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Implementing a Flipped Classroom Approach Assisted by Edpuzzle Video Annotations to Improve Students' Cognitive Abilities on Global Warming Topics

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Abstract: This study was prompted by students' low cognitive abilities in solving physics problems, particularly those related to global warming. The research aimed to determine the extent to which a flipped classroom strategy assisted by Edpuzzle video annotations could enhance students' cognitive abilities. A quasi-experimental design with a control group pretest-posttest approach was employed. The sample comprised 70 tenth-grade students from public high schools in Bandung City. Data were collected through essay-based cognitive tests, an instrument assessing the feasibility of video annotation media, and classroom observation sheets. The n-gain formula was used for data analysis. The results showed a moderate improvement in students' cognitive abilities. Both the video annotation media and the flipped classroom strategy were considered feasible, with nearly all planned activities successfully implemented. Overall, integrating a flipped classroom approach with Edpuzzle video annotations proves effective in improving students' cognitive abilities on global warming topics.

INTRODUCTION

Technological advancements in the 21st century provide extensive opportunities for educators and students alike, facilitating more dynamic learning processes. Such developments significantly enhance educational quality by fostering innovation. One key innovation is the creation of learning media that help students grasp abstract concepts by transforming them into more tangible forms (Davoodi, 2024; Razmeh & Salgado, 2024). The growing sophistication of information media has also reached all levels of society, including students, who are now expected to comprehend diverse technological advances, particularly in the digital realm (Kholili, 2021; Mizan et al., 2022; Muflihin & Warsito, 2024). Correspondingly, 21st-century education demands learners who possess independent learning skills, critical thinking abilities, and collaborative competencies (Februannisa & Anggraini, 2022; Lestari et al., 2023; Nur Fitria, 2024).

These rapid technological changes have substantially reshaped traditional learning, enriching students' experiences via digital resources, distance learning, interactive media, and online collaboration. Moreover, educators now serve as facilitators who integrate a variety of tools, resources, and communication platforms to optimize the classroom environment (Gustian et al., 2023; Irianti et al., 2024). As Zhou (2023)

notes, the flipped classroom represents an innovative pedagogical method that prioritizes student-centered learning by reversing the conventional teacher-led system. The aim extends beyond achieving learning outcomes to also emphasize the learning process itself.

Limited interaction between students and teachers—often resulting from the teacher's dominant role—can render students passive. Unidirectional communication is not always effective, especially given differences in learning speeds and restricted class time (Mohamad Agung Rokhimawan et al., 2023). Students with strong technological literacy often feel disengaged when learning is conducted through traditional methods (Jeong, 2022; Richards, 2015). In line with this, Mesnan et al. (2023) found that conventional learning approaches are less effective for attaining optimal learning outcomes. Students' difficulties in solving physics problems are partially attributable to their study habits; in one study, 73% of students reported studying physics only during class, foregoing study at home unless homework or tests were imminent (Ivanjek et al., 2022).

Interviews with teachers at Public Senior High School 10 Bandung during the 2022/2023 academic year indicated that instruction predominantly relied on lectures and discussions. Occasionally, teachers integrated laboratory equipment and videos sourced from platforms such as YouTube, yet they faced limitations in developing innovative learning materials. Consequently, the teacher-centered model remains common, thus highlighting the need for alternative learning strategies to address the existing challenges in this school.

One such alternative is the flipped classroom approach, augmented with Edpuzzle video annotations. In this strategy, students review course materials prior to class, reserving in-class time for discussions and problem-solving—thereby using class hours more efficiently (Baig & Yadegaridehkordi, 2023). This approach can be combined with Problem-Based Learning (PBL), which centers on in-class problem-solving activities. By providing learning resources beforehand (pre-class), the flipped classroom complements PBL by equipping students with foundational knowledge before they engage in deeper learning tasks (in-class) (Liu et al., 2024).

Notably, flipped classroom strategies have been shown to significantly influence students' cognitive learning outcomes (Al-Shabibi & Al-Ayasra, 2019; Sergis et al., 2018; Shooli et al., 2022). In contrast, teacher-centered approaches often yield lower academic performance and diminished cognitive skills. Lavrijsen and Verschueren (2020) observed that teachers rarely measure higher-order cognitive abilities, focusing instead on lower-level skills, such as remembering and understanding, while overlooking more advanced skills like application and analysis. This trend was evident in a physics course, where the highest score achieved by students was only 55 out of 100 (Cardino & Ortega-Dela Cruz, 2020).

