



How Can Hypermedia Improve Students' Learning of Newton's Law of Gravitation?

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Article Info

Article history:

Received Aug 3, 2026

Revised Sep 7, 2026

Accepted Oct 6, 2026

Online First Oct 14, 2026

Keywords:

Cognitive Levels

Hypermedia Learning

Learning Outcomes

Newton's Law

Physics Learning

ABSTRACT

Purpose of the study: This study aims to examine the effect of hypermedia-supported learning on Grade 11 students' physics learning outcomes in Newton's Law of Universal Gravitation and to identify differences in achievement across remembering, understanding, applying, and analyzing cognitive levels, as well as students' responses to the hypermedia learning environment.

Methodology: A quantitative quasi-experimental method with a nonequivalent control group design was employed. The participants were 61 Grade 11 students selected through purposive sampling from two existing classes. The experimental group used hypermedia developed with XAMPP and Adobe Flash, while the control group received conventional instruction. Data were collected using a 40-item multiple-choice achievement test and a 14-item Likert questionnaire and analyzed using chi-square, Fisher's test, and independent-samples t-test.

Main Findings: The experimental group achieved a higher posttest mean than the control group (78.07 vs. 68.50). The posttest difference was statistically significant ($t = 4.57 > t\text{-critical} = 2.00$). The experimental group outperformed the control group across C1–C4, with the largest difference at C3 (12.32 percentage points) and the smallest at C4 (3.12 percentage points). Students' overall response to the hypermedia was positive (73.00%).

Novelty/Originality of this study: This study contributes empirical evidence on hypermedia-supported physics learning by examining achievement not only as an overall outcome but also across four cognitive levels. The findings show that the learning benefit was strongest for applying concepts (C3) and comparatively weaker for analyzing concepts (C4), providing a more specific perspective on how integrated hypermedia supports different cognitive processes in abstract physics learning.

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1. INTRODUCTION

Physics learning requires students to connect natural phenomena with concepts, mathematical equations, and multiple forms of representation. This demand becomes challenging when the phenomena being studied cannot be directly observed or easily reproduced in classroom settings [1]–[3]. Newton's Law of

Universal Gravitation is particularly challenging because it involves relationships among mass, distance, gravitational force, and celestial motion that occur across scales that are difficult to visualize [4]-[6]. Research in physics education indicates that external representations play an important role in helping students connect concrete phenomena with abstract concepts and symbolic representations [7]-[9]. Therefore, learning environments that integrate visual, textual, and dynamic representations are increasingly relevant for supporting students' conceptual understanding of abstract physics concepts.

The central problem in physics learning is not merely students' ability to recall mathematical equations, but their ability to interpret relationships among physical quantities and apply concepts to phenomena. Students often need to translate information across different representations, such as verbal explanations, diagrams, graphs, and mathematical expressions, during physics learning [10]-[12]. This challenge is particularly relevant to Newton's Law of Universal Gravitation because understanding the concept requires students to relate gravitational force to mass, distance, and planetary motion [13]-[15]. Research on multiple representations further indicates that the effectiveness of representations depends on how they are selected, organized, and integrated into instructional materials [16]-[18]. Consequently, physics instruction requires learning resources that can make abstract relationships more accessible while maintaining the conceptual connections necessary for meaningful learning.

Hypermedia provides a digital learning environment in which text, images, animation, exercises, and hyperlinks can be integrated within an interconnected learning structure. Such an environment enables learners to access different forms of information and revisit specific learning components according to their learning needs [19]-[21]. Evidence from multimedia learning research shows that the effectiveness of representational formats can depend on learners' prior knowledge, with animation providing particular benefits for students with lower levels of physics prior knowledge [22], [23]. Digital environments can also provide interactive simulations and virtual experiments that enable students to engage with scientific phenomena that may be difficult to reproduce physically [24]-[26]. Accordingly, hypermedia has potential as an integrated learning environment for connecting multiple representations and supporting students in developing understanding of abstract physics concepts.

