JPPS (Jurnal Penelitian Pendidikan Sains)
Homepage : https://journal.unesa.ac.id/index.php/jpps
Email : jpps@unesa.ac.id

p-ISSN : 2089-1776 ; e-ISSN : 2549-1597
JPPS, Vol. 14, No. 2, May 2025 : 214-226

Effectiveness of TITANICS (Three-Dimensions Interactive Animation of Thermodynamics) Learning Media to Improve Students' Cognitive Learning Outcomes

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DOI: *https://doi.org/10.26740/jpps.v14n2.p214-226*

Sections Info

Article history:
Submitted: June 04, 2025
Final Revised: June 24, 2025
Accepted: June 25, 2025
Published: June 28, 2025

Keywords:
Animation
Three Dimensions
Media Interactive
Thermodynamics
Cognitive

ABSTRACT

Objective: *This study aims to describe the effectiveness of the development of TITANICS media (Three-Dimensional Interactive Animation of Thermodynamics) in improving students' cognitive learning outcomes. This is based on the need for future innovative learning strategies that integrate digital technology into educational institutions.* ***Method:*** *This research uses a development approach using the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). The sample consisted of 28 students from class XI Science 1 at Trensains Tebuireng High School, selected through purposive sampling.* ***Results:*** *Based on the data and analysis conducted, it can be concluded that the TITANICS learning media (Three-Dimensional Interactive Animation of Thermodynamics) is effective in improving students' cognitive learning outcomes in thermodynamics.* ***Novelty:*** *This study presents the development of digital media featuring 3D animation, formed into interactive videos that include educational content and quiz questions contextualized with real-life applications of thermodynamic concepts.*

INTRODUCTION

The rapid advancement of science and technology in the 21st century, driven by the era of Industry 4.0, has significantly transformed various fields, including education. This transformation is encapsulated in the concept of Education 4.0, which emphasizes the integration of digital technologies to facilitate continuous and unrestricted learning processes (Agussani, 2020). According to recent studies by Makaruku et al. (2021), Education 4.0 focuses on developing flexible and interactive educational environments that empower students to engage actively in their learning journey. Additionally, current curriculum reforms, like Indonesia's Kurikulum Merdeka aim to cultivate these essential skills by promoting student autonomy and flexibility in learning processes. This approach is supported by recent research from Kong et al. (2023), which emphasizes the effectiveness of student-centered curricula in enhancing educational outcomes and preparing learners for future challenges.

In many classrooms today, learning still revolves around students listening and taking notes while teachers deliver lectures. This traditional, teacher-centered approach continues to dominate (Rozali et al., 2022). Rather than encouraging deeper understanding, teaching often focuses on completing the curriculum and having students memorize concepts (Mukhtar, 2023). Unfortunately, this method can make learning feel uninspiring and one-sided, which may reduce students' motivation, creativity, and engagement (Mujahida, 2019). Research has shown that such conventional methods have little impact on students' ability to analyze, particularly in subjects like physics (Maulani

et al., 2021). That's why it's so important to rethink our teaching strategies especially in physics to create more active, engaging learning environments where students can truly participate and grow.

According to the 2019 National Exam (UN) report by Pusmenjar (Center for Assessment and Learning), students' understanding of thermodynamics in high school was notably low, with an average score of just 42.50 which categorized as red, meaning the mastery level was at or below 55.00. Among the four physics topics tested which mechanics, waves and optics, electricity and magnetism, and modern physics which thermodynamics scored the lowest. This indicates a clear need to improve student comprehension in this area. Since 2020, the National Exam has been suspended due to the COVID-19 pandemic, which has further impacted student learning outcomes (Cerelia, 2021). For this reason, the researcher has chosen thermodynamics as the focus of this study, aiming to help students improve their learning outcomes in this topic.