Physics comprehension varies widely among students, largely due to cognitive factors. These factors influence learning outcomes such as verbal information, intellectual abilities, motor skills, attitudes, and cognitive strategies (Arlianty et al., 2018; Thu & Hieu, 2019). Anderson and Krathwohl's revision of Bloom's Taxonomy structures the cognitive domain into six hierarchical levels—from remembering (C1) and understanding (C2) to applying (C3), analyzing (C4), evaluating (C5), and creating (C6)—and remains a robust framework for designing intellectual skills assessments (Karmila & Handayani, 2024).

Evidence suggests that students more readily attain lower-order thinking skills (LOTS) such as remembering and

understanding, whereas higher-order thinking skills (HOTS), like analyzing, evaluating, and creating, are more challenging (Arlianty et al., 2018). This underscores the necessity of diverse assessment tools targeting every level of cognitive processing. Furthermore, when educators thoroughly understand cognitive assessment principles, they can refine learning and evaluation methods (Karmila & Handayani, 2024; Lestari et al., 2023; Willis, 2024).

In sum, investigating and enhancing students' cognitive abilities is pivotal to improving learning outcomes. By leveraging the revised Bloom's Taxonomy, educators can develop more balanced assessments that address both lower- and higher-order thinking skills, thereby fostering more effective educational practices.

Lastly, teachers must preemptively address low academic performance by designing instructional activities that move beyond conventional, teacher-centered paradigms. Encouraging students to be active participants not only enlivens the classroom environment but also promotes deeper intellectual and emotional engagement. To tackle such learning challenges, teachers need to adopt strategies or models that motivate active student participation, thereby reducing teacher dominance and facilitating improvements in student achievement (Dwivedi et al., 2023).

METHOD

This study employs a quantitative research method with a quasi-experimental design, specifically using a Control Group Pretest-Posttest Design with two groups. The experimental group first completed a pretest to evaluate their cognitive abilities before receiving instruction via a flipped classroom approach supported by Edpuzzle video annotations; afterward, a posttest was administered to measure any changes in these abilities. Conversely, the control group also took a pretest to assess their initial cognitive abilities prior to participating in the flipped classroom approach but without Edpuzzle video annotations, instead following independent learning at home according to the teacher's instructions; a posttest then evaluated any subsequent changes in their cognitive abilities.

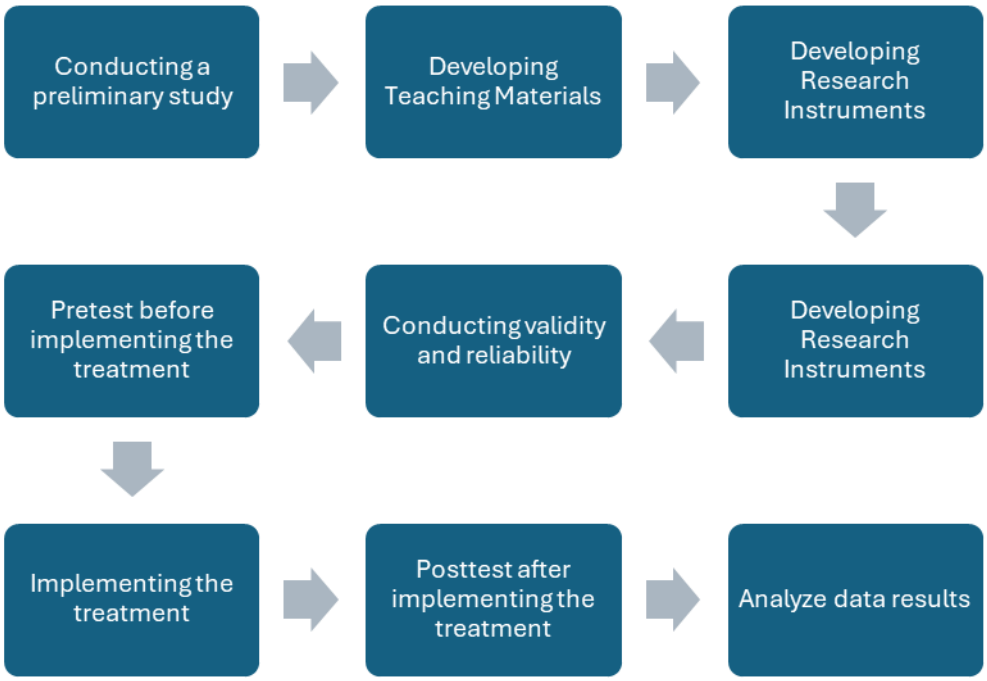

Figure 1. Research Procedures.