Recent research has demonstrated the potential of digital representations and interactive learning environments to support physics learning. Kokkonen et al. [7] found that different sequences of external representations could support students' learning of secondary-school physics concepts, highlighting the importance of representation design in conceptual learning. Flegr et al. [27] demonstrated that virtual and video-based experiments could foster conceptual understanding among secondary-school students learning physics through inquiry. Hsu et al. [22] further reported that multimedia representation formats interacted with students' prior knowledge, with students having lower prior knowledge benefiting more from animation than from static graphics or simulation. A recent systematic review and meta-analysis also found that integrating multiple external representations can support learning and problem-solving in STEM education when the representations are appropriately designed and supported [16], [28], [29].

Despite the growing evidence supporting digital representations in physics learning, important gaps remain concerning the use of hypermedia as an integrated and non-linear learning environment. Recent studies have predominantly examined specific digital formats, including virtual experiments, simulations, animations, videos, or combinations of external representations, rather than hypermedia designed to integrate these resources through flexible navigation. Moreover, evidence concerning the effectiveness of multiple representations indicates that simply increasing the number of representations does not guarantee improved learning, because representational design and instructional support remain important [16]. Empirical evidence specifically examining hypermedia for Newton's Law of Universal Gravitation also remains limited. Therefore, further evidence is needed from a controlled comparison between hypermedia-supported learning and conventional instruction, particularly with respect to students' cognitive achievement across different levels of learning.

The originality of this study lies in its empirical examination of hypermedia as an integrated learning environment for teaching Newton's Law of Universal Gravitation through interconnected textual, visual, animated, and interactive resources. Unlike studies focusing primarily on individual digital formats, the hypermedia environment examined in this study provides flexible navigation across learning components and allows students to revisit information according to their learning needs. The study also employs a quasi-experimental comparison between students learning with hypermedia and those receiving conventional instruction. In addition, learning outcomes are examined across four cognitive levels, namely remembering (C1), understanding (C2), applying (C3), and analyzing (C4). This combination provides more specific empirical evidence regarding how an integrated hypermedia environment may support cognitive achievement in learning an abstract physics concept [30], [31].

The urgency of this study arises from the continuing need for learning environments that can connect abstract physical phenomena with representations that students can observe, interpret, and explore. The empirical findings of the present study indicate that students who learned through hypermedia achieved higher learning outcomes than those who received conventional instruction. The difference was statistically significant, with a

calculated t value of 4.57 exceeding the critical t value of 2.00. The hypermedia group also demonstrated higher achievement across C1, C2, C3, and C4 and showed a positive response toward the use of the learning medium. Therefore, this study aims to examine the effect of hypermedia on Grade 11 students' physics learning outcomes in Newton's Law of Universal Gravitation and to identify their cognitive achievement and responses to hypermedia-supported learning.

2. RESEARCH METHOD

2.1. Research Design

This study employed a quantitative quasi-experimental design to examine the effect of hypermedia-supported learning on students' physics learning outcomes in Newton's Law of Universal Gravitation. A nonequivalent control group design was used because the participants were assigned to existing classes rather than randomly allocated to experimental conditions [32]-[34]. Two groups participated in the study: an experimental group that received hypermedia-supported instruction and a control group that received conventional instruction. Both groups completed a pretest before instruction and a posttest after the instructional treatment. The independent variable was hypermedia-supported learning, while the dependent variable was students' physics learning achievement.

2.2. Participants and Sampling

The study was conducted at State Senior High School 3 South Tangerang during the second semester of the 2025/2026 academic year, in January 2026. The target population comprised students of State Senior High School 3 South Tangerang, with the accessible population consisting of Grade 11 science-track students. Purposive sampling was used to select two existing classes with comparable instructional characteristics. Class XI IPA 3 was assigned as the experimental group ($n = 29$), whereas Class XI IPA 4 served as the control group ($n = 32$), resulting in a total sample of 61 students. The experimental group received instruction supported by hypermedia, whereas the control group received conventional instruction.

2.3. Instructional Treatment

The instructional intervention focused on Newton's Law of Universal Gravitation and its related concepts. The hypermedia used in the experimental group was developed using XAMPP and Adobe Flash and was designed to provide interactive learning content and flexible navigation among learning components. The learning material covered Newton's law of gravitation, gravitational force, gravitational field strength and acceleration, and Kepler's laws. The hypermedia was intended to provide students with opportunities to access and revisit learning materials through interconnected content and visual representations. The control group studied the same topic using conventional instructional methods without the hypermedia treatment.

