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Identification of Students' Creative Thinking Ability in Solving Open-Ended Problems on Rigid Object Equilibrium Material Using Digital-Based Assessment

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ABSTRACT

Objective: *To identify students' creative thinking ability in solving open-ended problems on rigid object equilibrium material through digital-based assessment at SMA Negeri 1 Badegan.* ***Method:*** *A descriptive quantitative method involving 108 eleventh-grade students at SMA Negeri 1 Badegan. Data were collected through observation, documentation, and open-ended problem tests administered digitally using Google Form integrated with a learning management system (LMS). Students' creative thinking ability was analyzed based on four indicators: fluency, flexibility, originality, and elaboration. The data analysis was conducted by calculating the percentage of achievement for each indicator and categorizing students' creative thinking ability levels.* ***Results:*** *The results showed that students' creative thinking ability in solving open-ended problems on rigid object equilibrium material was still relatively low. The fluency indicator obtained an average achievement score of 42.98% (poor category), flexibility reached 30.53% (very poor category), originality obtained 20.35% (very poor category), and elaboration reached 25.61% (very poor category). The findings indicate that students experienced difficulties in generating diverse ideas, producing original solutions, and providing detailed explanations when solving open-ended physics problems. The utilization of digital platforms through Google Form and LMS facilitated systematic data collection, efficient response management, and documentation of students' creative thinking performance.* ***Novelty:*** *The novelty of this study lies in the identification of students' creative thinking ability in rigid object equilibrium material through digital-based assessment. The integration of digital platforms as a data collection medium provides an efficient approach for analyzing students' responses to open-ended physics problems and contributes to the development of technology-supported physics assessment practices.*

INTRODUCTION

Curriculum changes are one of the efforts to organize and improve the quality of education. The demands of independent curriculum learning require a learning process that provides opportunities for students to develop all their potential (Kasneci et al., 2023). The goal is to encourage students to be able to be more active to be able to carry out activities such as observation, questioning, reasoning, and critical thinking (Thornhill-Miller et al., 2023). In recent years, there has been a decline in interest in learning Physics when students are in class. Often researchers find and encounter symptoms of problems when learning Physics takes place (Downing et al., 2020). Students tend to get bored with the monotonous learning process of only listening to the teacher's explanation or watching learning videos. Based on these frequently encountered symptoms, researchers developed an initial diagnosis plan about students' creative thinking abilities (Pink et al., 2022).

The ability to think creatively is the result of interaction between individuals and their environment. A person will be influenced and influenced by the environment in which he is located (Dwivedi et al., 2022). Therefore, changes in individuals and environments

will support or hinder the ability to think creatively, meaning that creative thinking skills can be improved through education, namely through learning (Gerlich, 2025). The creative thinking process is one of the variables that researchers often use to conduct research on student creativity. The creative thinking process is defined as a stage or process that combines logical thinking and divergent thinking to be able to solve problems (Dwivedi et al., 2019).

According to Bubeck et al. (2023) in the learning process, teachers can help students by implementing learning based on the level of thinking ability students. If most of the students are at a creative thinking level of 0 or 1, which means they do not have creativity, then the teacher will apply learning by guiding students in the problem-solving stage, so that students are proficient (fluent) in solving problems and provide opportunities for them to be able to solve various types of problems with different approaches and strategies. One of the symptoms that is often found in students is that students tend to only memorize without understanding the material and are not active in the learning process. This is because some of the students' thoughts only come from teachers (Reynolds, 2017). argue that learning process activities that are less active and do not train students' thinking skills result in decreased student learning achievement (Wulf & Lewthwaite, 2016).