The research involved several stages: conducting an initial study, preparing teaching materials, designing and validating research instruments, collecting data, and analyzing the data for normality, homogeneity, hypothesis testing, and n-gain. Conclusions were drawn after completing these analyses. Over two weeks, the experimental group engaged in a flipped classroom strategy enhanced by Edpuzzle video annotations, while the control group received a similar flipped classroom intervention without such annotations. Both groups began by completing a pretest consisting of 16 essay questions with a 60-minute time limit. The experimental group was provided with educational videos on Edpuzzle and assignments to complete at home, submitting their work in class. Meanwhile, the control group was instructed to study independently and complete homework assignments, including note-taking. During classroom sessions, both groups received worksheets containing problems aligned with the Problem-Based Learning (PBL) model.

Table 1. Student Cognitive Ability Learning Achievement Indicators.

No	Indicators	Cognitive Abilities	Number of Questions
1.	Solving a problem related to the greenhouse effect.	C4	2
2.	Reading, comparing, evaluating, and drawing conclusions from graphs related to greenhouse gases and temperature deviations.	C4	3
3.	Interpreting images depicting the greenhouse effect.	C5	1
4.	Analyzing events that exacerbate global warming.	C4	1
5.	Evaluating activities that contribute to the negative impacts of global warming.	C4	4
6.	Providing opinions on problems related to global warming.	C4	1
7.	Formulating problems related to the phenomenon of global warming.	C4	2
8.	Presenting ideas on issues related to global warming.	C6	2

Data were collected offline using pretests and posttests. The research instrument consisted of 16 essay questions aimed at assessing cognitive skills in analyzing (C4), evaluating (C5), and creating (C6), with eight questions measuring C4, one measuring C5, and two measuring C6; these questions were aligned with the Student Cognitive Ability Learning Achievement Indicators. All instruments underwent expert validity testing. Descriptive quantitative analysis, including tests for normality and homogeneity, was carried out, and because the assumptions for these tests were met, an independent t-test was employed using SPSS 27.0 software. Variations in the results may stem from differences in methodology, population characteristics, or the duration of the intervention.

RESULT AND DISCUSSION

Eligibility of Edpuzzle Video Annotations by Media Experts

The eligibility of Edpuzzle video annotations was evaluated by two media experts, two content experts, and a high school physics teacher to assess the quality of annotated educational videos prior to classroom implementation. Data on the media's eligibility were gathered using a non-test questionnaire completed by three validators—two physics lecturers and one high school physics teacher—who provided evaluations, suggestions, and comments related to content presentation and interactivity. The validation results were analyzed using the Guttman scale, which incorporates binary ("Yes" or "No") responses, as outlined in Table 2.

Table 2. Interpretation of Learning Media Eligibility Validation.

Alternative Answers	Interpretation	Score
Yes	Indicates that the aspect meets the criteria or is deemed suitable.	1
No	Indicates that the aspect does not meet the criteria or is considered unsuitable.	0

Table 3. Results of Media Expert Validation Data.

Validator	Score	Results
Media Expert 1	10	Ready for use in an educational context
Media Expert 2	8	Ready for use in an educational context
Media Expert 3	10	Ready for use in an educational context

It can be concluded that Media Expert 1 and Media Expert 2 found the instructional media to be suitable for use, contingent upon revisions recommended in their evaluations. These revisions primarily addressed improvements in visual clarity, interactivity, and content organization to enhance the overall learning experience. Media Expert 3 deemed the instructional video fit for immediate application, underscoring its potential effectiveness as a complementary resource in physics instruction. By integrating feedback from all three experts, the final version of the media aligns more closely with best practices in instructional design, thereby meeting diverse learner needs. Thus, as summarized in Table 3, the educational video is considered suitable for use in fostering an engaging and effective learning environment.