2.4. Instruments and Data Collection

Two instruments were used to collect the data: a physics achievement test and a student response questionnaire. The achievement test was administered as a pretest and posttest and consisted of multiple-choice items with five response alternatives. The test was developed based on the competency standard and indicators for Newton's Law of Universal Gravitation and covered four cognitive levels: remembering (C1), understanding (C2), applying (C3), and analyzing (C4). The initial test consisted of 40 items, with an equal distribution of 10 items across the four cognitive levels.

Table 1. Blueprint of the Physics Achievement Test

Main concept	Indicator	Cognitive level	Initial items
Newton's Law of Gravitation	Identify Newton's theory of gravitation	C1–C2	1–3
Newton's Law of Gravitation	Identify units and dimensions of quantities in Newton's gravitational equation	C1–C2	4–6
Newton's Law of Gravitation	Calculate the gravitational force of an object	C2–C3	7–9
Newton's Law of Gravitation	Analyze the relationship between gravitational force, mass, and distance	C3–C4	10–13
Gravitational Force	Identify gravitational force as a vector quantity	C1–C2	14–16
Gravitational Force	Analyze the resultant gravitational force in a system of point masses	C2–C4	17–19
Gravitational Field Strength and Gravitational Acceleration	Explain gravitational fields and gravitational field strength	C1–C2	20–22

Main concept	Indicator	Cognitive level	Initial items
Gravitational Field Strength and Gravitational Acceleration	Compare gravitational acceleration and field strength at different positions	C2–C3	23–25
Gravitational Field Strength and Gravitational Acceleration	Analyze gravitational acceleration among planets	C2–C4	26–28
Kepler's Laws	State Kepler's laws	C1–C2	29–31
Kepler's Laws	Apply Kepler's third law to determine orbital period and radius	C2–C3	32–34
Kepler's Laws	Analyze planetary motion based on Kepler's laws	C2–C4	35–37
Kepler's Laws	Analyze planetary motion based on the consistency of Kepler's and Newton's laws	C2–C4	38–40
Total			40

Note. The original instrument allocated 10 items to each cognitive level, representing 25% of the 40-item test for C1, C2, C3, and C4. The asterisk in the original blueprint identified items retained after validity testing.

The instrument was calibrated through item validity, reliability, difficulty, and discrimination analyses. Item validity was examined using the point-biserial correlation. From the 40 items tested with 26 students, 26 items were found to be valid, representing 65% of the initial instrument. The valid items were 2, 3, 7, 8, 10, 11, 12, 14, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 29, 30, 31, 32, 33, 35, 36, and 38.

The reliability analysis produced a coefficient of $r_{11} = 0.77$, which was classified as high reliability according to the criteria used in the original study. The item analysis also showed that the 40 items comprised 10 easy items (25%), 18 moderate items (45%), and 12 difficult items (30%). Discrimination analysis classified 4 items as very good, 12 as good, 14 as satisfactory, 6 as poor, and 4 as requiring removal.

Table 2. Summary of Achievement-Test Quality

Parameter	Result
Initial number of items	40
Try-out participants	26 students
Valid items	26
Validity proportion	65%
Reliability coefficient (r_{11})	0.77
Reliability category	High
Easy items	10 (25%)
Moderate items	18 (45%)
Difficult items	12 (30%)

In addition to the achievement test, a 14-item Likert-type questionnaire was administered to students in the experimental group to assess their responses to the hypermedia-supported learning. The questionnaire used five response categories: strongly disagree, disagree, neutral, agree, and strongly agree. The questionnaire consisted of seven positive and seven negative statements covering five aspects of the hypermedia learning experience.

Table 3. Blueprint of the Hypermedia Response Questionnaire

No.	Aspect assessed	Positive items	Negative items	Total
1	Use of hypermedia during learning	1	2	2
2	Presentation of learning concepts	3	4	2
3	Presentation of images and animations	5–6	7–8	4
4	Suitability of colors and background	9	10	2
5	Explanation of formulas in hypermedia	11–12	13–14	4
Total		7	7	14

The questionnaire was subjected to expert judgment for content validity. The aspects evaluated included the development of indicators, representation of learning stages, scoring procedures, wording and sentence construction, and clarity and effectiveness of language. The available research document reports this expert-validation procedure but does not provide a numerical content-validity coefficient for the questionnaire. Therefore, a numerical validity value should not be reported for this instrument unless the original expert-rating data are available.