During Physics learning activities, a teacher hopes that his students have the ability to think critically, logically, and reason. Through this ability, it is hoped that students will be able to develop the ideas they already have. This aims to ensure that each student is able to solve the problems faced during learning activities. The focus of this research is limited to students' creative thinking skills. When studying Physics, the activity of a person who studies is mostly thinking. According to the mathematical creative thinking skills of students who learn based on open ended problems have better results than conventional ones. stated that students' mathematical creative thinking skills can be improved with an open-ended approach to rigid object equilibrium material. According to with the MEAs approach, the ability to think creatively is much better than ordinary learning (Bishop, 2021). The same thing according to students' mathematical creative thinking skills can be improved using an open ended approach and better than conventional, students' confidence is increased (Hews et al., 2023).

On the other hand, according to, PjBL is able to improve students' creative and critical thinking skills. Based on the results of the research that learning through open ended using creative thinking makes students' attitudes towards Physics very positive. To deal with open ended problems, students need to develop methods, methods, or approaches so that they vary when searching and getting the right answers. Creative thinking activities and mindsets can be helped by developing open ended learning (Hikmah et al., 2023).

On the other hand, it is also able to provide students with opportunities to investigate various strategies, ways that are in accordance with their elaboration skills (Dwivedi et al., 2023). According to the aspect of openness in open ended is classified into three types, namely (1) an open solution process, the way of solving is varied, (2) the final result is open, which has many correct answers, and (3) open advanced development, after students solve problems, they can develop new problems, change the conditions, conditions of the problems that are solved. The dimensions that teachers can see to students to know whether they think creatively or not, include (a) students are sensitive to problems, (b) flexible in thinking, (c) creating useful new ideas, (d) originality in thinking, and (e) formulating the solution process smoothly, creatively, and systematically (Rahayuningsih et al., 2021). The components of solving problems in

Physics with creative thinking include fluency, flexibility, and novelty . Fluency, students can come up with many solutions in solving problems. Flexibility, students are able to solve problems in different ways or methods.

RESEARCH METHOD

This research was carried out by providing problems in the form of open-ended problems on the equilibrium material of rigid objects. The goal is to identify students' abilities based on the level of creative thinking to solve *open ended* problems of rigid object equilibrium material based on aspects, namely fluency, flexibility, originality, and elaboration. The problems given consist of four questions, each of which is to measure creative thinking skills from the aspects of fluency, flexibility, originality, and elaboration. The respondents of this study were 108 high school grade XI students (Damayanti et al., 2018).

Types of research

This research uses descriptive research with a qualitative approach that can dig up data based on what is said, felt, and done by the data source (Sugiyono, 2015). Therefore, the researcher chose qualitative descriptive research to be able to analyze the data and describe the data produced.

Research time and place

The place where this research was carried out at SMA Negeri 1 Badegan which is located at Jl. Ki Ageng Punuk No 2, Jambon District, Ponorogo and the time for the research was carried out in December 2024.

Population and sample

The population of this study is students in grades XI-3, XI-4, XI-5 at SMA Negeri 1 Badegan. The sample used amounted to 108 students with a total of 36 students in each class.

Data and data collection techniques on

In this study, the data collection technique uses a ability test test in which there are written questions and then analyzed descriptively. The data collection in this study has properties that can combine various data collection techniques and existing data sources. So to collect data, it is carried out in stages, including observation, ability tests, and documentation.

Data analysis techniques

Data analysis in this study can be obtained information from students' creative thinking skills in solving *open-ended* problems on rigid object equilibrium material (Bickley et al., 2024). The data produced from a research must go through the analysis stage first carefully by giving a code to each student's answer, then giving a score in the answer based on the rubric of scoring students' answers from the aspect of creative thinking, so that it can be drawn in a conclusion to get the value of the existing problem (Siddiq et al., 2016). The results of all the data obtained from the results of *the open ended* test with creative thinking skills were analyzed using the percentage Formula 1.

$$NP = \frac{R}{S} \times 100\% \quad (1)$$

Description:
NP =Percentage value
R = Raw score obtained by the student
S = Score maximum

To be able to find out the creative thinking ability of each student in grades XI3, XI4, XI5, each indicator of creative thinking ability uses the criteria of the percentage of creative thinking which will be adjusted to the criteria and answer results categorized based on creative thinking ability. It can be seen in Table 1.

