



Contextual Interactive Multimedia: Improving Students' Learning Outcomes in Dynamic Fluid Physics

Siti Robiah Hazan¹, Víctor Hugo Velasco Galarza²

¹Physics Education Study Program, Faculty of Educational Sciences and Teacher Training, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Tangerang Selatan, Indonesia

²Physics Teacher, Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador

Article Info

Article history:

Received Aug 3, 2026

Revised Sep 27, 2026

Accepted Oct 11, 2026

Online First Oct 16, 2026

Keywords:

Contextual Learning

Dynamic Fluid

Interactive Multimedia

Physics Education

Student Learning Outcomes

ABSTRACT

Purpose of the study: This study aimed to examine the effect of contextual interactive multimedia on Grade XI students' learning outcomes in dynamic fluid concepts and determine whether its use produced better learning outcomes than PowerPoint-supported instruction.

Methodology: A quantitative quasi-experimental method with a pretest-posttest nonequivalent control group design was employed. The participants were 58 Grade XI science students from State Senior High School 3 of South Tangerang City, Indonesia. Data were collected using a 20-item multiple-choice test, observation sheet, and student-response questionnaire. The multimedia was developed using Adobe Flash CS3, AVS Video Editor, and Audio Edit Magic. Data were analyzed using normality, homogeneity, independent-samples *t*-test, Cohen's *d*, and normalized gain.

Main Findings: The experimental group achieved a higher posttest mean (89.76) than the control group (80.71). The independent-samples *t*-test showed a significant difference between groups ($t = 5.08 > t_{critical} = 2.003$). The intervention produced a large effect (Cohen's $d = 1.12$) and a high normalized gain ($g = 0.84$), compared with $g = 0.69$ in the control group. Student activity reached 82.33%.

Novelty/Originality of this study: This study integrates contextual learning with interactive multimedia specifically for dynamic fluid instruction. Unlike conventional presentation-based media, the developed product combines animation, instructional video, simulation, interactive exercises, contextual problems, and real-life applications within an integrated learning environment, providing an accessible approach to visualizing abstract physics concepts and supporting their application in meaningful contexts.

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Corresponding Author:

Siti Robiah Hazan,

Physics Education Study Program, Faculty of Educational Sciences and Teacher Training, Universitas Islam Negeri Syarif Hidayatullah Jakarta,

Jl. Ir. H. Djuanda No. 95, Ciputat, South Tangerang City, Banten 15412, Indonesia

Email: sitirobiahhazan1@gmail.com

1. INTRODUCTION

The rapid development of digital technology has created new opportunities for improving science learning through more interactive and meaningful learning environments. Physics, however, remains challenging because many concepts involve abstract processes that students cannot directly observe [1]-[3]. Dynamic fluid is one such topic because its principles require students to connect mathematical representations with observable phenomena in everyday life [4]-[6]. Consequently, learning media should not merely present information but

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also facilitate visualization, interaction, and meaningful connections between scientific concepts and real-world contexts [7]-[9]. Interactive multimedia offers such potential by integrating text, images, animation, audio, video, and interactive activities within a single learning environment.

Despite these opportunities, physics instruction at the secondary-school level may still rely heavily on conventional presentations that provide limited opportunities for students to interact with representations of physical phenomena. This problem becomes more significant when students have difficulty relating physics concepts to phenomena encountered in everyday life [10]-[12]. In the original study context, students demonstrated relatively low physics learning outcomes and difficulties connecting daily-life phenomena with formal physics concepts [13]-[15]. Such conditions indicate that the problem is not simply the availability of technology but the pedagogical integration of technology with meaningful learning contexts [16]-[18]. Therefore, an instructional approach is needed that simultaneously supports conceptual visualization, student interaction, and contextual understanding.