2.5. Data Analysis

The achievement-test data were analyzed quantitatively to determine differences in learning outcomes between the experimental and control groups. Before hypothesis testing, the data were examined for normality and homogeneity assumptions. Normality was assessed using the chi-square test, while homogeneity of variance was examined using Fisher's test. When the statistical assumptions were satisfied, an independent-samples *t* test was used to compare the posttest achievement of the two groups. The statistical hypothesis concerned whether students receiving hypermedia-supported instruction achieved significantly different learning outcomes from students receiving conventional instruction.

Students' achievement data were also analyzed across the four cognitive levels assessed in the test: C1 (remembering), C2 (understanding), C3 (applying), and C4 (analyzing). Descriptive statistics were used to compare students' performance at each cognitive level between the experimental and control groups. Questionnaire responses were analyzed descriptively to determine students' overall perceptions of the hypermedia-based learning. The results indicated a statistically significant difference between the two groups, with the calculated *t*-value (4.57) exceeding the critical *t*-value (2.00) at the 5% significance level.

2.6. Ethical and Source Considerations

This article reports an empirical study originally conducted in January 2026 at State Senior High School 3 South Tangerang. The methodological and empirical information presented in this article is based on the original research documentation, including its participants, instructional treatment, instruments, and statistical procedures. Because the study used data collected in 2026, the article does not claim that the underlying hypermedia technology represents a contemporary digital innovation. Instead, the study is positioned as empirical evidence concerning the effectiveness of an integrated hypermedia learning environment for an abstract physics topic.

3. RESULTS AND DISCUSSION

3.1. Descriptive Results of Physics Achievement

The study involved 61 Grade 11 students, comprising 29 students in the experimental group and 32 students in the control group. The experimental group received physics instruction supported by hypermedia, whereas the control group received conventional instruction. The pretest results showed that the experimental group had a lower mean score than the control group, with means of 41.69 and 46.38, respectively. Thus, the experimental group did not begin the intervention with a higher level of achievement.

After the instructional treatment, both groups demonstrated higher achievement scores. The mean posttest score increased to 78.07 in the experimental group and 68.50 in the control group. The experimental group therefore achieved a posttest mean that was 9.57 points higher than the control group. Within-group improvement was also greater in the experimental group, increasing by 36.38 points compared with 22.13 points in the control group.

Table 4. summarizes the descriptive statistics of the pretest and posttest scores.

Statistic	Experimental	Control
Pretest mean	41.69	46.38
Pretest minimum	20	32
Pretest maximum	72	68
Pretest median	40.71	45.50
Pretest SD	13.06	9.69
Posttest mean	78.07	68.50
Posttest minimum	56	48
Posttest maximum	96	88
Posttest median	84.20	66.35
Posttest SD	9.88	9.41

The descriptive pattern indicates that hypermedia-supported instruction was associated with a greater improvement in physics achievement than conventional instruction. Notably, although the experimental group started with a lower pretest mean, it exceeded the control group at posttest. This pattern strengthens the interpretation that the observed posttest advantage was not simply attributable to a higher initial achievement level.

3.2. Hypermedia Learning Media

The experimental group received physics instruction supported by a hypermedia-based learning environment developed for the topic of Newton's Law of Universal Gravitation. The learning media integrated structured textual explanations, mathematical representations, visual illustrations, navigation menus, examples, and interactive exercises to facilitate students' access to the learning content. The main components of the hypermedia are presented in Figure 1, including the main interface, Newton's gravitational law, gravitational field and acceleration, and interactive exercises with feedback.