Table 1. Assessment guidelines and creative thinking categories

Percentage of Achievement (%)	Aspects of Creative Thinking	Categories of Levels of Thinking
81–100	Creative Students	Excellent
61–80	Creative Students	Good
41–60	Creative Students	Enough
21–40	Creative Students	Less
0–20	Creative Students	Very Less

RESULTS AND DISCUSSION

Results

Overall creative thinking indicators

Based on the results of the study, it showed that the overall achievement of the indicators of the 3 classes studied showed that the results of the fluency indicator obtained a score of 42.98% (poor category), the flexibility indicator of students received a score of 30.53% (very poor category), the originality indicator obtained a score of 20.35% (very poor category), and the elaboration indicator obtained a score of 25.61% (very insufficient category). The results of the data analysis of the four indicators of creative thinking ability can be seen in the following Figure 1.

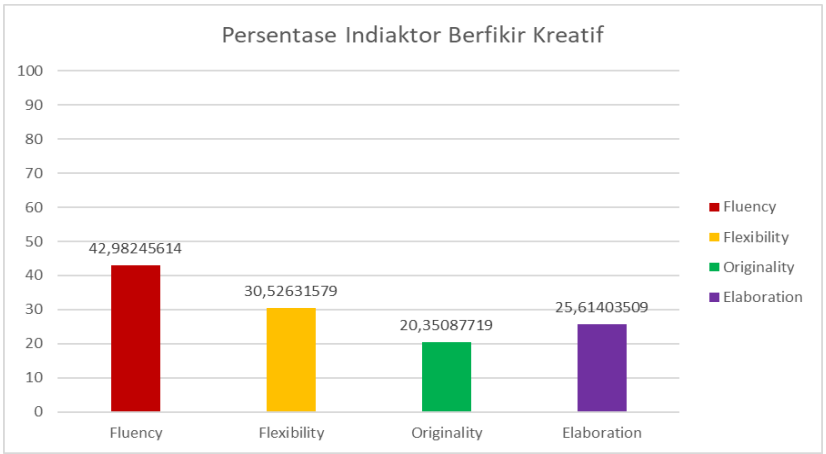

Figure 1. Average achievement percentage of creative thinking aspects

Fluency

The fluency aspect or called the *fluency aspect,* that the fluency aspect refers to students who can solve problems with several alternative answers (Jumi et al, 2018). The ability to think creatively in the fluency aspect in this study was obtained with an average

achievement data that was classified as a good category, which was 42.98%. Based on the overall results of the analysis of students' creative thinking skills based on categories, namely the very good category there is 1% (1 student), the good category is 13% (14 students), the fair category is 19% (20 students), *the* poor category is 47% (51 students), and the very poor category is 20% (22 students). In this case, the percentage obtained based on the category of students' creative thinking ability from the fluency aspect can be seen in Figure 2.

