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ORIGINAL

Effectiveness of Animated Simulation Video Media in Promoting Higher-Order Thinking Skills in Grade 10 High School Physics Material

La eficacia de los videos de simulación animada en la promoción de habilidades de pensamiento de orden superior en el grado 10 en el material de Física de secundaria

Rosynanda Nur Fauziah[1], Anik Ghufron[1], Ali Muhtadi[1], Muhamad Restu Fauzi[2]

[1]Education Science, Graduated School, Universitas Negeri Yogyakarta, Yogyakarta. Indonesia.
[2]Faculty of Tarbiyah and Teacher Training, Univeristas Islam Negeri Sunan Kalijaga, Yogyakarta. Indonesia.

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Corresponding author: Rosynanda Nur Fauziah

ABSTRACT

Introduction: physics instruction in Grade 10 of senior high school is still predominantly conducted through conventional approaches with minimal interactivity, making it less effective in fostering students' Higher-Order Thinking Skills (HOTS). Preliminary studies indicate that both teachers and students face difficulties in understanding and teaching abstract physics concepts due to the lack of supportive visual media. The use of animated simulation videos serves as a strategic alternative to address this issue, as it can dynamically and contextually visualize complex concepts while also stimulating higher-level cognitive processes.
Method: this study employed a quantitative method with a quasi-experimental design of the nonequivalent control group type. The research was conducted on 10th-grade high school students who were divided into two groups is the experimental group, which received treatment using animated simulation video media, and the control group, which followed conventional instruction.
Results: the research findings show that students who learned using animated simulation video media achieved higher HOTS scores compared to those who learned through conventional methods. The HOTS instrument used was validated and found to be reliable, and the data met the requirements for normality and homogeneity. T-tests and ANOVA revealed significant differences in students' abilities in analysis, evaluation, and creation between the experimental and control groups.
Conclusions: animated simulation video media has been proven effective in enhancing students' higher-order thinking skills in Grade 10 physics material.

Keywords: HOTS; Animated Simulation; Quantitative; Physics; Instructional Media.

RESUMEN

Introducción: la enseñanza de la física en el décimo grado de la escuela secundaria superior todavía se realiza predominantemente a través de enfoques convencionales con una interactividad mínima, lo que la hace menos eficaz para fomentar las habilidades de pensamiento de orden superior (HOTS) en los estudiantes. Estudios preliminares indican que tanto los docentes como los estudiantes enfrentan dificultades para comprender y enseñar conceptos abstractos de la física debido a la falta de medios visuales de apoyo. El uso de videos de simulación animada representa una alternativa estratégica para abordar este problema, ya que permite visualizar de manera dinámica y contextual conceptos complejos, al tiempo que estimula procesos cognitivos de nivel superior.

Método: este estudio empleó un método cuantitativo con un diseño cuasi-experimental del tipo grupo de control no equivalente. La investigación se llevó a cabo con estudiantes de décimo grado de escuela secundaria, quienes fueron divididos en dos grupos: el grupo experimental, que recibió el tratamiento utilizando medios de video de simulación animada, y el grupo de control, que siguió una instrucción convencional.
Resultados: los hallazgos de la investigación muestran que los estudiantes que aprendieron utilizando videos de simulación animada obtuvieron puntuaciones más altas en HOTS en comparación con aquellos que aprendieron mediante métodos convencionales. El instrumento HOTS utilizado fue validado y se encontró que era confiable, y los datos cumplieron con los requisitos de normalidad y homogeneidad. Las pruebas T y el análisis de varianza (ANOVA) revelaron diferencias significativas en las habilidades de análisis, evaluación y creación entre los grupos experimental y de control.
Conclusiones: se ha comprobado que el uso de medios de video de simulación animada es eficaz para mejorar las habilidades de pensamiento de orden superior de los estudiantes en el contenido de física de décimo grado.

Palabras clave: HOTS; Simulación Animada; Cuantitativo; Física; Medios de Enseñanza.

INTRODUCTION

The development of digital technology has revolutionized various aspects of human life, including the education sector.[1] One of the most evident impacts of this transformation is the emergence of interactive learning media that can present information in a more dynamic and contextual manner. Animated simulation videos represent a form of instructional media that effectively captures students' attention through dynamic and interactive visual displays. These animated simulation videos not only offer aesthetic appeal but also hold significant potential in supporting meaningful and in-depth learning processes. The use of animated simulation videos in physics education can enhance the learning process, particularly in addressing challenges such as limited laboratory facilities.[2] The limitations of laboratory facilities remain a significant challenge in creating meaningful learning experiences. Many schools lack adequate measuring instruments, both in terms of quantity and variety. As a result, students do not have the opportunity to directly interact with essential tools such as micrometers, calipers, or balances. This lack of hands-on practice not only hinders the acquisition of fundamental skills but also contributes to the low level of student competence.[3]