A preliminary study on 12th-grade students at SMA Trensains Tebuireng showed that their understanding of thermodynamic laws remains low, with an average score of just 38.89. One contributing factor is the lack of innovative learning media in the classroom, which has negatively impacted students' cognitive development (Aryani, 2021). In solving physics problems, students are influenced by both internal and external factors. One key external factor is the limited variety and interactivity of the media used in teaching (Hijriani, 2021). While internally, low learning motivation often due to boredom from unengaging classroom media also plays a role in decreasing student performance (Alwie, 2019). Research shows that learning media has the greatest influence on student achievement, with a contribution of 66.8%, compared to teaching methods 63.9% and social environment 50.5% (Kurniawan, 2017). Therefore, physics learning requires engaging and innovative media to better capture students' attention and ultimately improve their cognitive learning outcomes.

One of the main reasons for students' low understanding and academic performance is the lack of innovative learning media in the classroom, which impacts their cognitive development (Aryani, 2021). Most teachers still rely heavily on textbooks used by 100% of teachers while only 12.5% use modules or encyclopedias, and 62.5% use student worksheets (LKS). Meanwhile, more dynamic media like videos and PowerPoint presentations are used by just 37.5% of teachers (Hamida, 2020). When it comes to solving physics problems, students are influenced by both internal and external factors. A key external factor is the limited variety and interactivity of the learning media provided (Hijriani, 2021). Internally, low motivation which often caused by boredom with uninspiring classroom tools also contributes to poor understanding (Sukma, 2022). Therefore, physics education urgently needs more engaging and innovative media to help boost student learning outcomes in the classroom.

Various types of learning media both digital and conventional can be used in physics education, and one particularly effective option is animated video. Studies have shown that animated videos can significantly improve students' conceptual understanding (Zakirman, 2017). In fact, the use of physics learning videos in distance learning has been shown to increase student motivation (Widianta, 2021). Because animated media is interactive, it enhances communication between teachers and students, making learning more efficient and effective (Hidayat, 2010). It also boosts students' motivation, which ultimately leads to better learning outcomes (Puspitasari, 2019). Research confirms that student understanding improves after using animated videos in class (Astika, 2019). As

such, animated video is a relevant and powerful tool in the era of Education 4.0, where digital technology plays a central role in the learning process.

Based on the discussion above, it is important to examine the effectiveness of innovative digital learning media, particularly those designed to visualize abstract physics concepts such as thermodynamics. Effective learning media are characterized by their ability to engage students through interactivity, visual appeal, and content relevance, ultimately enhancing cognitive learning outcomes (Titin, 2021). The effectiveness of such media can be evaluated based on their impact on students' conceptual understanding and academic performance. The TITANICS media developed in this study has never been studied before, in integrating 3D animation on a video player that can be accessed online or offline with interactive quizzes accompanied by interactive feedback, interactive evaluations, discussions, Student Worksheets (LKPD), contextual learning materials, and specifically to improve student cognitive learning outcomes in the material on the laws of Thermodynamics. Therefore, this study aims to analyze the effectiveness of TITANICS (Three-Dimensions Interactive Animation of Thermodynamics), a digital learning medium specifically developed to improve students' cognitive learning outcomes in thermodynamics. Through empirical testing and evaluation, this research seeks to provide insight into how interactive 3D animation can support the development of more engaging and effective physics instruction in the era of Education 4.0. The findings are expected to serve as a reference for the future integration of digital media in science education and contribute to designing innovative learning strategies.

RESEARCH METHOD

This study employed the ADDIE model as its research approach, which consists of five distinct stages: Analyze (analysis), Design (planning/development), Develop (creation), Implement (application), and Evaluate. The TITANICS media was developed with the specific goal of improving students' cognitive learning outcomes. The instrument used to measure students' cognitive learning outcomes is a student response and test sheet with 10 multiple-choice questions where this a student response and test sheet instrument has been validated and declared reliable. The data collection method used is by providing the student response and test sheet directly to students after students have finished learning using the TITANICS media. For the expected cognitive indicators are from cognitive levels C1 (remembering), C2 (understanding), C3 (applying), and C4 (analyzing). This is made in accordance with the objectives of learning the laws of Thermodynamics, namely analyzing changes in the state of gas in the study of the laws of Thermodynamics and providing examples of their application to heat engines. Then, it will be explained how to analyze the results of the instrument which will be carried out as follows:

Student Response Analysis

This study used Likert-scale responses in its surveys to minimize potential bias by encouraging participants to answer questions neutrally. The specific 1-4 point scale employed categories like those shown below in Table 1.