Contextual interactive multimedia provides a promising approach because it can represent abstract physical phenomena while connecting them with situations that students encounter outside the classroom. Through animation, simulation-like representations, visual explanations, and contextual examples, students can observe relationships that are difficult to communicate through conventional presentation media [19], [20]. Recent research supports the effectiveness of interactive multimedia, although its impact depends on the characteristics of learners and the instructional design in which it is embedded [21], [22]. Thus, interactive multimedia should be designed not simply as a technological supplement but as an instructional environment that supports conceptual meaning-making [23], [24]. In the present study, contextual interactive multimedia was therefore positioned as an alternative to PowerPoint-based instruction for learning dynamic fluid.

Recent research provides substantial evidence that technology-supported learning can improve science learning outcomes, but the findings also demonstrate important contextual and design-related considerations. Adeyele [21], for example, found that interactive multimedia was more effective than conventional instruction for improving basic science achievement among pupils in mainstream schools. Similarly, Koç and Kanadlı (2025), through a network meta-analysis of 53 studies, reported positive effects of interactive learning environments on cognitive and affective outcomes, although the magnitude of effects differed across technological formats. In physics education, Hsu et al. [25] showed that multimedia representation formats interacted with students' prior knowledge, with animation benefiting learners with lower prior knowledge more than static graphics or simulation. Meanwhile, Yalçın and Sadık [26] demonstrated that interdisciplinary context-based physics learning improved students' ability to relate knowledge to daily life and strengthened physics problem-solving skills. Collectively, these studies indicate that technology and contextualization can support learning, but their effectiveness cannot be assumed independently of representation format, learner characteristics, and pedagogical context.

Although these studies establish the potential of interactive and contextual learning, several gaps remain relevant to secondary physics education. First, previous studies have frequently examined interactive technologies, multimedia formats, or contextual learning as relatively distinct instructional components rather than integrating them into one coherent learning intervention. Second, systematic evidence indicates that multimedia research has concentrated heavily on particular multimedia principles and conventional learning environments, while important combinations of design principles and learning contexts remain underexplored [27]-[29]. Third, Hsu et al. [25] emphasized the role of prior knowledge in determining the effectiveness of multimedia representations, suggesting that the same technological format may not produce equivalent learning benefits across learners. Fourth, Yalçın and Sadık [26] demonstrated the value of contextual physics learning but did not specifically investigate contextual interactive multimedia as an integrated medium for dynamic fluid instruction. Therefore, empirical evidence remains limited regarding whether contextual interactive multimedia can produce significantly better learning outcomes than commonly used presentation-based media for secondary-school dynamic fluid learning.

The originality of this study lies in integrating interactive multimedia with a contextual learning approach specifically for the teaching of dynamic fluid at the secondary-school level. Rather than treating multimedia merely as a digital presentation tool, the intervention connects multimedia representations with familiar physical phenomena to support students' interpretation of abstract fluid concepts. The study also provides a direct comparison between contextual interactive multimedia and PowerPoint-based instruction under a quasi-experimental design. This comparison is important because the observed learning advantage can be interpreted relative to an instructional practice that is commonly used in classroom teaching rather than against an absence of instruction. Accordingly, the study contributes empirical evidence concerning how pedagogically contextualized multimedia can be used to strengthen physics learning outcomes.

The urgency of this research is associated with the continuing need to develop physics instruction that enables students to understand abstract concepts through meaningful representations and real-world connections. This need is particularly relevant for dynamic fluid, where conceptual understanding requires students to interpret relationships among physical quantities, processes, and observable phenomena. The empirical findings

of the underlying study showed that students receiving contextual interactive multimedia achieved higher posttest performance than students receiving PowerPoint-based instruction, with a significant difference between the groups. The experimental group obtained an average score 9.05 points higher than the control group, while the hypothesis test produced $t = 5.08$, exceeding the critical value of 2.003. Therefore, this study aims to examine the effect of contextual interactive multimedia on the learning outcomes of secondary-school students in dynamic fluid instruction.

2. RESEARCH METHOD

2.1. Research Design

This study employed a quantitative approach using a quasi-experimental design. A pretest–posttest nonequivalent control group design was used because the participants were organized in intact classroom groups rather than randomly assigned to individual treatment conditions [30], [31]. The design involved an experimental group that received contextual interactive multimedia instruction and a control group that received PowerPoint-based instruction. Both groups completed the same pretest before instruction and posttest after the intervention. The effect of the intervention was determined by comparing students' learning outcomes between the experimental and control groups.