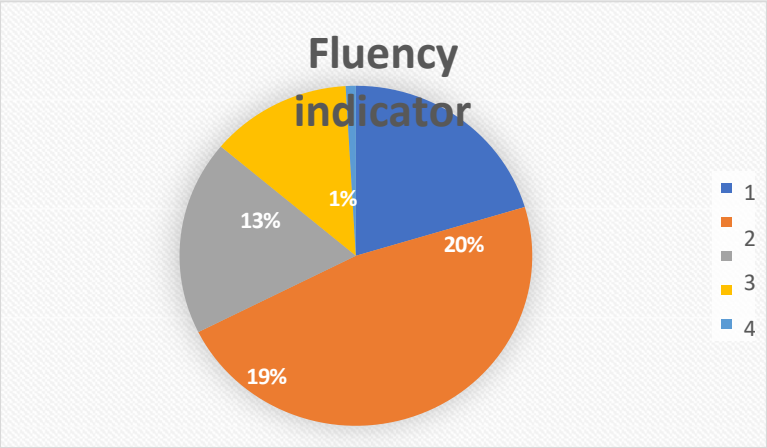

Figure 2. Percentage of fluency achievement

Flexibility

The flexibility aspect or called the flexibility aspect, that the flexibility aspect refers to students who can solve problems using different ways (Jumi et al, 2018). The ability to think creatively in the aspect of flexibility in this study was obtained with average achievement data classified as a good category, which is 30.52%. Based on the overall results of the analysis of students' creative thinking skills based on categories, namely the very good category there are 0% (0 students), the good category there is 0% (0 students), the fair category there is 3% (3 students), *the* poor category there is 55% (60 students), and the very poor category there are 42% (45 students). In this case, the percentage obtained based on the category of students' creative thinking ability from the aspect of flexibility can be seen in the following Figure 3.

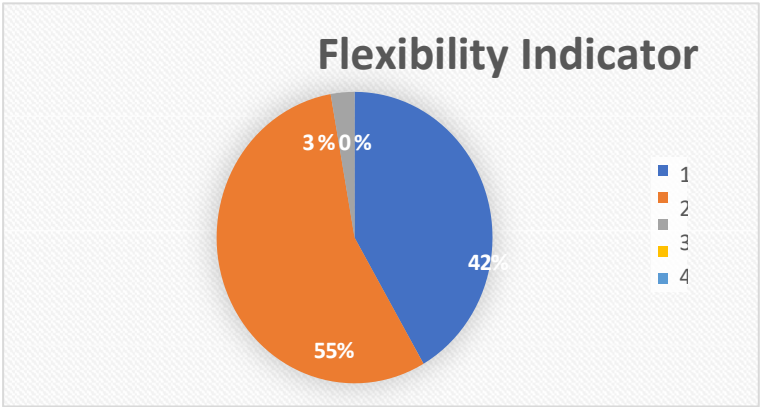

Figure 3. Percentage of achievement of flexibility aspect

Novelties

The novelty aspect or called the *originality aspect,* that the novelty aspect refers to students who can solve problems with several different answers but have the correct value and have one answer that other students usually do not do (Jumi et al, 2018). The ability to

think creatively in the aspect of novelty in this study was obtained with an average achievement data that was classified as a good category, which was 20.35%. Based on the overall results of the analysis of students' creative thinking skills based on categories, namely the very good category there are 0% (0 students), the good category there is 0% (0 students), the sufficient category there is 0% (0 students), *the* insufficient category there is 35% (38 students), and the very poor category there are 65% (70 students). In this case, the percentage obtained based on the category of students' creative thinking ability from the aspect of novelty can be seen in the following Figure 4.

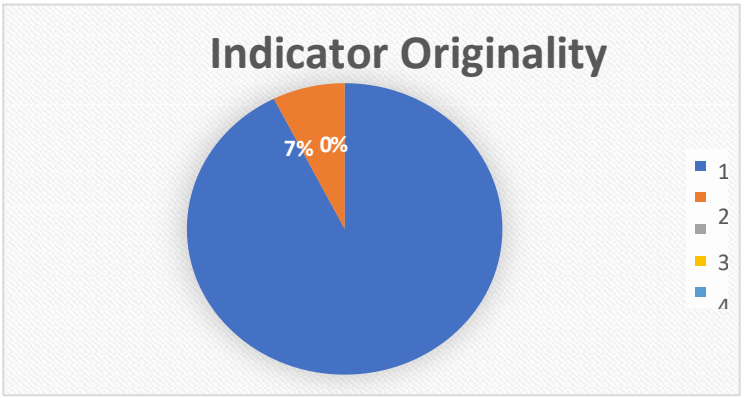

Figure 4. Percentage of achievement of the originality aspect

Elaboration

The elaboration aspect or called the *elaboration aspect,* that the elaboration aspect refers to students who have the ability to add or detail things that are details of an object, idea or situation (Jumi et al, 2018). The ability to think creatively in the aspect of novelty in this study was obtained with an average achievement data that was classified as a good category, which was 25.61%. Based on the overall results of the analysis of students' creative thinking skills based on categories, namely the very good category there are 0% (0 students), the good category there is 0% (0 students), the sufficient category there is 0% (0 students), *the* insufficient category there is 35% (38 students), and the very poor category there are 65% (70 students). In this case, the percentage obtained based on the category of students' creative thinking ability from the novelty aspect can be seen in the following Figure 5.