Eligibility of Edpuzzle Video Annotations by Material Experts

The feasibility of the learning materials was assessed using a non-test questionnaire completed by three validators—two physics lecturers and one high school physics teacher. These validators provided assessments, suggestions, and comments regarding learning materials, methods, resources, and activities. The validation results employed the Guttman scale, which offers binary response options (“Yes” or “No”), as shown in Table 4.

Table 4. Interpretation Validation of Material Eligibility.

Alternative Answers	Interpretation	Score
Yes	Learning media is suitable for use	1
No	Learning media is not suitable for use	0

Table 5. Material Validation Interpretation.

Validator	Score	Results
Media Expert 1	10	Worth using
Media Expert 2	8	Worth using
Media Expert 3	10	Worth using

Material experts were consulted to provide suggestions and feedback on annotated learning videos, which served as a reference for improving the media to enhance its feasibility in classroom instruction. The validation data from these experts are shown in the accompanying table. The material validation questionnaire consisted of 17 items, evaluated by three validators using the Guttman scale. Based on the results, Material Experts 1 and 2 concluded that the learning media instruments were suitable for use, contingent upon revisions reflecting their suggestions, while Material Expert 3 deemed the instruments suitable without further modification. Overall, as indicated in Table 5, the learning video materials were found to be

appropriate for classroom implementation.

Cognitive Ability

Students' cognitive abilities were evaluated using Bloom's taxonomy, comprising the levels of C1 (knowledge), C2 (comprehension), C3 (application), C4 (analysis), C5 (evaluation), and C6 (creation). The pretest results revealed an average cognitive ability score of 33.35 for the experimental class and 38.43 for the control class, indicating the need for improvement. Following the pretest, the experimental class received a flipped classroom intervention assisted by Edpuzzle video annotations for two sessions, each lasting 3 × 40 minutes. After this treatment, the posttest average score increased to 74.57, suggesting a marked improvement in students' cognitive abilities. Meanwhile, the control class underwent the same flipped classroom model without video annotations, completing independent study at home according to the teacher's instructions. After this independent learning phase, the posttest average score rose to 60.56, exceeding the pretest score. To facilitate a clear comparison of highest scores, lowest scores, means, and standard deviations in both classes, data were analyzed using SPSS 27.0, and the results are presented in Table 6.

Table 6. Pretest and Posttest Results of The Control Experiment

Calculation	Pretest Results		Posttest Results	
	Experiment	Control	Experiment	Control
Mean	33.35	38.43	74.57	60.56
Standard Deviation	18.5612	16.7010	9,2994	11.0043
The Highest Score	73.44	64.06	92.19	82.81
Lowest Score	0	0	50	39.06

The pretest results in the experimental class showed a highest score of 73.44 and a lowest score of 0, with an average of 33.35 and a standard deviation of 18.5612. In the control class, the highest pretest score reached 64.06, while the lowest was 0, yielding an average of 38.43 and a standard deviation of 16.7010. After the intervention, the posttest results in the experimental class indicated a highest score of 92.19 and a lowest score of 0, with an average of 74.57 and a standard deviation of 9.2994. In contrast, the control class attained a highest posttest score of 82.81 and a lowest of 39.06, with an average of 60.56 and a standard deviation of 11.0043.

Improved Cognitive Abilities

To assess students' cognitive abilities regarding global warming, an essay-based test instrument containing 16 questions (including five sub-questions) was administered. Each question carried four points, making 100 the ideal total score if all answers were correct. The increase in students' cognitive abilities was calculated by comparing the pretest and posttest scores on identical items in both the experimental and control classes. The resulting normalized N-gain values, categorized according to Hake's criteria, are presented in Table 7.

Table 7. Cognitive Ability N-Gain Score.

Group	Average Score			Category
	Pretest	Posttest	N-Gain	
Experiment	33.35	74.57	0.61	Currently
Control	38.43	60.56	0.34	Currently

Table 7 presents the results of students' cognitive ability tests in both the experimental and control classes. The experimental class showed an

average N-gain of 0.61, while the control class reached 0.34. Despite both classes falling into the "medium" N-gain category according to Meltzer (2002), the experimental group displayed a higher overall increase in cognitive abilities after receiving flipped classroom instruction supported by Edpuzzle video annotations. The observed difference in N-gain between the experimental and control groups was 0.27, indicating that the experimental class experienced a greater improvement in cognitive abilities. Therefore, the application of a flipped classroom strategy assisted by Edpuzzle video annotations on global warming material can be concluded to effectively enhance students' cognitive performance.