Table 1. Pretest–Posttest Non-Equivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O ₁	X ₁	O ₂
Control	O ₁	X ₂	O ₂

Note. O₁ = pretest; O₂ = posttest; X₁ = contextual interactive multimedia instruction; X₂ = PowerPoint-based instruction.

2.2. Research Setting and Participants

The study was conducted at SMA Negeri 3 Kota Tangerang Selatan, Indonesia, during the second semester of the 2013/2014 academic year. The participants were students enrolled in Grade XI science classes. Two intact classes were selected as the research sample, namely XI IPA 3 as the experimental group and XI IPA 4 as the control group. The sampling technique was purposive sampling, in which classes were selected based on predetermined research considerations rather than individual random assignment. The intervention focused on the dynamic fluid topic and was implemented over three instructional sessions, preceded by a pretest and followed by a posttest.

2.3. Variables and Learning Intervention

The independent variable was the use of contextual interactive multimedia, whereas the dependent variable was students' learning outcomes in dynamic fluid. The contextual interactive multimedia integrated physics concepts with phenomena encountered in everyday life and presented learning content through interactive visual and audiovisual representations. The multimedia was developed using Adobe Flash CS3, AVS Video Editor, and Audio Edit Magic. In the experimental group, students participated in discussion and group-learning activities supported by the contextual interactive multimedia. In the control group, students participated in comparable discussion and question-and-answer activities using PowerPoint as the primary instructional medium.

2.4. Research Instruments

Three instruments were used to collect the research data: a learning-outcome test, an observation sheet, and a student-response questionnaire. The primary instrument was a 20-item multiple-choice test administered as a pretest and posttest to measure students' cognitive learning outcomes. The test covered cognitive levels C1–C4 based on the revised Bloom's taxonomy and focused on the learning objectives of dynamic fluid. The observation sheet was used to document student participation, responses to the instructional media, and involvement in group discussions during the intervention. The questionnaire was administered to students in the experimental group to obtain information about their responses to the contextual interactive multimedia.

2.5. Data Collection Procedure

Data collection consisted of preparation, implementation, and final assessment stages. During preparation, the researchers developed the learning instruments, lesson plans, contextual interactive multimedia, and assessment materials, followed by instrument try-out and revision. At the beginning of the implementation, both groups completed the pretest to establish their initial learning outcomes before instruction. The experimental group then received instruction using contextual interactive multimedia, while the control group

received instruction using PowerPoint. After the instructional sessions were completed, both groups completed the posttest, while observations and student-response data were collected to provide supporting information regarding the implementation.

2.6. Data Analysis

The quantitative test data were analyzed to determine whether contextual interactive multimedia produced a significant effect on students' learning outcomes. Before hypothesis testing, the pretest and posttest data were examined for normality and homogeneity to determine whether the assumptions for parametric analysis were satisfied [32], [33], [34]. The similarity of students' initial learning outcomes was examined using the pretest data. The posttest scores were subsequently analyzed using an independent-samples *t*-test at a significance level of 0.05 to determine whether the learning outcomes of the experimental and control groups differed significantly after the intervention [35], [36], [37]. The null hypothesis stated that contextual interactive multimedia had no significant effect on students' learning outcomes, whereas the alternative hypothesis stated that its use significantly affected students' learning outcomes.

The observation and questionnaire data were analyzed descriptively. Observation scores were converted into percentages and interpreted using qualitative categories to describe students' participation and responses during the learning process. Questionnaire responses were similarly tabulated and converted into percentages to describe students' perceptions of the contextual interactive multimedia. These non-test data served as supporting evidence for interpreting the implementation and student responses to the intervention rather than as the primary basis for testing the research hypothesis.