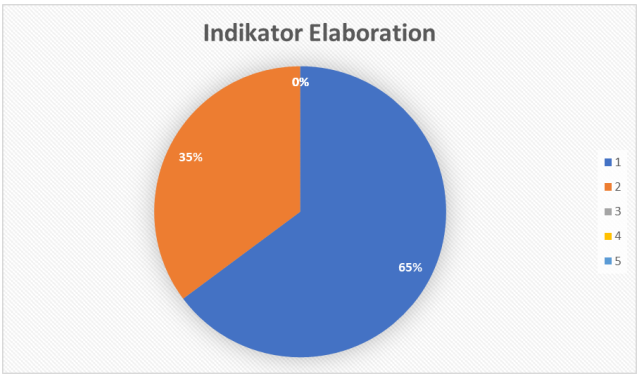

Figure 5. Percentage of achievement of elaboration aspect

Creative thinking indicators per class

The respondents were students of grades XI-3, XI-4, XI-5 of SMA Negeri 1 Badegan. The total number of students who worked on the questions was 108 students and the number of each student per class was 36 students. Here are the results for each class:

1. Class XI-3
   In class XI-3, a total of 36 students were studied, the results on the fluency indicator obtained a score of 40.55% (poor category), the flexibility indicator of students received a score of 31.67% (very poor category), the originality indicator obtained a score of 21.67% (very poor category), and the elaboration indicator received a score of 25% (very insufficient category). The results of the data analysis of the four indicators of creative thinking ability can be seen in the following Figure 6.

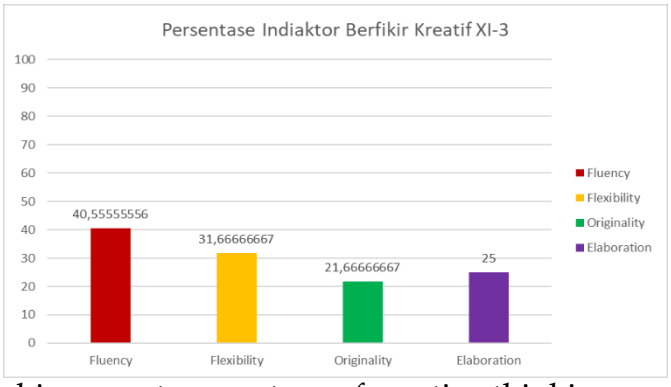

Figure 6. Average achievement percentage of creative thinking aspects of class XI-3

2. Class XI-4
   Class XI-4 of 36 students studied showed results on the fluency indicator obtained a score of 44.44% (poor category), the flexibility indicator of students received a score of 30% (very poor category), originality indicator obtained a score of 21.11% (very poor category), and the elaboration indicator received a score of 26.67% (very poor category). The results of the data analysis of the four indicators of creative thinking ability can be seen in the following Figure 7.