Table 1. Likert Scale Categories

Score	Description	Score	Description
4	Very good	2	Poor
3	Good	1	Very poor

(Sari, 2017)

After collecting these responses from the students using survey questionnaire, the data was analyzed using formula 1 below:

$$PR = \frac{\sum X}{\sum Xi} \; x \; 100\% \qquad ...(1)$$

Description:

PR : Percentage Response

∑X : Sum of Scores for Each Item

∑Xi : Maximum Possible Score

Then after calculating the percentage response, the results were used as a reference against specific criteria, details of which are shown in Table 2 below.

Table 2. Categories of Student Responses

Score	Category
80% < PR ≤ 100%	Very Good
60% < PR ≤ 80%	Good
40% < PR ≤ 60%	Sufficient
20% < PR ≤ 40%	Poor
0% ≤ PR ≤ 20%	Very Poor

(Riduwan, 2012)

The effectiveness of this media regarding student responses after using TITANICS is considered effective if the percentage score meets or exceeds 61%.

Test Analysis

For test analysis (test) employed the N-Gain technique. This method calculates the increase in learning outcomes by comparing results before and after a specific treatment (intervention) (Oktavia, 2019). The formula 2 used is as follows:

$$N\text{-}Gain = \frac{\text{Score } Posttest - \text{Score } Pretest}{\text{Score maximum} - \text{Score } Pretest} \qquad ...(2)$$

The results obtained from the gain calculations are then used as a reference according to specific criteria detailed in Table 3 below:

Table 3. Categories of Effectiveness

N-Gain	Category	Description
g > 0.7	High	Very Effective
0.3 ≤ g ≤ 0.7	Moderate	Effective
g < 0.3	Low	Less effective

(Sundayana, 2015)

The effectiveness of this media regarding student test after using TITANICS is considered effective if the percentage score meets the criteria g ≥ 0.3.

RESULTS AND DISCUSSION

Results

Stage of Analyze

At this stage, the study conducted needs analysis activities through observations of the school situation and interviews with key personnel including one physics teacher, the curriculum deputy head, the facilities/deputy resources person and selected students in one class during a PLP (Pengenalan Lapangan Persekolahan) activity specifically, an introduction to school practice or teaching experience held at SMA Trensains Tebuireng Jombang in November 2023. The information gathered revealed that physics learning in the classroom primarily uses teacher lectures (teacher-centered) and a significant portion of teachers employ drills with exercises. There was also mention, somewhat ironically perhaps given its online nature and often unrelated to complex scientific phenomena, of YouTube videos being used occasionally. Crucially, many teachers seem struggling to visualize physics phenomena effectively. The learning media commonly utilized by these educators are traditional tools like textbooks and PowerPoint presentations. This situation is consistent with the findings from Rojabiyah study (2019), which highlighted a tendency for students to be passive, listening rather than engaging actively, while teacher instruction often remains teacher-centered, or learning focused around the teacher. Following the curriculum analysis, it was found that for the material on the laws of thermodynamics to be taught to students, materials covering cognitive levels from C1 (recall) to C4 (analysis) are required.

Stage of Design

At this stage, activities were conducted to design the initial layout of the media product tailored to align with learning objectives (ATP) for thermodynamics material. The design combines video and PowerPoint presentations. The TITANICS learning medium for physics thermodynamics material incorporates everyday phenomena that are turned into 3D animations in video format, aimed at making the material more relatable and easier to understand for students. The design of these educational materials can be viewed in Figure 1.