Animated simulation video media, as a supportive tool in physics education, must be capable of bridging the gap between theoretical concepts and real-world applications. Therefore, this technology can serve as an effective alternative to enhance students' conceptual understanding and HOTS.[4] HOTS that students must possess include the ability to analyze data, evaluate measurement results, and design independent experiments. These skills are essential for meeting the challenges of 21st-century education, which demands critical and creative thinking abilities. By visually and interactively representing the working processes of measuring instruments, these tools enable students to grasp measurement principles and procedures contextually, even in the absence of a physical laboratory.[5] Far beyond functioning as mere visual aids, such media serve as pedagogical resources that foster cognitive engagement through observation, interpretation, and scenario-based problem solving. In addition to addressing limitations in physical infrastructure, they offer significant potential to boost concept mastery and the development of HOTS. Hence, it is vital to empirically assess their effectiveness in tenth-grade physics instruction, in order to establish a solid scientific foundation for their broader adoption in the educational field.

Animated simulation video media plays a crucial role in explaining the working principles of measuring instruments in a visual and systematic manner.[6] Through digital simulations, students can understand the function of each component of measuring instruments such as micrometers, calipers, and balances, including how these tools are used in the process of physics measurement. This media visualizes the step-by-step procedures for using the instruments, starting from zero adjustment, placement of the object to be measured, to accurately reading the results. With interactive animations, students do not simply view static images of the instruments but also observe their operational dynamics in scenarios that resemble real experiments. This is especially beneficial in situations where schools lack sufficient equipment or face time constraints for practical sessions. The use of such simulations also stimulates students' analytical thinking skills, as they are encouraged to observe, predict, and draw conclusions from the virtual measurement processes they conduct.[7] Animated simulation video media functions not only as a technical aid but also as an instructional tool that reinforces conceptual understanding and enhances students' HOTS. Without the support of representative visual media, students tend to merely memorize the functions of instruments without deeply understanding their underlying principles of operation.[8,9] Therefore, the use of animated simulation videos is highly beneficial in clarifying concepts, demonstrating usage procedures, and enhancing the understanding of the relationship between measuring instruments and the physical variables being measured.

Physics is a discipline that demands not only the ability to understand concepts but also the skills to think logically, critically, and systematically.(10) Unfortunately, physics instruction at the senior high school level is still largely dominated by conventional, one-way teaching methods, where the teacher serves as the primary source of information and students tend to remain passive.(11) Learning under such limitations tends to be one-directional and provides little opportunity for students to actively engage in the learning process. As a consequence, students often become passive recipients of information, without being deeply involved in scientific thinking or independent exploration of concepts.(12)

This contributes to students' low conceptual mastery and weak HOTS. Abilities such as analyzing relationships between variables, evaluating experimental results, and designing solutions to real-world problems are essential competencies that are critically needed to face the challenges of the 21st century.

To address these challenges, the use of animated simulation video media presents a promising strategic alternative. Animated simulation videos can visualize complex physics phenomena that are difficult or impossible to observe directly in the classroom.(13)

Animated simulations can also present variable changes in real time, allowing students to observe cause-and-effect relationships more concretely.(11) Moreover, animated simulation video media can stimulate students' cognitive activity through engaging visual and auditory interactions.(14) Exposure to structured, problem-based simulations can encourage students to think critically, (5)effective questions,(15) and develop logical arguments based on the visual evidence presented.(16)

Animated video media not only supports conceptual understanding but also fosters the comprehensive development of HOTS.(17)

The integration of animated simulation videos serves not only as a teaching aid but also as a pedagogical strategy to promote higher levels of cognitive engagement.(4) This media provides visual and temporal stimuli that can facilitate advanced mental processes such as making inferences, decision-making, and constructing scientific arguments.(18) A preliminary study was conducted at two public senior high schools in the Yogyakarta area with the aim of obtaining an initial overview of the physics learning process and the extent to which students' HOTS are developed during instructional activities. The methods used in this preliminary study included classroom observations, interviews with physics teachers, and the distribution of questionnaires to tenth-grade students.(19)

Observation results indicate that the majority of physics teachers still predominantly use conventional instructional media, with an emphasis on delivering formulas and solving practice problems. This approach tends to focus on rote memorization and procedural tasks, offering limited opportunities for students to engage in critical thinking or express their understanding creatively.(20)

Although some teachers have attempted to incorporate technology, such as presentation slides, its use remains largely one-directional and does not actively involve students in the learning process. This suggests that the teaching and learning of physics has not yet fully aligned with the development of higher-order thinking skills, as emphasized in the *Kurikulum Merdeka* and the demands of 21st-century education.