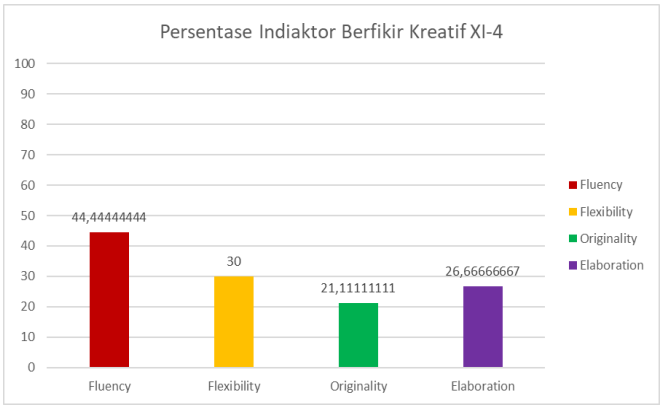

Figure 7. Average achievement percentage of creative thinking aspects

3. Class XI-5Class XI-5 of 36 students studied showed results on the fluency indicator obtained a score of 51.11% (poor category), the flexibility indicator of students received a score of 35% (very poor category), originality indicator obtained a score of 21.67% (very poor category), and the elaboration indicator received a score of 29.44% (very insufficient category). The results of the data analysis of the four indicators of creative thinking ability can be seen in the following Figure 8.

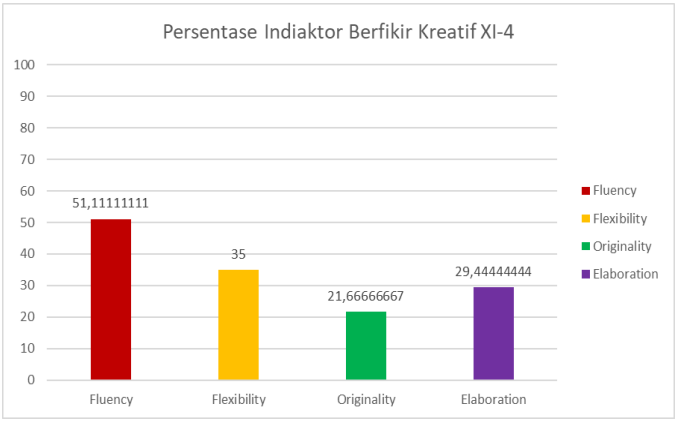

Figure 8. Average achievement percentage of creative thinking aspects of class XI-5

Discussion

Fluency

In this study, especially in the ability to think creatively in the aspect of fluency, the average achievement was 42.98% so that students' creative thinking skills were in the sufficient category. In this aspect, students are quite capable of solving problems using several alternative answers or have answers that have many solutions (Kulsum et al., 2019). The ability of students to provide ideas or ideas in solving problems is included in the aspect of fluency, but the ideas that have been put forward are still in development so that they can show an idea if the student's answer only triggers a few ideas (Singer et al., 2016).

Based on the results of the data analyzed by obtaining a percentage, which is 42.98% which is classified as a sufficient category, in this study the fluency aspect has the highest percentage value of the three aspects of creative thinking skills. Because it is classified as a sufficient category, it needs to be improved (Leasa et al., 2021).

Flexibility

In this study, especially in the ability to think creatively in terms of flexibility, the average student achievement was 30.52% so that the ability to think creatively can be categorized as very lacking. In this aspect students solve problems by using different methods. Meanwhile, according to Marginson et al., (2016) students' ability to think creatively, flexibility or called flexible thinking ability is the ability to produce ideas that have different categories or the ability to see from a point of view. This can be seen that the achievement of students being able to fulfill creative thinking in solving open ended problems has successfully entered the category of flexibility which is ranked high with the second position from the fluency aspect. While looking at the comparison of Reynolds et al. (2017) in the creative thinking ability aspect of students' flexibility has not been able to show ideas or has not been able to provide varied ideas to solve problems, problems based on the information seen make learning that students' creative thinking skills have different levels and ideas.

In this study, the flexibility aspect is ranked second out of the four aspects. According to Gatt et al. (2018) stated that the aspect of the ability to think creatively from flexibility has a very important value by occupying the second aspect of novelty, because students are able to show an ability to generate creativity in solving different problems. From the results of the research, the flexibility aspect really needs to be improved again.

Aspects of originality

In this study, especially in the ability to think creatively in the aspect of novelty, the average student achievement was 20.35%, so that the ability to think creatively can be categorized as very lacking in the open ended test. The novelty aspect is the ability of students to provide a variety of new ideas, but these ideas must have different and innovative values. In this study, the achievement of the novelty aspect has a low score compared to the fluency aspect and the flexibility aspect because the student's ability is still not enough to achieve an aspect in solving problems with new ideas. Meanwhile, according to Gatt (2018), the novelty aspect or novelty aspect is the ability that has the highest position because students are required to have new values and characteristics to produce a novelty thought.