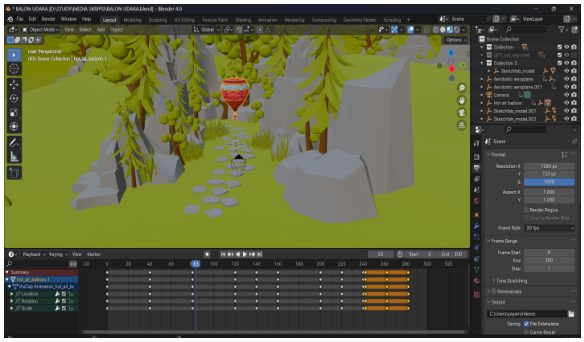

Figure 1. Learning Material Design Display

The material in the TITANICS learning medium was designed utilizing 3D animations created with Blender software. Interesting objects and characters were incorporated to enhance students' engagement and interest in the subject matter. Additionally, the learning medium incorporates interactive features such as quiz questions designed to train students' cognitive thinking skills across various cognitive levels (C1 to C4). These questions are organized in slide or PowerPoint format. An example of a quiz created for practice to enhance cognitive thinking is provided in Figure 2.

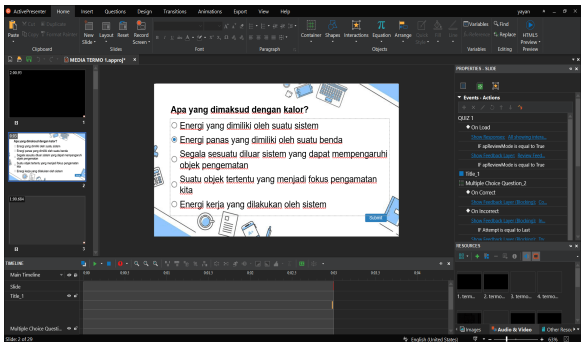

Figure 2. Learning Media Interactive Design Display

Stage of Development

At this stage, activities were carried out to finalize, validate, and revise the media creation. Once the TITANICS learning medium had undergone finalization and undergone validation and revisions based on feedback from validators, the results of its validation are very good or media is valid for use in learning physics. Further explanation of the results of the product development stage as shown Figure 3.

Figure 3. Initial Display of the Media

In the initial display of the developed learning product/media, there is a greeting and the author's identity. Additionally, the content and learning menu are available within the TITANICS medium as seen in the Figure 4.

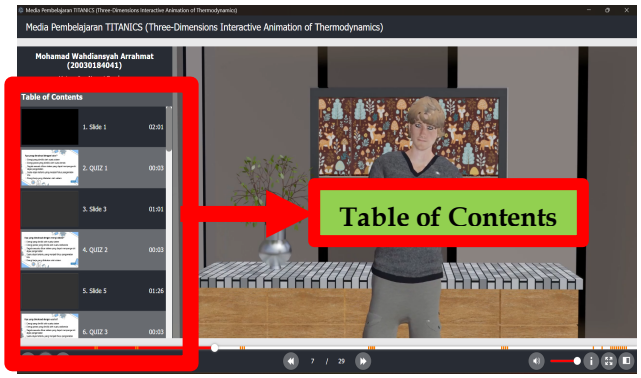

Figure 4. Learning menu display

Then, the learning material is presented using everyday occurrences (contextualized) as seen in the following Figure 5.

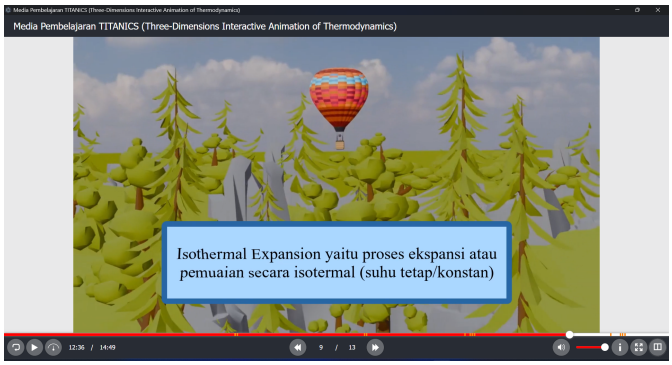

Figure 5. Display Learning Materials

There is an interactive element consisting of quiz questions tailored to each cognitive level, from C1 to C4, as seen in the following Figure 6.