Increasing Cognitive Abilities in Each Cognitive Domain

The improvement in cognitive abilities across specific domains was analyzed using normalized N-gain, a widely recognized metric for gauging instructional effectiveness. This measure was derived from students' performance on essay-based test items administered before and after two different flipped classroom treatments: one supported by Edpuzzle video annotations (experimental class) and one without such annotations (control class). The test comprised 16 questions targeting the cognitive domains of analyzing (C4), evaluating (C5), and creating (C6), all of which were carefully aligned with the achievement indicators listed in Table 5. By focusing on these distinct cognitive levels, the research aimed to determine not only the overall effectiveness of the instructional approach but also how it influenced higher-order thinking skills that are crucial for deep learning.

To obtain a more precise analysis, the average pretest and posttest scores were calculated separately for C4, C5, and C6. This approach enabled a clearer identification of the specific areas in which students demonstrated the greatest improvements, providing insights for refining future instructional strategies. It also facilitated comparisons of whether Edpuzzle-assisted flipped classrooms yielded more pronounced gains in complex tasks (e.g., evaluation and creation) than the standard flipped classroom model. The comparative results for the pretest and posttest scores at each of the three cognitive levels are presented in Figure 2, offering a visual representation of the degree to which each domain improved after the respective interventions.

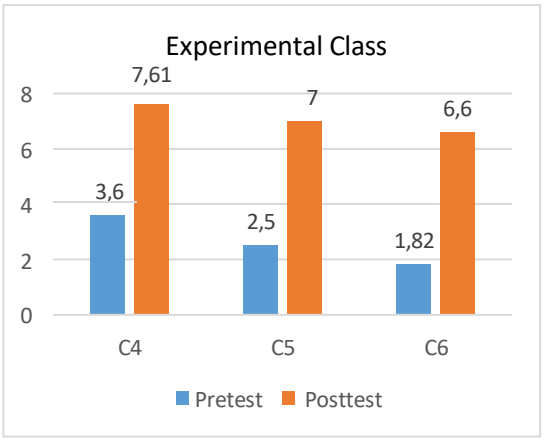

Figure 2. Experimental Class Pretest Posttest Average Diagram.

Figure 2 illustrates the distribution of cognitive ability aspects in the experimental class across 16 essay questions on global warming. The accompanying N-gain analysis highlights the degree of improvement in each cognitive domain—namely analyzing (C4), evaluating (C5), and creating (C6)—following the flipped classroom intervention assisted by Edpuzzle video annotations. By examining how students progressed at each level of cognitive complexity, the figure provides a detailed overview of which skills were most positively impacted by the instructional approach. Notably, the data suggest that certain cognitive domains may benefit more than others from video annotation support, underscoring the importance of

aligning multimedia tools with higher-order thinking objectives. These findings also offer valuable insights for educators seeking to optimize instructional strategies and foster deeper student engagement in scientific topics such as global warming.

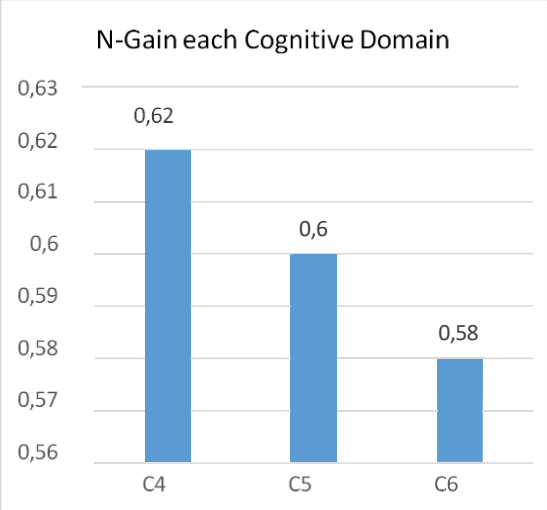

Figure 3. N-Gain Diagram for each Cognitive Domain.

Based on Figure 3, the N-gain scores for the cognitive domains of analyzing (C4), evaluating (C5), and creating (C6) all showed improvements, with average N-gain values of 0.62 for C4, 0.60 for C5, and 0.58 for C6. These scores fall into the "moderate" category, indicating that students experienced a meaningful increase in their higher-order thinking skills. Notably, the higher N-gain for the C4 domain suggests that students' ability to analyze serves as a strong foundation for further development in evaluating (C5) and creating (C6), particularly within the experimental class supported by Edpuzzle video annotations. This trend underscores the importance of scaffolding analytical skills as a precursor to more complex cognitive tasks, such as evaluation and creation.