3. RESULTS AND DISCUSSION

3.1. Characteristics of the Contextual Interactive Multimedia

The contextual interactive multimedia was designed as an integrated digital learning environment to support students in understanding dynamic fluid concepts through interactive and contextual representations. The product combines text, images, animations, instructional videos, simulations, interactive exercises, contextual problems, and evaluation activities within a single learning interface. The multimedia was developed using Adobe Flash CS3 for the interactive interface and animation, AVS Video Editor for instructional video production, and Audio Edit Magic for audio editing. These technological components were integrated to provide students with multiple representations of dynamic fluid phenomena and their applications in everyday life.

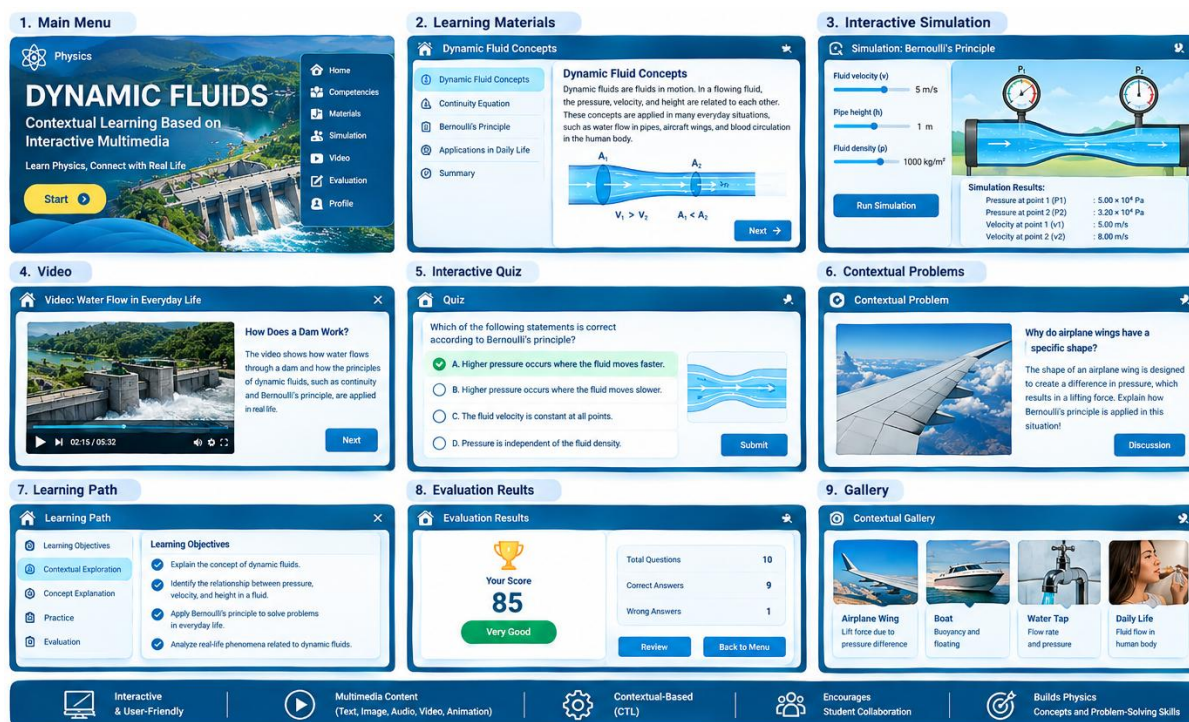


Figure 1. Interface and Interactive Features of the Contextual Interactive Multimedia for Dynamic Fluid Learning

As shown in Figure 1, the multimedia provides several interconnected learning features, including the main menu, contextual learning materials, an interactive simulation of Bernoulli's principle, instructional videos, interactive exercises, contextual problem-solving activities, material summaries, evaluation results, and examples of dynamic fluid applications in everyday life. The interface was designed to allow students to navigate between learning components independently while engaging with visual and interactive representations of abstract physics concepts.

The technological design also supports the contextual learning approach by connecting formal physics concepts with phenomena that students can encounter in their daily lives. For example, applications of dynamic fluids are presented through phenomena related to aircraft wings, fast-moving boats, water flow, pipes, and perfume spraying. The simulation component enables students to observe the relationship among flow velocity, pressure, fluid density, and height, whereas the interactive exercises and contextual problems provide opportunities for students to apply the concepts they have learned. Thus, the multimedia functions not only as a presentation medium but also as an interactive learning environment that integrates conceptual explanation, visualization, exploration, practice, and evaluation.