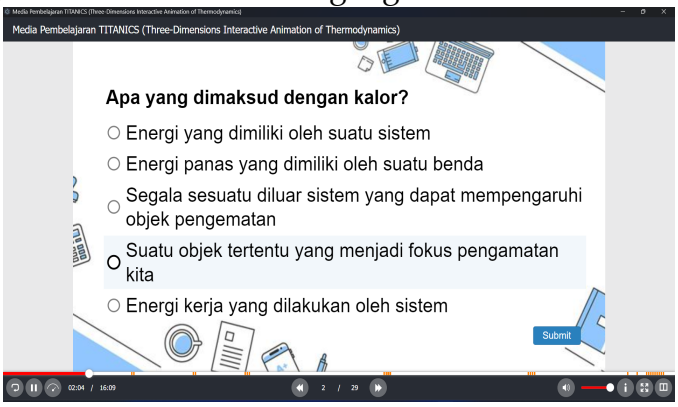

Figure 6. Display QUIZ Question

Finally, there is a feature for reporting on students' performance while using the developed TITANICS medium, as shown in the following Figure 7.

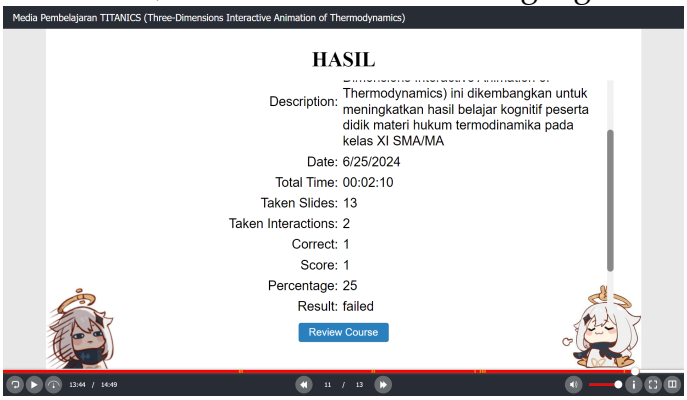

Figure 7. Display media report

Stage of Implementation

At this stage, activities were conducted to integrate the TITANICS learning medium into the lessons. Subsequently, tests and student response surveys were administered. The results of the students' responses are presented in Table 4.

Table 4. Result of Student Responses

Aspects	Percentage Score	Description
Language	91.07%	Very Good
Learning materials	88.39%	Very Good
Media View	85.71%	Very Good
Suitability	84.30%	Very Good
Operation	89.73%	Very Good
Benefits	87.86%	Very Good
Average Score	**87.84%**	Very Good

Stage of Evaluation

During this phase, assessments included a pretest at the beginning of the lesson as an initial evaluation and a posttest at the end of the lesson as a final evaluation. The students' test results are highlighted in Table 5.

Table 5. Result of Student Test

Category Gain	Percentage of Students	Average Gain	Description
High	21.43%		
Mid	75%	0,59	Effective
Low	3.57%		

Table 6. Result of Student Cognitive

Cognitive Level of Questions	Percentage Students	
	Pretest	*Posttest*
C1	96%	93%
C2	45%	73%
C3	35%	68%
C4	21%	60%

Discussion

Based on the results that have been obtained as in Table 4, it appears that for the response results of students get an average value of 87.84% with a very good category and declared effective. Furthermore, related to the analysis of the results of students' responses that from the six aspects assessed, including language aspects that get a score of 91.7% with a very good category which consists of indicators of language use in accordance with good and correct Indonesian language rules, the use of short language, congested and does not cause a double understanding, and the use of interactive language. These results are in line with research from Sari in the year (2022) related to the use of Android-based learning media on thermodynamics material with an average result in the language aspect of 96.67%. Although, it can be seen that the value obtained is lower, but not significantly different. According to Ibrahim in (2019) explained that the language used in learning must use language in accordance with the rules of Indonesian language that is good and right so that there is no understanding that is misunderstood. In the aspect of delivery of the material, it gets a value of 88.39% which includes the delivery of material that is not convoluted and the delivery of interesting material. These results are in line with research from Mustaghfaroh in the year (2021) with the results of students'

responses to the use of learning media for material aspects of 92% with a very good category. Although, it can be seen that the value obtained is lower, but not significantly different. According to research from Wiliyanti Year (2023) explained that the delivery of material in physics learning is very important so that students can understand the material well.

