust Cooking using an electric stove Which of the statements above involve energy transformation? (1), (2), (5), dan (8) (2), (4), (5), dan (8) (3), (4), (6), dan (7) (2), (4), (5), dan (7) (3), (4), (5), dan (8)	B
9	Summarizin g (students' ability to grasp the main points or draw conclusions from various available information)	Determining the relationship between the work done on an object and its change in kinetic energy based on the given information.	Layla pushes a table with a mass of 7 kg on a smooth floor with a force of 40 N until it moves a distance of 2 meters. If the table is initially at rest, which conclusion is correct? Layla does not do any work because the table is on a smooth floor. The table's potential energy increases by 80 J due to Layla's work. The table's kinetic energy increases by 80 J due to Layla's work. The table's kinetic energy remains the same, even though Layla does 80 J of work. The table's kinetic energy decreases by 80 J due to Layla's work.	C
10	Comparing (students' ability to identify similarities and differences between two or more concepts).	Determining the comparison of electrical power between two devices based on the work done and the time taken.	Satya has two incandescent lamps in his room, namely Lamp A and Lamp B. If Lamp A does 45 J of work every 3 seconds and Lamp B does 100 J of work every 4 seconds, which lamp has greater power? Lamp A has greater power. Lamp B has greater power. Lamp A and Lamp B have no power. Lamp A and Lamp B have negative power. Lamp A and Lamp B have the same power.	B
11	Summarizing (students' ability to convey the main information concisely and clearly).	Briefly summarizing key information about power efficiency.	At night, Tyla is studying in her room. She turns on an incandescent lamp to illuminate her study desk. However, the lamp emits dim light. After some time, the lamp feels hot when touched. She then realizes that although the lamp produces light, most of the electrical energy supplied to the lamp is converted into heat. Based on the event above, which statement is correct? The incandescent lamp has low efficiency because most of the electrical energy is converted into heat. The incandescent lamp is efficient because all electrical energy is converted into light.	A

No.	Indicators	Question Indicators	Questions	Answer Key
			The incandescent lamp does not require electrical energy to produce light. The incandescent lamp is more efficient than all other types of lamps. The incandescent lamp has no efficiency at all.	
12	Comparing (students' ability to identify similarities and differences between two or more concepts).)	Determining the differences in the characteristics of geothermal and biomass renewable energy.	Renewable energy is an energy source that can be replenished and is environmentally friendly. It is important to use renewable energy to help protect the Earth. Examples of renewable energy sources include geothermal energy and biomass. Which of the following statements best describes the difference between these two energy sources? Biomass is always more efficient than geothermal energy. Geothermal energy and biomass come from limited heat sources. Geothermal energy depends on weather conditions, whereas biomass does not. Geothermal energy comes from the Earth's natural heat, while biomass comes from organic materials. Geothermal energy and biomass use fossil fuel combustion.	D
13	Classifying (students' ability to group objects, events, or information based on shared characteristics in accordance with a concept).	Classifying renewable and non-renewable energy sources.	Observe the following energy sources! Waterfall Natural gas Biogas Geothermal energy Coal Ocean waves The Sun Petroleum Wind Which of the following are classified as non-renewable energy sources? (1), (3), dan (5) (2), (5), dan (9) (4), (6), dan (7) (3), (5), dan (8) (2), (5), dan (8)	D
14	Explaining (students' ability to present a logical and coherent explanation of a concept).	Explaining the reasons why it is important to reduce the use of fossil energy and shift to renewable energy.	Why should the use of fossil energy be reduced and gradually replaced with renewable energy? Because fossil energy has no economic value at all. Because fossil energy can only be used in certain areas. Because fossil energy can be quickly renewed if it is used efficiently. Because renewable energy takes a long time to form, like fossil energy. Because fossil energy is limited and its combustion produces carbon emissions.	E

Appendix B. Instrument Validation

Instrument validation was conducted on the concept comprehension instrument developed to measure students' level of concept mastery. Content validity assessment was carried out by experts based on four aspects, namely (A) the suitability of the items to the learning objectives, (B) the substance or correctness of the concepts, (C) the suitability of the items in measuring indicators of concept comprehension, and (D) language and writing. The assessment was carried out by writing scores in the available assessment aspect columns using a five-point Likert scale, namely scores of 1 (not good), 2 (not very good), 3 (fairly good), 4 (good), and 5 (very good). The following are the results of the validation of the energy and its transformations concept comprehension instrument.

Table 8. *Conceptual understanding Instrument Validation Results*

Question No.	Validator 1				Validator 2			
	Aspect				Aspect			
	A	B	C	D	A	B	C	D
1	5	5	4	5	5	5	4	5
2	3	3	3	5	4	4	3	5
3	5	5	5	5	5	5	5	5
4	5	5	5	5	5	5	5	5
5	4	4	4	5	5	5	4	5
6	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	4	5
8	4	4	4	5	5	4	4	5
9	4	4	4	5	4	4	5	5
10	4	4	4	5	4	4	5	5
11	4	4	4	5	4	4	4	5
12	4	4	4	5	4	5	5	5
13	4	4	4	5	4	4	5	5
14	4	4	4	5	5	5	4	5

The scores given by validators for each aspect were then analyzed using Aiken's V coefficient to determine the content validity of each item in the conceptual understanding instrument. The validity test results can be seen in Table 9.

Table 9. *Content Validity Test Results for Items Using Aiken's V*

Question No.	Aiken's V	Category
1	0,94	Very valid
2	0,69	Valid
3	1,00	Very valid
4	1,00	Very valid
5	0,88	Very valid
6	1,00	Very valid
7	0,97	Very valid
8	0,84	Very valid
9	0,84	Very valid
10	0,84	Very valid
11	0,81	Very valid
12	0,88	Very valid
13	0,84	Very valid
14	0,88	Very valid
	Avarage Aiken's V	0,89

This instrument uses a 1–5 rating scale and was validated by two validators, with the number of rating categories set at $c = 5$. The validity criteria were defined as follows: $V \geq 0.80$ indicates high validity (highly valid), while $0.60 \leq V < 0.80$ indicates acceptable validity (valid).

The content validity of the instrument was analysed using Aiken's V index based on the assessment of two experts on four assessment aspects. The results of the calculation show that all items in the instrument are in the valid to highly valid category, so the instrument is suitable for use in research.