The use of instructional media is still largely limited to static tools, such as whiteboards or projectors, which are insufficient for visually and contextually representing abstract concepts in physics.(19)

The lack of dynamic visualization makes it difficult for students to imagine complex physics phenomena, such as the motion of microscopic particles, energy transformations in closed systems, or force interactions in various contexts. As a result, students' cognitive engagement tends to be low, as they merely follow the teacher's explanation without visual stimuli that spark curiosity or analytical thinking. This situation is further exacerbated by the limited time allocated for discussion, exploration, or contextual problem-solving during lessons.(21)

Student's difficulty in visualizing complex physics phenomena often leads to passive behavior and a lack of motivation to ask questions or explore the material in depth.(22)

The low level of student initiative in learning reflects that the current instructional process has not fully accommodated their diverse learning needs, particularly in developing higher-order thinking skills. Therefore, innovation is needed in the selection and use of instructional media—media that are not only visually engaging but also capable of optimally activating students' cognitive engagement. One potential solution to bridge this gap is the use of animated simulation video media, which offers a visual, dynamic, and contextual approach to delivering physics concepts.(23)

Interviews with physics teachers revealed that although teachers are aware of the importance of developing higher-order thinking skills, the implementation is hindered by several major constraints, including limited resources,(24) restricted instructional time,(25)and a lack of teacher training in the use of technology-based media.(26)

Teachers noted that most training they had attended still focused on administrative matters or general pedagogy, while interactive and practical instructional technologies had not been adequately addressed. As a result, teachers tend to revert to methods they are already familiar with, even though these approaches may not effectively meet the demands of complex learning or foster critical thinking. Teachers also emphasized that students urgently need instructional media that can concretely and engagingly visualize physics concepts, especially for abstract topics such as measuring instruments. Without the support of visualizations or interactive simulations, students often resort to memorizing formulas without truly understanding the context or application of the concepts in real life. When asked to solve analytical or high-level reasoning problems, many students appeared confused due to a lack of strong conceptual foundations. This points to a clear gap between the complexity of the subject matter and the conventional teaching methods still in use.

Teachers expressed a strong need for tangible support from schools and education authorities to provide access to technology-based instructional media such as animated simulation videos. This type of media is seen as beneficial not only in helping teachers deliver material more effectively but also in encouraging students to participate more actively in the learning process. In the interviews, some teachers reported that limited trials of animated simulation videos with students had successfully captured students' attention and improved their understanding of the material. [27] However, due to the lack of widespread availability and integration into the curriculum and teacher training, their use remains sporadic. Therefore, this study is considered important to provide empirical evidence and to support the systematic and sustainable adoption of innovative instructional media.

The preliminary study involving 60 tenth-grade students showed that more than 70 % of students struggled to understand physics concepts presented verbally without visualization support. Furthermore, only about 15 % of students were able to correctly answer HOTS-based questions (analysis, evaluation, and creation) in practice exercises. These data reinforce the finding that current physics instruction is not yet optimal in fostering students' higher-order thinking skills. The results of the preliminary study highlight an urgent need to integrate technology-based instructional media that facilitate visualization, active student engagement, and the development of critical and creative thinking skills. Based on these findings, the intervention in the form of using animated simulation video media in tenth-grade physics instruction is considered relevant and worthy of further effectiveness testing through this research.

In line with these findings, the importance of integrating technology into education has also been highlighted in various previous studies. However, most of these studies have primarily focused on improving students' conceptual understanding or learning motivation, without thoroughly examining the impact of instructional media on the development of higher-order thinking skills.[28] In fact, within the context of 21st-century education, mastering HOTS—particularly the abilities to analyze, evaluate, and create solutions—is an essential skill set that must be cultivated from an early stage in schooling.[29] Tenth-grade physics material, which is abstract and complex in nature, requires a learning approach that is not only informative but also capable of stimulating higher-order cognitive processes.

Animated simulation video media emerges as a potential solution because it allows students to observe physics phenomena that are difficult to demonstrate directly in the classroom.[30] The dynamic visualization offered by this media can bridge the limitations of space and time in the classroom, facilitating students to learn in a more contextual and exploratory manner. Moreover, this media can also enhance students' interest in learning physics, which has often been perceived as difficult and boring by many students.[31]

However, to date, there has been limited empirical research examining the effectiveness of this media in enhancing student's HOTS, particularly in the context of tenth-grade senior high school physics material, which is abstract and highly conceptual.

This gap forms the fundamental basis for conducting this research. The study aims to provide empirical evidence on the effectiveness of animated simulation video media in promoting the development of students' HOTS at the levels of analysis (C4), evaluation (C5), and creation (C6) in accordance with the revised Bloom's taxonomy. Utilizing a quantitative approach supported by valid and reliable instruments, this research seeks to ensure that the findings can serve as credible scientific references. Furthermore, the focus is not merely on improving general learning outcomes but specifically on assessing the development of students' higher-order thinking abilities through innovative technology-based learning. [32]

The findings of this study are expected to make a tangible contribution to both the theory and practice of physics education. Theoretically, the results can strengthen the foundation for developing instructional models that integrate visualization and simulation as part of strategies to enhance HOTS. Practically, teachers can adopt animated simulation video media as an effective and relevant alternative instructional tool tailored to students' needs in the digital era. Thus, this research not only addresses the empirical need for evaluating technology-based media effectiveness but also provides a basis for transforming physics education into a more meaningful, innovative, and 21st-century thinking skills-oriented process. Therefore, this study aims to empirically test the effectiveness of animated simulation video media in tenth-grade physics learning, particularly in fostering the enhancement of students' HOTS. The primary focus is directed toward three cognitive indicators in the revised Bloom's taxonomy such as analysis (C4), evaluation (C5), and creation (C6), which reflect complex and deep thinking processes. These three indicators were chosen because they are essential in shaping students who can critically understand concepts and generate innovative solutions to problems encountered. Through a quantitative approach and experimental design, this research endeavors to reveal the extent of contribution that animation and simulation-based media offer in improving students' thinking abilities. It is hoped that the results will provide valuable contributions both theoretically for media development and practically for teachers in selecting more effective and relevant instructional strategies aligned with 21st-century demands.