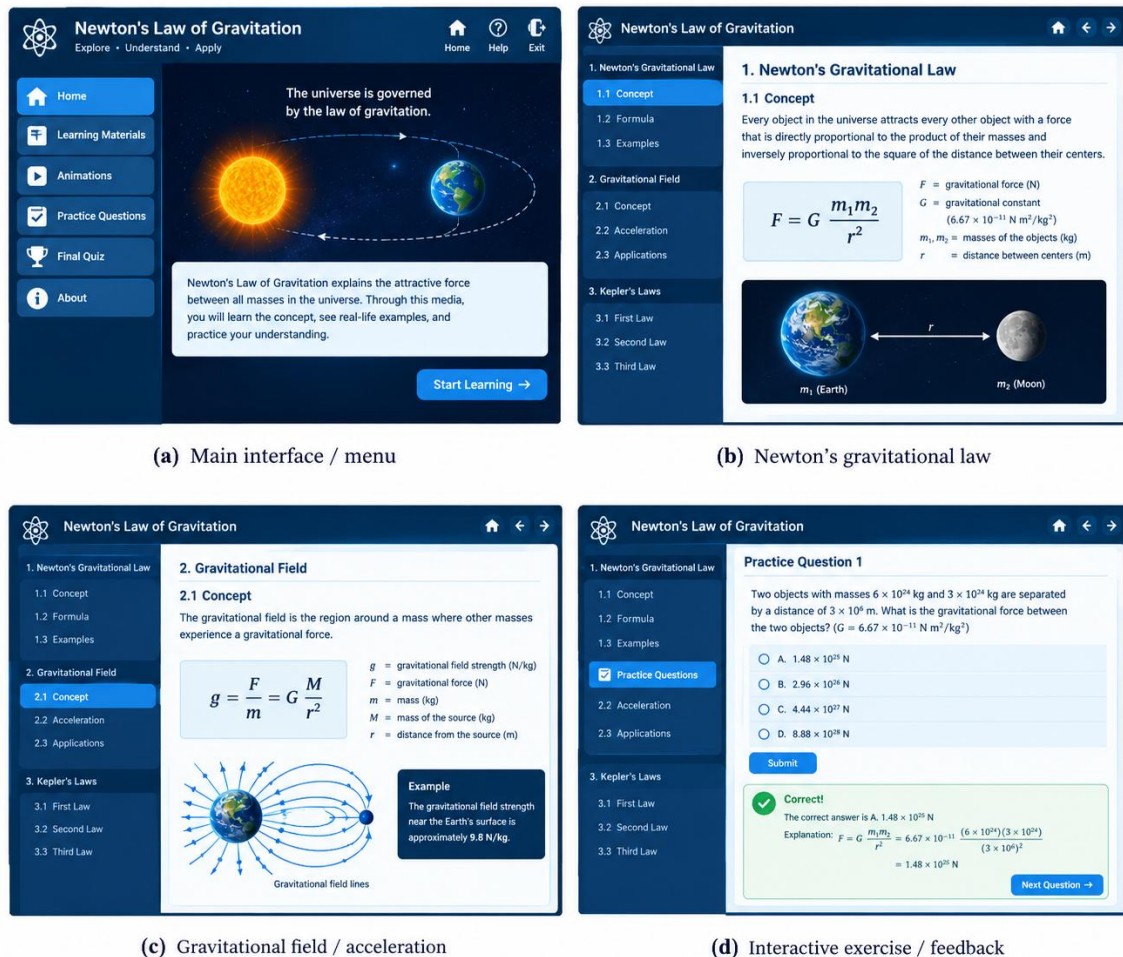


Figure 1. Hypermedia-Based Physics Learning Media Used in the Experimental Group

Figure 1 shows that the hypermedia provided multiple representations of gravitational concepts through text, equations, diagrams, illustrations, and interactive practice. The main interface and navigation structure allowed students to move between learning materials, while the gravitational law and gravitational-field sections presented abstract concepts through mathematical and visual representations. The interactive exercise component provided opportunities for students to apply the concepts and receive immediate feedback. These features indicate that the hypermedia was designed not merely to present information but to support conceptual understanding and active engagement with the learning material. This instructional structure is consistent with the higher posttest performance observed in the experimental group, particularly in the application-level cognitive domain.

3.3. Assumption Testing and Hypothesis Testing

Before testing the research hypothesis, the distributions of the pretest and posttest scores were examined using the chi-square normality test. The calculated chi-square values were 4.06 and -0.90 for the experimental and control pretests, respectively, and 2.80 and 7.42 for the corresponding posttests. These values were below the reported critical value of 11.07, leading to the conclusion that the datasets were normally distributed.

Homogeneity testing produced F values of 0.14 for the pretest and 1.10 for the posttest, compared with an F critical value of 1.85. Both datasets were therefore considered homogeneous. The pretest comparison

produced a calculated t value of 1.60, which was lower than the critical value of 2.00, indicating no significant initial difference between the groups.