Meanwhile, Figure 4 presents the average pretest and posttest cognitive ability scores in the control class, which implemented a flipped classroom model without Edpuzzle video annotations. Although an improvement in students' cognitive abilities is still observed, the results indicate that the absence of video annotation support may lead to a lower overall gain compared to the experimental group. By examining these comparative trends, educators and researchers can better understand how targeted interventions, like Edpuzzle video annotations, can differentially enhance specific cognitive domains and foster more robust learning outcomes in science education.

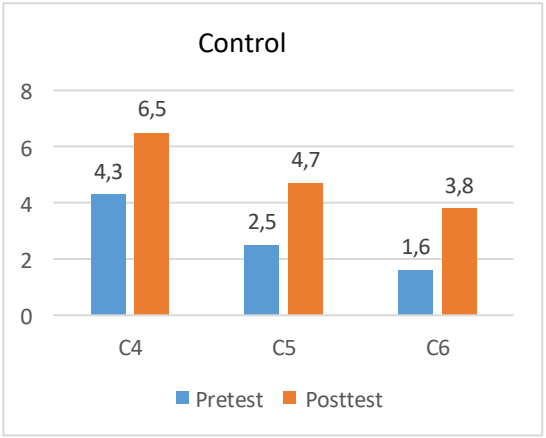

Figure 4. Control Class Pretest Posttest Average Diagram.

Figure 4 illustrates the distribution of cognitive ability aspects in the control class across 16 essay questions on global warming. In particular, it shows how students performed on questions targeting the cognitive domains of analyzing (C4), evaluating (C5), and creating (C6) before and after undergoing a flipped classroom approach without Edpuzzle video annotations. The results of the N-gain analysis for each cognitive domain in the control class are presented in Figure 5, offering further insight into how these students' cognitive abilities developed. By comparing Figures 4 and 5 with the corresponding data from the experimental class, educators can discern the potential impact of video annotations in supporting higher-order

thinking skills and identify areas where pedagogical adjustments may enhance learning outcomes.

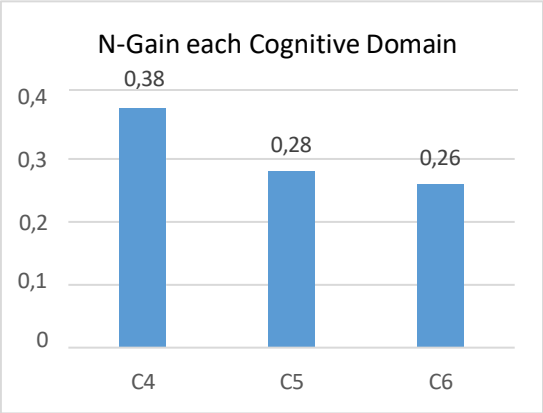

Figure 5. N-Gain Diagram of each Control Class Cognitive Domain.

Based on Figure 5, the average N-gain scores for analyzing (C4), evaluating (C5), and creating (C6) in the control class are 0.38, 0.28, and 0.26, respectively. Although these values indicate an overall increase in cognitive abilities, only C4 is categorized as "moderate," whereas both C5 and C6 are classified as "low." Nevertheless, the stronger gains in the C4 domain suggest that enhanced analytical skills could serve as a foundation for further development in evaluation (C5) and creation (C6). These findings highlight the need for more targeted instructional strategies and resources to help students advance beyond the initial stages of higher-order thinking, thereby promoting a more comprehensive mastery of global warming material.

CONCLUSION

The results of this study show that integrating a flipped classroom model with Edpuzzle video annotations significantly improves students' cognitive abilities in global warming material, as evidenced by the higher N-gain score in the experimental class (0.61) compared to the control class (0.34). Notably, gains in the experimental class were observed not only in analyzing (C4) but also in evaluating (C5) and creating (C6), underscoring the potential of Edpuzzle annotations to support higher-order thinking skills. These findings confirm the feasibility of employing annotated videos to enhance physics instruction, with recommended refinements for broader implementation. Future research could extend this approach to diverse physics topics, ensuring consistent video production and annotation processes to maximize the effectiveness of the flipped classroom strategy.

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