METHOD

This study employed a quasi-experimental design using a pretest-posttest control group design, involving two groups: an experimental group that received instruction using animated simulation video media, and a control group that followed conventional classroom instruction without such media. The research was conducted during the second semester of the 2024/2025 academic year, from January to April 2025, in three senior high schools in Yogyakarta, Indonesia: SMA Negeri 1 Godean, SMA Negeri Dlingo, and SMA Negeri 4 Yogyakarta City. These schools were chosen based on their readiness to implement technology-assisted learning and the availability of tenth-grade students with characteristics that matched the study criteria.[33]

The population in this study consisted of all tenth-grade students enrolled in the selected senior high schools. From this population, a sample of 216 students was drawn to represent both the experimental and control groups. To ensure each school was proportionally represented and to minimize sampling bias, stratified random sampling was employed. In each participating school, two science classes with similar characteristics were selected, with one class randomly assigned as the experimental group and the other as the control group. The inclusion criteria required students to be actively enrolled in the tenth grade, regularly participating in physics classes, and present during both the pretest and posttest phases. Students who had prolonged absences exceeding two weeks or who failed to complete either the pretest or posttest were excluded from the sample. Additionally, students who dropped out or voluntarily withdrew from the study at any point were removed from the final analysis as part of the exit criteria. The sample size of 216 students was considered sufficient to meet the statistical power requirements for comparative educational research, allowing meaningful differences between groups to be detected and analyzed.

The data collection instrument used was a HOTS test in the form of essay questions, developed based on indicators C4 (analysis), C5 (evaluation), and C6 (creation) of the revised Bloom's Taxonomy. The HOTS instrument was administered before and after the treatment (pretest and posttest). This instrument serves to measure, record, or obtain relevant information systematically and consistently regarding the variables or phenomena under study. A quantitative approach was applied in this research. The data analysis techniques were adjusted according to the types of instruments used, namely pretest-posttest assessments, observation sheets, and questionnaires.

The research instruments were also used to evaluate whether they met the required criteria in terms of validity and reliability. A valid instrument indicates that the measuring tool can accurately be used to obtain appropriate data.[33,34] Validity indicates the extent to which an instrument is capable of measuring what it is intended to measure. An item is considered valid if the correlation value between the item score and the total score has a significance level of less than 0,05. Conversely, if the significance value of the correlation between the item score and the total score is greater than 0,05, the item is deemed invalid. Reliability testing refers to the extent to which an instrument can produce consistent and stable results when used in repeated measurements. An unreliable instrument may yield untrustworthy data, leading to inaccurate and misleading analysis and conclusions. Therefore, reliability is a crucial aspect in the evaluation of research instruments. Reliability testing is conducted after the instrument has first been declared valid, meaning each tested item has met the criteria for validity. One commonly used method for measuring reliability is the Cronbach's Alpha coefficient. If the Cronbach's Alpha value is greater than 0,60, the instrument is considered to have good reliability or is deemed reliable. Conversely, if the value is less than 0,60, the instrument is considered unreliable because it fails to produce consistent results in measurements.

Data analysis for observation sheets and questionnaires in this study employed the Likert scale as a measurement instrument. The likert scale is a commonly used scale to measure respondents' attitudes, opinions, or perceptions toward a given statement, with a range of graded response options.

Tabel 1. Assessment with a likert scale

Assessment score	Category
4	Strongly Agree
3	Agree
2	Disagree
1	Strongly Disagree

Tabel 2. Average score range

Score range	Category
3,26 – 4,00	Very valid
2,51 – 3,25	Valid
1,76 – 2,50	Quite valid
1,00 – 1,75	Less valid

This study employed several statistical analysis techniques to assess the effectiveness of the implemented learning media. These tests were used to determine whether there was a significant difference in the effectiveness of animated simulation videos in enhancing students' Higher-Order Thinking Skills (HOTS). The data were first analyzed using normality and homogeneity tests, followed by t-tests and ANOVA to examine differences in HOTS outcomes between the experimental and control groups.

The N-Gain (Normalized Gain) test is an analytical method used to measure the effectiveness of a learning intervention based on the improvement in students' learning outcomes between the pretest (before instruction) and the posttest (after instruction). The N-Gain indicates the extent of students' knowledge or skill improvement relative to the maximum possible gain that could be achieved. The N-Gain (Normalized Gain) test is an analytical method used to measure the effectiveness of a learning process based on the improvement in students' learning outcomes between the pretest (before instruction) and the posttest (after instruction). The N-Gain indicates the extent of students' knowledge or skill improvement relative to the maximum possible gain that could be achieved.