The posttest comparison produced a calculated t value of **4.57**, exceeding the critical value of **2.00** at the 5% significance level. The null hypothesis was therefore rejected and the alternative hypothesis was accepted. These findings indicate a statistically significant difference in physics achievement between students who learned using hypermedia and those who received conventional instruction.

Table 5. Results of the Independent-Samples t -Test for Pretest and Posttest Scores

Analysis	Calculated value	Critical value	Decision
Pretest t -test	1.60	2.00	Not significant
Posttest t -test	4.57	2.00	Significant

The statistical evidence is consistent with the descriptive results: students receiving hypermedia-supported instruction achieved significantly higher posttest performance than students in the control group.

3.4. Achievement across Cognitive Levels

The analysis was further conducted according to four cognitive levels: remembering (C1), understanding (C2), applying (C3), and analyzing (C4). Both groups improved from pretest to posttest across all four cognitive levels. However, the experimental group demonstrated higher posttest performance than the control group at every level.

Table 6. Comparison of Physics Achievement across Cognitive Levels

Cognitive level	Experimental pretest (%)	Experimental posttest (%)	Control pretest (%)	Control posttest (%)	Posttest difference (%)
C1 – Remembering	60.00	97.24	58.13	86.88	10.37
C2 – Understanding	41.38	73.40	42.41	66.07	7.33
C3 – Applying	33.19	81.47	44.53	69.14	12.32
C4 – Analyzing	24.83	60.00	43.13	56.88	3.12

The largest posttest advantage was observed at C3, where the experimental group exceeded the control group by 12.32 percentage points. The smallest difference occurred at C4, with an advantage of 3.12 percentage points. The experimental group also showed substantial within-group gains of 37.24 percentage points for C1, 32.02 percentage points for C2, 48.28 percentage points for C3, and 35.17 percentage points for C4.

These results suggest that the hypermedia intervention was particularly beneficial for remembering, understanding, and applying concepts. Although the experimental group also outperformed the control group at the analyzing level, the relatively small difference at C4 indicates that higher-order analytical performance was less strongly differentiated by the intervention. This finding is important because it identifies C4 as an area requiring stronger instructional support in subsequent development.

3.5. Students' Responses to Hypermedia

Students' responses to the hypermedia were analyzed across five aspects: use of hypermedia during learning, presentation of concepts, presentation of images and animations, suitability of colors and background, and explanation of formulas.

Table 7. Students' Responses to Hypermedia-Supported Physics Learning

Hypermedia aspect	Response (%)	Interpretation
Use of hypermedia during learning	74.14	Good
Presentation of learning concepts	72.41	Good
Presentation of images and animations	72.76	Good
Suitability of colors and background	71.38	Good
Explanation of formulas	74.31	Good
Overall mean	73.00	Good

The overall response score was 73.00%, categorized as good. The highest response was obtained for the explanation of formulas (74.31%), whereas the lowest was obtained for the suitability of colors and background (71.38%). Thus, students generally responded positively to the use of hypermedia, while visual design remained the relatively weaker aspect of the learning media.

The findings indicate that hypermedia-supported instruction produced a meaningful improvement in students' physics achievement compared with conventional instruction. Although the experimental group initially had a lower pretest mean than the control group (41.69 vs. 46.38), its posttest mean increased to 78.07,

compared with 68.50 in the control group. The statistically significant posttest difference ($t = 4.57 > t_{\text{critical}} = 2.00$) suggests that the observed achievement advantage was associated with the instructional treatment rather than a higher initial achievement level. The stronger improvement in the experimental group may be explained by the affordances of hypermedia, which combined conceptual explanations, visual representations, animation, flexible navigation, practice questions, and immediate feedback. These features are particularly relevant to Newton's law of gravitation because students must connect abstract relationships among force, mass, distance, gravitational fields, and planetary motion rather than merely memorize equations. The cognitive-level findings further show that the strongest comparative advantage occurred at C3 (applying), with a 12.32-percentage-point difference, whereas the C4 difference was only 3.12 percentage points, indicating that hypermedia was more effective for supporting conceptual recall, understanding, and application than higher-level analytical reasoning.