To further clarify the technological and instructional characteristics of the developed multimedia, Table 2 summarizes the main digital components, their functions, and their contribution to the contextual learning process. The table highlights how each technological feature was integrated to support the presentation of dynamic fluid concepts, student interaction, contextual exploration, and learning evaluation.

Table 2. Technological and Instructional Characteristics of the Contextual Interactive Multimedia

Component	Characteristics	Learning Function
Development technology	Adobe Flash CS3	Development of the interactive learning interface and animations
Video production	AVS Video Editor	Development and integration of instructional videos
Audio production	Audio Edit Magic	Preparation and integration of audio components
Text	Explanations, formulas, instructions	Presentation of conceptual and procedural information
Images	Physics illustrations and contextual phenomena	Representation of concepts and real-world situations
Animation	Dynamic representations of fluid phenomena	Visualization of processes that are difficult to observe directly
Video	Contextual demonstrations and phenomena	Connecting physics concepts with everyday situations
Simulation	Interactive representation of phenomena	Supporting inquiry and conceptual exploration
Practice	Interactive exercises	Reinforcing students' understanding
Contextual problems	Everyday applications of dynamic fluid concepts	Connecting formal physics concepts with students' experiences
Group activities	Observation, discussion, and conclusion	Supporting collaborative and inquiry-oriented learning

The technological design therefore served an instructional purpose rather than functioning only as a visual enhancement. The combination of animation, video, simulation, and contextual examples was intended to reduce the abstraction of dynamic fluid concepts while providing students with opportunities to interact with the learning content.

3.2. Implementation of the Multimedia-Based Learning Intervention

The intervention was implemented in the experimental class, while the control class received instruction supported by PowerPoint. Both groups completed a pretest before instruction and a posttest after the instructional intervention. The experimental class consisted of 29 students, and the control class also consisted of 29 students. The learning activities in the experimental class involved students working with the contextual interactive multimedia, participating in group discussions, observing multimedia-based representations, and completing learning tasks.

The observation results indicate that the multimedia-supported learning process was implemented effectively. Students' participation in completing learning tasks reached 78.67%, their response to the instructional medium reached 85.00%, and their participation in group discussions reached 83.33%. The overall activity score was 82.33%, categorized as very good.

Table 3. Student Activity During Multimedia-Supported Learning

Observed Activity	Percentage	Interpretation
Participation in learning tasks	78.67%	Good
Response to the learning medium	85.00%	Very good
Participation in group discussion	83.33%	Very good
Overall	82.33%	Very good

The highest percentage was observed for students' responses to the learning medium (85.00%). This finding indicates that the technological features of the multimedia were not merely accessible to students but were actively engaged with during the learning process. Group discussion participation was also high (83.33%), suggesting that the multimedia was compatible with collaborative learning activities rather than encouraging students to learn individually without interaction.

3.3. Descriptive Results of Students' Learning Outcomes

The descriptive analysis demonstrated a substantial increase in students' learning outcomes in both groups. Before the intervention, the experimental group obtained a mean pretest score of 36.15, whereas the control group obtained 37.55. The difference of 1.40 points indicates that the initial achievement levels of the two groups were relatively comparable. The pretest independent-samples *t*-test further showed no statistically significant difference between the groups ($t = 0.62 < t_{\text{critical}} = 2.003$).

After the intervention, the experimental group achieved a mean posttest score of 89.76, compared with 80.71 for the control group. Thus, the experimental group exceeded the control group by 9.05 points. The experimental group also had a lower posttest standard deviation (7.39) than the control group (8.71), indicating that the experimental students' scores were relatively concentrated around their higher mean.