Description:

g = N-Gain
Spost = Posttest score (final learning outcome)
Spre = Pretest score (initial learning outcome)
Smax = Maximum possible score

After the N-Gain value is calculated, it is then categorized to indicate the level of effectiveness using the following classification table:

Tabel 3. Normalized N-gain category

Score range	Interpretation
-1,00, ≤ g ≤	There is a decrease
g = 0,00	Still
0,00 < g < 0,30	Quite good
0,30 ≤ g ≤ 0,70	Good
0,70 ≤ g ≤ 1,00	Very good

RESULTS

Observations during the learning process also revealed that students in the experimental group were more active in discussions, asked more questions, and showed a higher level of interest in solving complex physics problems. This contrasted with the control group, which tended to be more passive and simply followed the teacher's explanations with minimal interaction or exploration. Thus, the findings of this study reinforce the conclusion that animated simulation video media is not only effective in improving cognitive learning outcomes but also in creating a more active, reflective, and participatory learning environment.

This study aimed to measure the effectiveness of using animated simulation video media in enhancing students' HOTS in tenth-grade physics material. Data were collected through a HOTS test that covered three key indicators in the revised Bloom's Taxonomy: analysis (C4), evaluation (C5), and creation (C6). The research subjects consisted of two groups: an experimental group that received instruction using animated simulation videos, and a control group that received conventional instruction.

A total of 15 HOTS test items were validated by three expert judges, focusing on the three main indicators of the revised Bloom's Taxonomy—analysis (C4), evaluation (C5), and creation (C6). The validation process aimed to assess the extent to which each item aligned with higher-order thinking skill indicators and its relevance to the tenth-grade physics content. The validators evaluated various aspects, including the alignment of each item with cognitive indicators, clarity of language, contextual relevance, and the level of difficulty.

Table 4. HOTS Instrument Validation Results by Expert Judgment

No	Aspect	Mean	Information
1	Suitability of questions with indicator C4 (Analysis)	3,67	Very valid
2	Suitability of questions with indicator C5 (Evaluation)	3,67	Very valid
3	Suitability of questions with indicator C6 (Creation)	3,67	Very valid
4	Suitability of question content with class X physics material	3,67	Very valid
5	Clarity of language and wording of questions	3,33	Valid
6	Clarity of instructions for working on questions	3,67	Very valid
7	Relevance of questions to students' daily lives	3,33	Valid
8	Suitability of questions to the cognitive level of class X students	3,67	Very valid

Based on the results of the HOTS instrument validation by three expert judges, it can be concluded that most of the assessed aspects demonstrated a very high level of validity. The alignment of the test items with the indicators of C4 (Analysis), C5 (Evaluation), and C6 (Creation) each received an average score of 3,67, which falls into the "very valid" category. This indicates that the items were appropriately constructed to assess higher-order thinking skills in accordance with the revised Bloom's Taxonomy.

The aspects related to the alignment of the test content with the tenth-grade physics curriculum, the clarity of the instructions, and the appropriateness of the items to the cognitive level of tenth-grade students also received an average score of 3,67, indicating a very high level of validity. This suggests that the test items are well-suited to the subject matter and the cognitive development level of the targeted students.

However, two aspects received a slightly lower average score of 3,33 the clarity of language and item phrasing, and the relevance of the items to students' daily lives. Although both are categorized as valid, they are not as strong as the other aspects. This indicates the need for minor improvements in the wording of the questions to make them more communicative and contextually relevant for students. Overall, these results suggest that the developed instrument is suitable for use, with some minor refinements needed in phrasing and contextualization.

Table 5. Limited Instrument Trial Results

Statistical test	Value
Number of Respondents	108 grade X students
Number of Question Items	15 HOTS questions (C4–C6)
Alpha Cronbach	0,876
Reliability Criteria	Very high

Based on the results of the limited trial of the HOTS instrument as shown in table 3, a Cronbach's Alpha value of 0,876 was obtained from 15 test items administered to 108 tenth-grade students. This value indicates that the instrument has a very high level of reliability, as it exceeds the commonly accepted threshold of 0,80 in reliability testing criteria. The HOTS instrument is capable of producing consistent and dependable data in measuring students' higher-order thinking skills, particularly in the indicators of analysis (C4), evaluation (C5), and creation (C6) in accordance with the revised Bloom's Taxonomy. It can be concluded that this instrument is both appropriate and reliable for use in data collection for the main study.