In the aspect of the media display, it gets a value of 85.71% which includes the selection of attractive colors, selecting the right writing fonts, the selection of attractive objects/characters and the readability of the text clearly. These results are in line with research from Basriyah in the year (2018) related to the use of animated video learning media on thermodynamic material with an average result of the media design aspect of 85.35%. Another study from Fauziah in the year (2022) said that indeed the appearance of animated media was more in demand by students than using other learning media.

In the conformity aspect gets a value of 85.30% which includes the suitability of the writing that appears in the sound, the selection of attractive voice actor, the suitability of the animation with the writing that appears, the suitability of the animation with the material, the suitability of the background color with the color of the text and the suitability of the use of the image. This aspect gets a smaller value than other aspects. This is in line with research from Syahiddah in the year (2021) which shows that aspects of suitability in the physics learning media used do get lower results than other aspects. According to research from Syarifuddin in the year (2022) this can happen because it is indeed a challenge to make three -dimensional animation (3D) on quality physics material with the need for very complicated and expensive software, and requires people with special expertise to create this three-dimensional animation.

In the aspect of media operation gets a value of 89.73% which includes the ease of operating the media, can be operated without the internet, can be opened anywhere and anytime and does not require a high device operating system. These results are in line with research from Handoyono in 2020 related to aspects of media operation with a value of 75%. Another study by Ngurahrai in (2019) also received aspects of media operation of 75% which is quite good. That is, the results of this study received a significant increase from previous research.

In aspects of usefulness to get a value of 87.86% which includes increasing curiosity, helping to learn independently, increase interest in learning, facilitate understanding material and provide new learning experiences. This is in line with research from Dewi in the year (2021) related to the use of animated video in physics learning with research results of 88.51%. From this it is known that the media that has been developed is feasible and beneficial for students.

Then, for the results of student tests such as in Table 5, the N-Gain results are 0.59 with a medium category which indicates that the TITANICS media developed can effectively improve student learning outcomes. This is supported from the results as in Table 6 that the posttest results of students have more students in answering questions at the overall level of cognitive questions from C1 to C4. These results are in line with research from Maryana in (2019) related to the results of N-Gain students who get a score of 0.49 with a medium category. Other studies from Lake Year (2023) regarding the development of animated media also showed the N-Gain value obtained by 0.43 with a medium category. From this it is known that the results of the N-Gain in this study have been fairly good and have increased from previous research on the development of animated media.

There is a significant increase at the C4 level which was originally only 21% of students who can answer, then after being given and using TITANICS media in studying the law of thermodynamics, it becomes 60% of students can better understand the material. So there is an increase of 39% which is greater than other cognitive levels. According to research from Alfiah in the year (2018) shows that the ability of students to answer questions with cognitive levels C4 (analyzing) is still low compared to other cognitive levels. From this it can be seen that from the results of this study it has been very good because it can significantly improve the problem with the cognitive level of C4 (analyze). Also at the cognitive level C3 gets an increase of 33% and C2 gets an increase of 28%. This means that after giving TITANICS media students can better understand the material with C3 and C2 cognitive levels. Finally, at the cognitive level C1 actually decreased by 3%, although not significantly from 96% to 93%.

CONCLUSION

Fundamental Finding: Based on the results of the data and analysis conducted, it can be concluded that the TITANICS learning media (Three-Dimensional Interactive Animation of Thermodynamics) is effective in improving students' cognitive learning outcomes in thermodynamics. **Implications:** (1) Digital media in the form of TITANICS learning media can facilitate easier access for students and teachers, (2) TITANICS Learning Media Can Help Students Become Accustomed to High Level Thinking, **Limitation:** The student sample in the product trials was relatively small and lacked diversity. **Future Research:** Expansion of development to include other subject areas.

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