Table 4. Descriptive Statistics of Learning Outcomes

Statistic	Experimental	Control
N	29	29
Pretest mean	36.15	37.55
Posttest mean	89.76	80.71
Posttest SD	7.39	8.71
Mean improvement	53.61	43.16
Difference in posttest means	9.05	—

The mean improvement in the experimental group was 53.61 points, whereas the control group improved by 43.16 points. Therefore, the experimental group demonstrated an additional improvement of approximately 10.45 points compared with the control group. The descriptive pattern demonstrates that both instructional conditions supported learning, but the increase was greater when students learned through contextual interactive multimedia.

3.4. Normality, Homogeneity, and Hypothesis Testing

Before testing the research hypothesis, the data were examined for normality and homogeneity. The normality results showed that the calculated chi-square values for the pretest and posttest data were below the critical value of 11.07. The data could therefore be considered normally distributed. The homogeneity analysis also indicated that the experimental and control groups had comparable variance, with the calculated *F* values below the critical value of 1.85.

Because the assumptions were satisfied, an independent-samples *t*-test was used to examine differences between the groups. The pretest analysis produced $t = 0.62$, which was lower than $t_{\text{critical}} = 2.003$. Therefore, no significant difference was identified between the groups before the intervention. In contrast, the posttest analysis produced $t = 5.08$, exceeding $t_{\text{critical}} = 2.003$ at the 5% significance level.

Table 5. Hypothesis Testing Results

Test	<i>t</i> _{calculated}	<i>t</i> _{critical}	Decision	Interpretation
Pretest	0.62	2.003	Not significant	Comparable initial achievement
Posttest	5.08	2.003	Significant	Significant difference after intervention

The result demonstrates that the higher posttest achievement in the experimental group was statistically significant. In other words, students who learned using contextual interactive multimedia achieved significantly higher learning outcomes than students who learned using PowerPoint-supported instruction.

3.5. Effect Size of the Multimedia Intervention

To determine the practical magnitude of the difference between the two groups, Cohen's d was calculated using the posttest means and standard deviations.

Table 6. Effect Size of the Intervention

Measure	Value	Interpretation
Experimental posttest mean	89.76	
Control posttest mean	80.71	
Mean difference	9.05	
Pooled SD	8.08	
Cohen's d	1.12	Large effect

The effect-size result provides additional evidence that the intervention had substantial practical importance. The difference between the groups was therefore not merely statistically detectable; it represented a large difference in learning achievement.

3.6. Normalized Gain of Students' Learning Outcomes

Normalized gain was calculated to examine the proportion of the possible improvement achieved by students from pretest to posttest:

Table 7. Normalized Gain of Learning Outcomes

Group	Pretest	Posttest	Raw Gain	Normalized Gain (g)	Category
Experimental	36.15	89.76	53.61	0.84	High
Control	37.55	80.71	43.16	0.69	Medium
Difference			10.45	0.15	

The experimental group achieved a normalized gain of 0.84, indicating a high level of improvement, whereas the control group achieved 0.69, which falls within the medium category under the conventional normalized-gain interpretation. The difference of 0.15 indicates that the contextual interactive multimedia produced a greater proportion of the theoretically possible learning improvement.

These findings are particularly important because the two groups started from relatively similar pretest levels. The greater normalized gain in the experimental group therefore provides evidence that the difference in posttest performance was accompanied by a stronger learning improvement during the intervention.

3.7. Learning Outcomes Across Cognitive Levels

The learning outcome test consisted of items representing four cognitive levels: remembering (C1), understanding (C2), applying (C3), and analyzing (C4). The experimental group demonstrated improvement across all four cognitive levels following the multimedia intervention.

Table 8. Changes in Cognitive-Level Achievement in the Experimental Group

Cognitive Level	Pretest	Posttest	Increase
C1 – Remembering	48%	88%	40 percentage points
C2 – Understanding	66%	86%	20 percentage points
C3 – Applying	26%	91%	65 percentage points
C4 – Analyzing	27%	85%	58 percentage points*

The greatest improvement occurred at the C3 level, increasing by 65 percentage points from 26% to 91%. This was followed by C1, which increased by 40 percentage points, and C2, which increased by 20 percentage points. The C4 level increased from 27% to 85%, although the exact improvement should be verified because of the discrepancy in the original report.