Table 6. Reliability test results

Indicator HOTS	Amount	Alpha Cronbach	Criteria
C4	5	0,852	Realibel
C5	5	0,866	Realibel
C6	5	0,879	Realibel
Total	15	0,869	Realibel

The results of the prerequisite analysis indicate that the data from both groups—the experimental group and the control group—meet the assumptions of normality and homogeneity. The normality test, conducted using the Kolmogorov-Smirnov method, yielded a significance value of 0,174 for the experimental group and 0,200 for the control group, both of which are greater than 0,05. This indicates that the data in both groups are normally distributed. Meanwhile, the homogeneity of variance test using Levene's Test produced a significance value of 0,324, which is also greater than 0,05, indicating that the data have homogeneous variances.

Table 7. Normality test and homogeneity test results

Group	Normality test (Sig. Kolmogorov-Smirnov)	Homogeneity test (Sig. Levene)	Criteria
Experiment	0,174	0,324	Normal, Homogeneous
Control	0,200	0,324	Normal, Homogeneous

The results of the independent t-test between the experimental and control groups indicate a significant difference in HOTS scores. The experimental group, which used animated simulation video media, achieved an average HOTS score of 82,60 with a standard deviation of 6,21, while the control group, which received conventional instruction, had an average score of 74,13 with a standard deviation of 5,98. The calculated t-value was 5,432 with a significance level (2-tailed) of 0,000, which is below the 0,05 threshold. This indicates that there is a statistically significant difference between the two groups. The use of animated simulation video media has been proven to be more effective in enhancing students' HOTS in tenth-grade physics material compared to conventional teaching methods.

Table 8. T-test results

Group	N	Mean	Std. Dev	t-count	Sig. (2-tailed)	Information
Experiment	108	82,60	6,21	5,432	0,000	Significant
Control	108	74,13	5,98			

To determine the practical significance of the score difference between the experimental and control groups, an effect size calculation was conducted using the Cohen's *d* formula. Based on the posttest mean scores of the experimental group (82,60) and the control group (74,13), along with their respective standard deviations (6,21 and 5,98), the resulting Cohen's *d* value was 1,39. This value was calculated by dividing the mean difference between the two groups (8,47) by the pooled standard deviation (6,10), resulting in $d = 8{,}47 / 6{,}10 \approx 1{,}39$. According to Cohen's (1988) classification, this value falls into the large effect size category. This finding indicates that the use of animated simulation video media in physics instruction has a strong and practically significant impact on improving tenth-grade students' HOTS. Thus, this media is not only statistically effective but also demonstrates a meaningful impact in the learning process.

The data analysis results based on HOTS indicators reveal significant differences in scores between the experimental and control groups across each indicator in the revised Bloom's Taxonomy. For the C4 (Analysis) indicator, the experimental group achieved an average score of 83,2, while the control group scored 75,0. The calculated F-value was 7,121 with a significance level of 0,000, indicating a statistically significant difference. For the C5 (Evaluation) indicator, the experimental group obtained an average score of 81,4, whereas the control group scored 73,5, with an F-value of 6,674 and a significance level of 0,000, also indicating a significant difference. Meanwhile, for the C6 (Creation) indicator, the experimental group achieved the highest average score of 83,3 compared to the control group. The analysis showed an F-value of 8,203 with a significance level of 0,000, confirming that the difference between the two groups was statistically significant. It can be concluded that the use of animated simulation video media effectively enhances students' skills in analysis, evaluation, and creation compared to conventional teaching methods.

Table 9. ANOVA test results

Indicator	Group	Mean	F count	Sig	Information
C4	Experiment	83,2	7,121	0,000	Significant
	Control	75,0			
C5	Experiment	81,4	6,674	0,000	Significant
	Control	73,5			
C6	Experiment	83,3	8,203	0,000	Significant
	Control	73,9			

To complement the statistical significance analysis, the effect size was calculated using eta squared (η^2) to determine the practical impact of the treatment on each HOTS indicator: C4 (analysis), C5 (evaluation), and C6 (creation). Based on a total sample of 216 students (108 in each group), the eta squared values were as follows: 0,41 for the analysis indicator (C4), 0,40 for the evaluation indicator (C5), and 0,44 for the creation indicator (C6). According to Cohen's (1988) classification, all three values fall into the large effect size category. These results provide further support for the conclusion that the use of animated simulation video media not only yields statistically significant differences but also brings about a strong and meaningful practical impact. This confirms that such media significantly enhances students' higher-order thinking skills in terms of their ability to analyze, evaluate, and create, reinforcing its effectiveness as a transformative tool in physics instruction.

The N-Gain analysis was conducted to measure the improvement in students' HOTS in tenth-grade physics learning, comparing the use of animated simulation video media (experimental group) with conventional instruction (control group). This analysis was based on students' pretest and posttest scores.

Table 10. N-gain test results

Group	Mean Pretest	Mean Posttest	N-gain	Information
Experiment	58,40	82,60	0,58	Medium-High
Control	57,80	74,13	0,39	Medium

Based on the N-Gain analysis, it was observed that the experimental group using animated simulation video media experienced a greater increase in HOTS scores compared to the control group. The experimental group demonstrated an average N-Gain of 0,58, which falls into the medium-to-high category, whereas the control group achieved an average N-Gain of 0,39, categorized as medium. These findings indicate that the use of animated simulation video media is more effective in promoting the development of students' higher-order thinking skills, particularly in analysis, evaluation, and creation. This significant improvement is likely due to the media's ability to visualize abstract physics concepts in a more concrete and interactive manner, thereby supporting students' understanding and reasoning development. Moreover, students in the experimental group exhibited more active engagement throughout the learning process. Therefore, the use of animated simulation videos can be considered a viable and effective alternative medium to be integrated into physics instruction to optimally develop HOTS.