The low achievement of novelty skills illustrates the weakness of students in answering open ended tests because students are not used to answering creative thinking tests. This is a concern in responding to a problem so that student achievement is further improved in learning to improve creative thinking skills. The novelty aspect is one of the indicators that plays a very important role in creative thinking to produce innovative new ideas.

The percentage of the novelty aspect shows the lowest value of the four aspects. Based on the overall results obtained from the novelty aspect, the novelty aspect really needs to be improved.

Aspects of elaboration

In this study, especially in the ability to think creatively in the elaboration aspect, the average student achievement was 25.61%, so that the ability to think creatively in the elaboration aspect can be categorized as very lacking in the open ended test. Because of the elaboration needs to be improved again.

Based on the four aspects of creative thinking in solving open ended problems, the results with the highest score are the fluency aspect with a score of 42.98% which is categorized as poor, then the position of the highest score in the second position is included in the flexibility aspect with a value of 30.52% which is categorized as very lacking, then the elaboration aspect with a score of 25.61% which is categorized as poor and then the novelty aspect is included in the last position with a very poor category that has a score of 20.35%. This indicates that students' ability in the creative thinking process is very lacking in reflecting on the extent of understanding concepts and student processes in solving problems on the open ended test.

CONCLUSION

Fundamental Findings: This research identified students' creative thinking ability in solving open-ended problems on rigid object equilibrium material at SMA Negeri 1 Badegan through digital-based assessment. The results showed that students' creative thinking ability remained in the low category based on four indicators of creative thinking. The fluency indicator obtained an achievement score of 42.98% (poor category), the flexibility indicator reached 30.53% (very poor category), the originality indicator obtained 20.35% (very poor category), and the elaboration indicator reached 25.61% (very poor category). These findings indicate that students still experience difficulties in generating various ideas, developing alternative solutions, producing original responses, and providing detailed explanations when solving open-ended physics problems. The use of Google Form integrated with a learning management system (LMS) also supported a systematic and efficient process for collecting and documenting students' creative

thinking responses. **Implications:** The results of this study imply that students' creative thinking abilities in physics learning, particularly in rigid object equilibrium material, need to be strengthened through learning strategies that provide opportunities for exploration, multiple solutions, and contextual problem-solving activities. Furthermore, the utilization of digital platforms as an assessment medium can support teachers in conducting more flexible, structured, and efficient assessments of students' higher-order thinking skills. **Limitations:** This study is limited to identifying students' creative thinking ability in one physics topic, namely rigid object equilibrium material, and was conducted with a limited sample from one senior high school. In addition, digital technology in this study was only utilized as a data collection medium and was not developed as an interactive learning intervention to improve students' creative thinking ability. **Future Research:** Further research is recommended to develop digital-based learning environments, such as interactive e-learning platforms, digital worksheets, or technology-assisted problem-solving activities, to enhance students' creative thinking abilities in physics. Future studies may also involve broader samples and examine the effectiveness of digital learning models in improving other 21st-century skills, including critical thinking, collaboration, and scientific problem-solving skills.

AUTHOR CONTRIBUTIONS

Ratna Purnamawati: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. **Wasis:** Supervision, Validation, Methodology, Writing – review & editing. **Muhammad Satriawan:** Supervision, Validation, Project administration.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, to support the research and writing processes of this article. Specifically, Mendeley was utilized for reference management and citation formatting, SPSS was used to conduct statistical analysis of the research data, and ChatGPT (OpenAI) was employed as a writing assistant to help refine language and organize the structure of the manuscript. All content generated with digital assistance was critically reviewed, validated, and revised by the authors to ensure academic integrity and ethical standards were maintained. The final responsibility for the content of this manuscript rests entirely with the authors.

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