The particularly strong increase at C3 suggests that the multimedia-supported learning environment was useful not only for presenting factual information but also for supporting students in applying physics principles to problems. The inclusion of contextual phenomena, simulation, animation, and examples from everyday life provided representations through which students could connect formal concepts with observable situations.

For comparison, the control group increased from 60% to 86% at C1, 66% to 75% at C2, 33% to 89% at C3, and 17% to 75% at C4. Thus, both groups improved, but the experimental group showed particularly strong improvement in the lower initial C3 and C4 performances.

3.8. Students' Responses to the Multimedia and Its Technological Features

Students' perceptions of the multimedia were also examined using a questionnaire. The questionnaire assessed four major dimensions: students' responses to physics before implementation, implementation of the multimedia, multimedia content, and contextual learning materials.

The results showed that students' response to physics learning increased from 63% before implementation to 82% during implementation. The multimedia implementation itself received a score of 82%, while the multimedia content and contextual materials each obtained 81%. The overall questionnaire response was 77%, categorized as good.

Table 9. Students' Responses to the Multimedia

Response Dimension	Percentage	Interpretation
Response to physics before implementation	63%	Good
Implementation of contextual interactive multimedia	82%	Very good
Multimedia content	81%	Very good
Contextual learning materials	81%	Very good
Overall response	77%	Good

The questionnaire further indicates that students perceived the animation and video components as useful for understanding dynamic fluid concepts. The instrument specifically included statements concerning the attractiveness and usefulness of animation and video, the relevance of contextual examples, the relationship between multimedia content and everyday life, and the usefulness of multimedia-based experiments.

The results therefore suggest that the technological features of the medium were positively received by students. The multimedia provided not only information delivery but also visual and interactive representations that students could use to explore dynamic fluid concepts.

3.9. Integrated Findings

The results provide convergent evidence from several sources. First, the experimental and control groups began with statistically comparable achievement levels, as indicated by the pretest comparison. Second, the experimental group achieved a higher posttest mean than the control group, with a difference of 9.05 points. Third, the posttest difference was statistically significant ($t = 5.08 > 2.003$). Fourth, the calculated Cohen's d of 1.12 indicates a large practical effect. Fifth, the experimental group achieved a high normalized gain of 0.84, compared with 0.69 in the control group. Finally, observational and questionnaire data demonstrated that students actively engaged with and positively responded to the multimedia.

Table 10. Summary of the Main Findings

Evidence	Experimental Result	Interpretation
Pretest mean	36.15	Initial achievement
Posttest mean	89.76	High final achievement
Mean improvement	53.61	Substantial improvement
Posttest difference from control	9.05 points	Higher achievement
t-test	5.08	Statistically significant
Cohen's d	1.12	Large effect
Normalized gain	0.84	High gain
Student activity	82.33%	Very good
Response to learning medium	85.00%	Very good
Overall student response	77%	Good

Overall, the findings indicate that the contextual interactive multimedia provided a stronger learning outcome than PowerPoint-supported instruction. The combination of interactive technology, animation, video, simulation, contextual examples, and collaborative learning activities was accompanied by higher achievement, greater normalized learning gain, and strong student engagement. The results therefore demonstrate both statistical effectiveness and practical educational relevance of contextual interactive multimedia for teaching dynamic fluid concepts in Grade XI physics.

The findings indicate that contextual interactive multimedia substantially improved students' learning outcomes in dynamic fluid concepts. The experimental group achieved a higher posttest mean (89.76) than the control group (80.71), with a large effect size (Cohen's $d = 1.12$) and a high normalized gain ($g = 0.84$). The strongest improvement occurred at the applying level (C3), increasing from 26% to 91%. These results suggest that the effectiveness of the multimedia was not merely attributable to digital content delivery, but to the integration of animation, simulation, video, contextual problems, and interactive activities that enabled students to visualize abstract fluid phenomena and apply physics concepts to real-life situations.