Based on the overall research findings, it can be concluded that the use of animated simulation video media has proven to be effective in enhancing students' HOTS in tenth-grade physics. The assessment instruments used in the study were validated by experts and found to be both appropriate and reliable, thus accurately reflecting students' HOTS abilities. The data analysis process showed that students who learned through animated simulation videos demonstrated stronger capabilities in analyzing, evaluating, and creating solutions to physics problems compared to those taught using conventional methods. The use of this media provided a more interactive and contextual learning experience, which effectively stimulated conceptual understanding and improved students' reasoning abilities. Animated simulation video-based instruction is therefore highly recommended as an alternative approach in physics education to foster higher-order thinking skills more optimally.

DISCUSSION

In school-based physics learning, especially when laboratory resources are limited, animated simulation videos offer a practical and impactful alternative to conventional instruction.[13]

Many schools struggle with inadequate quantities of essential tools such as micrometers, vernier calipers, and digital balances, as well as limited time for hands-on practice and insufficient opportunities for direct observation. In such contexts, simulation videos provide a valuable workaround—offering visual and interactive representations of how measurement tools function, the principles behind their use, and the correct procedures for reading and interpreting results.[35] These digital resources enable students to repeatedly explore instrument use without the risk of damage, while also encouraging self-paced learning and independent inquiry.[36Form Two (2] Beyond merely compensating for equipment shortages, animated simulations promote deeper cognitive engagement, fostering HOTS such as analysis, evaluation, and creation—skills that are essential for solving authentic problems in measurement and scientific experimentation.[37,38]

The results of this study indicate that the use of animated simulation video media significantly enhances students' HOTS compared to conventional learning methods. This suggests that a learning process incorporating visual and dynamic elements can strengthen the understanding of abstract physics concepts.[20]

Students find it easier to connect physical phenomena with concrete representations through animated visualizations, thereby sharpening their analytical skills. This finding reinforces previous studies indicating that interactive visual media can create meaningful learning experiences and enhance knowledge retention.

[39,40] In the experimental group, significant improvements were observed across three HOTS domains: analysis, evaluation, and creation. These competencies are crucial in 21st-century learning, emphasizing critical thinking and problem-solving skills.

The effectiveness test results indicate that the use of animated simulation video media has a significant positive impact on the improvement of students' Higher-Order Thinking Skills (HOTS). Based on the t-test analysis of posttest scores between the experimental and control groups, a significant difference was found. The analytical ability (C4) of students in the experimental group improved because the simulation enabled students to directly observe variable changes within virtual experimental scenarios. This encouraged students to recognize patterns, differentiate conceptual components, and logically establish causal relationships. Such processes are difficult to achieve through conventional approaches that tend to be one-way and less interactive.

Meanwhile, in the evaluation domain (C5), students were able to assess the validity of statements or conclusions based on visual evidence and data presented through the simulation. The presence of interactive features in the video allowed students to test hypotheses and independently evaluate experimental results. This approach fostered reflective thinking skills and decision-making based on scientific data. The creative ability (C6) demonstrated by students in the experimental group shows that simulation videos can facilitate tasks.[41] Students were not merely memorizing concepts but were given opportunities to design solutions, formulate new conclusions, or create explanatory models for physical phenomena.[42] This level of creativity was not optimally observed in the control group, which only received verbal explanations.

The N-Gain test results further showed that the improvement in HOTS among students in the experimental group using animated simulation videos was higher compared to the control group that used conventional learning. The average N-Gain value in the experimental group fell within the moderate to high category, while the control group's score only reached the moderate category. These findings indicate that simulation video-based learning can have a more significant impact on the development of students' HOTS. One underlying reason for this difference is the characteristic of animated simulation videos that dynamically and concretely represent physical phenomena, thereby assisting students in the processes of analysis (C4), evaluation (C5), and creation (C6) in accordance with the revised Bloom's taxonomy.[43]

The interactivity of the media also contributes to enhancing students' motivation and engagement in learning. Students do not merely receive information passively but actively observe, compare, and draw conclusions from the simulations presented.[44] This condition fosters higher-order cognitive processes that are rarely observed in conventional learning, which still emphasizes lectures and drill exercises. The difference in N-Gain results between the two groups also indicates that learning approaches integrating technology have great potential to create deeper and more meaningful learning experiences. Animated simulation videos serve not only as visual aids but also as a bridge between abstract concepts and observable reality that students can analyze, interpret, and recreate during the learning process.[45]