The present findings are consistent with previous studies demonstrating the effectiveness of technology-enhanced and context-based learning. Adeyele [21], reported that interactive multimedia significantly improved Basic Science achievement and was more effective than conventional instruction for mainstream learners. Similarly, Koç and Kanadlı [38], through a network meta-analysis of 53 studies, found that interactive learning environments positively influenced science learning outcomes. These findings support the present result of a large effect of contextual interactive multimedia. However, the current study extends previous evidence by demonstrating its effectiveness specifically for dynamic fluid concepts through an integrated combination of multimedia representations and contextual learning. Çeken and Taşkın [27], further showed that multimedia learning research has predominantly examined learning outcomes and cognitive processes, while Hsu et al. [25] found that animation can be particularly beneficial for students with lower prior knowledge in physics. This supports the present finding that visual and dynamic representations may help students understand concepts that are difficult to observe directly. In addition, Yalçın and Sadık [26], demonstrated that context-based physics learning improved students' connections between physics knowledge and everyday life, problem-solving, participation, and cooperation. The present study reinforces this evidence by embedding contextual applications directly into an interactive multimedia environment.

The novelty of this study lies in the integration of contextual learning and interactive multimedia into a unified learning environment for dynamic fluid physics. Rather than using technology solely to present information, the developed product combines animation, video, simulation, interactive exercises, contextual problems, and real-life applications to support conceptual understanding and application. This design is particularly relevant to dynamic fluid concepts because relationships among pressure, velocity, density, and height are difficult to visualize through conventional text-based instruction. The substantial improvement in C3 achievement further indicates that the multimedia supported students not only in understanding concepts but also in applying them to physics problems [39], [40]. Thus, the contribution of this study is the pedagogical integration of multiple digital representations with contextual learning rather than the use of technology as an instructional feature alone.

The findings have practical implications for physics teachers and instructional designers. Teachers can use interactive multimedia not simply as a replacement for PowerPoint but as an environment for students to explore concepts, observe simulations, solve contextual problems, discuss findings, and evaluate their understanding. The high student activity (82.33%) and response to the learning medium (85.00%) indicate that the multimedia was compatible with active and collaborative learning. For instructional designers, the findings emphasize that each technological component should have a clear pedagogical function: animation and simulation should visualize dynamic processes, videos should connect concepts with observable phenomena, and contextual problems should encourage students to apply physics principles to everyday situations. The findings therefore suggest that effective technology-enhanced learning does not necessarily depend on highly sophisticated technologies, but on the alignment between technological features, learning objectives, and students' learning needs.

The generalization of these findings should nevertheless be approached cautiously. The study involved 58 Grade XI students from two classes in one senior high school and used purposive sampling; therefore, the results may not automatically generalize to other schools, regions, or student populations. The intervention was also limited to dynamic fluid concepts and primarily assessed immediate learning outcomes. In addition, student responses and observational data may be influenced by subjective perceptions. Future studies should involve larger and more diverse samples, stronger experimental designs, delayed posttests, and measures of conceptual transfer and long-term retention. Further research could also examine which specific multimedia components—such as animation, simulation, video, or contextual problem-solving—contribute most strongly to students' learning gains.

4. CONCLUSION

This study concludes that the use of contextual interactive multimedia significantly improved Grade XI students' learning outcomes in dynamic fluid concepts compared with PowerPoint-supported instruction. The experimental group achieved a higher posttest mean (89.76), a large effect size (Cohen's $d = 1.12$), and a high normalized gain ($g = 0.84$), with particularly strong improvement in students' ability to apply physics concepts. The findings indicate that the integration of animation, instructional video, simulation, interactive exercises, contextual problems, and real-life applications can provide an effective and engaging learning environment for understanding dynamic fluid concepts. Future research should examine the effectiveness of contextual interactive multimedia with larger and more diverse student populations across different physics topics and educational contexts. Further studies should also investigate long-term learning retention and conceptual transfer to determine whether the learning gains are sustained beyond the immediate post-intervention period.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the school, physics teachers, and students who supported and participated in this research. The authors also appreciate all individuals who contributed to the implementation of the contextual interactive multimedia and the completion of this study. This research received no specific financial support or sponsorship from any public, commercial, or non-profit funding agency.

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