An important factor contributing to the success of this medium is its visual appeal and the emotional engagement of students. When students feel interested and involved, their learning motivation tends to increase.[45,46] Well-designed animated simulation videos can enhance students' attention and focus on the subject matter while also creating a learning environment that is both enjoyable and intellectually stimulating. In contrast, the control group relied on lecture-based instruction and textbooks, which often made it difficult for students to visualize abstract physics concepts. The lack of visualization and limited access to measuring instruments in such instruction led to low levels of cognitive engagement among students,[47] which results in weak abilities in analyzing, evaluating, and creating.[48] Conventional instruction tends to target only lower-order cognitive levels, such as remembering and understanding.[44]

The implementation of animated simulation video media in teaching measuring instrument material is highly favored by students because it provides a more concrete and engaging learning experience.[49]

In physics education at schools, limitations in laboratory facilities—such as the lack of adequate measuring instruments like micrometers, calipers, or digital balances—often serve as major obstacles to ideal learning practices. This situation results in students having insufficient opportunities to directly observe the proper use of measuring tools, ultimately leading to poor conceptual understanding and underdeveloped practical skills.[50,51]

Animated simulation video media emerges as an effective alternative solution to address these limitations. Through interactive and realistic animations, students can clearly observe how measuring instruments are used, understand their components, as well as grasp the working principles and reading techniques. Some simulations even allow students to perform virtual manipulations, such as adjusting the measurement scale or rotating parts of the instrument, giving them an experience similar to conducting real experiments. This not only enhances conceptual understanding but also fosters analytical and reflective thinking skills in the measurement process.[52]

The use of animated simulation video media is not merely a visual supplement; it has evolved into a highly relevant pedagogical tool for supporting HOTS-based physics learning, particularly in contexts where facilities and infrastructure are limited.[53] Animated simulation videos enable students to observe complex physical phenomena in a contextual and dynamic way, making it easier for them to analyze, evaluate, and generate

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solutions based on the presented visual information.[54] In situations where access to laboratories or measuring instruments is restricted, simulation videos serve as a bridge between theory and practice, enriching students' learning experiences both cognitively and affectively. These findings offer strategic insights for physics teachers to begin integrating technology-based media into their teaching practices, especially when dealing with abstract or experimental topics.[55] Animated simulation videos can serve as a practical solution when limitations in tools or time hinder the implementation of direct experimentation in the classroom.[56,57]

Overall, the use of animated simulation video media not only improves students' learning outcomes but also transforms the paradigm of physics learning into a more active, creative, and meaningful process. Emphasizing a visual, contextual, and reasoning-based approach, simulation videos on measuring instruments are highly relevant in today's digital era. This media helps students grasp abstract physics concepts through concrete and dynamic visualizations, making it easier for them to solve complex problems. Furthermore, students become more interested and enthusiastic about learning due to the engaging and interactive presentation of the material. Teachers also benefit, as the media serves as an effective tool to explain difficult concepts more systematically. The learning process is no longer one-way but fosters two-way communication between teachers and students. Student participation in discussions, asking questions, and developing ideas also increases with the use of this media. This indicates that animated simulation videos are capable of creating a constructive and collaborative learning environment. Therefore, the application of such educational technology needs to be further developed in the physics curriculum to support the formation of a critically thinking and innovative generation. Fully integrating this media into learning is expected to create a more enjoyable, meaningful learning experience that aligns with the demands of the 21st century.

CONCLUSIONS

Based on the results of the study, it can be concluded that the use of animated simulation video media on measuring instruments is proven to be effective in enhancing students' HOTS in tenth-grade physics learning. This medium facilitates a more interactive, visual, and meaningful learning process, encouraging students to think analytically, evaluate information, and generate solutions to given problems. Students who learned using animated simulation video media showed greater improvement in their abilities in analysis, evaluation, and creation compared to those who received conventional instruction. This finding indicates that animation-based media can serve as an effective alternative for bridging abstract physics concepts into more concrete and comprehensible forms. Furthermore, the use of simulation videos can also increase students' motivation and engagement due to the appealing and contextual presentation of the material. This media not only aids in conceptual understanding but also stimulates critical and creative thinking skills that are essential in the 21st century. Therefore, the integration of animated simulation video media in physics instruction is highly recommended as a strategy to promote the development of students' HOTS. Teachers should consider the use of such media as part of innovative instructional practices that not only focus on cognitive outcomes but also support sustained higher-order thinking processes.

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Conceptualization: Rosynanda Nur Fauziah.
Data curation: Rosynanda Nur Fauziah.
Formal analysis: Rosynanda Nur Fauziah.
Research: Rosynanda Nur Fauziah.
Methodology: Rosynanda Nur Fauziah.
Project management: Anik Ghufron.
Resources: Rosynanda Nur Fauziah.
Software: Rosynanda Nur Fauziah.
Supervision: Ali Muhatadi.
Validation: Anik Ghufron and Ali Muhatadi.
Display: M Restu Fauzi.
Drafting - original draft: Rosynanda Nur Fauziah.
Writing - proofreading and editing: M Restu Fauzi.