The present findings are broadly consistent with recent evidence showing that technology-supported learning can improve students' academic and conceptual outcomes, although the magnitude of benefit depends strongly on how technology is pedagogically designed. A large meta-analysis of 92 studies found an overall positive effect of digital tools on mathematics and science learning in secondary education, while also showing that hypermedia systems produced smaller effects than simulations and intelligent tutoring systems [35]. This comparison is important because the current study demonstrates that hypermedia can nevertheless produce a substantial classroom-level advantage when it is directly integrated with physics content and learning activities. Similarly, Wu [36], reported from a meta-analysis of 60 studies that digital technology positively influenced deep learning, particularly when accompanied by appropriate instructional guidance and systematic implementation. The present finding that students responded positively to the hypermedia and that achievement improved across C1–C4 supports this argument that technology alone is insufficient; its instructional organization and learning affordances matter. Evidence from physics education also supports the importance of multiple representations: a recent study involving high school students found that learners with lower prior physics knowledge benefited more from animation than from static graphics or simulation when learning complex scientific processes [22], [37]. Furthermore, Flegr et al. [27] found that virtual and video experiments supported students' conceptual understanding in physics, demonstrating the potential of digitally mediated representations to facilitate scientific concept development. At the broader secondary-school level, Msafiri et al. [38] concluded that ICT integration can improve learning outcomes, engagement, and personalized learning when technology is aligned with curriculum and pedagogy. Thus, the current study extends previous evidence by showing that a hypermedia environment can generate measurable advantages not only in overall physics achievement but also across distinct cognitive levels, although its effect on analytical performance appears comparatively limited.

The principal contribution of this study lies not in introducing hypermedia as a new technology, but in providing empirical evidence about how hypermedia-supported instruction differentiates physics achievement across cognitive levels within a specific secondary-school physics topic. Previous research has frequently examined digital technology in terms of overall achievement, engagement, conceptual understanding, or broad learning outcomes. In contrast, the present study disaggregates achievement into remembering (C1), understanding (C2), applying (C3), and analyzing (C4), thereby revealing that the benefit of hypermedia was not uniform across cognitive processes. The largest advantage was found for application (C3), while the smallest difference occurred for analysis (C4). This pattern provides a more nuanced interpretation of technology-supported learning than simply concluding that digital media "improves achievement." The study therefore contributes a cognitive-level perspective showing that hypermedia may be particularly useful for representing and reinforcing conceptual knowledge and its application, while higher-order analytical reasoning may require additional pedagogical strategies. This interpretation is also consistent with contemporary evidence that the effectiveness of digital technology depends on instructional guidance, learning design, and the specific affordances of the technology rather than technology exposure alone [36], [39].

The findings have several implications for physics teaching and instructional-media development. First, teachers can use hypermedia to complement, rather than simply replace, conventional instruction by integrating explanations, visualizations, animations, worked examples, exercises, and immediate feedback into a coherent learning sequence. Second, the positive response of students (73.00%) indicates that hypermedia was generally acceptable to learners, suggesting that usability and learner acceptance should be considered alongside achievement outcomes when evaluating digital learning environments. Third, the relatively small C4 advantage indicates that multimedia presentation alone may not be sufficient to develop analytical reasoning; teachers should therefore incorporate problem-solving tasks, comparison activities, prediction tasks, justification prompts, and open-ended questions that explicitly require students to analyze relationships among physical variables. Fourth, the lower response to the color and background component (71.38%) suggests that visual design remains an area for refinement, even though the overall response was categorized as good. More broadly, current evidence emphasizes that effective digital integration requires alignment among technology, pedagogy, curriculum objectives, and instructional support rather than simply adding digital resources to existing teaching practices [38], [40].

The findings should be interpreted within the boundaries of the study design. The research involved 61 students from two existing Grade 11 science classes in one senior high school, with purposive sampling and no random assignment; therefore, the results should not be generalized directly to all secondary-school students or all physics topics. The quasi-experimental design provides useful evidence of comparative effectiveness, but uncontrolled differences between existing classes cannot be completely excluded. In addition, the intervention focused specifically on Newton's law of gravitation, meaning that its effectiveness may differ for other physics topics requiring different forms of representation or reasoning. The study also measured achievement through a multiple-choice test and student responses through a questionnaire, which limits the assessment of deeper reasoning processes and long-term retention. Importantly, the study was conducted in 2026, when the technological environment and characteristics of hypermedia differed considerably from contemporary digital learning ecosystems; consequently, the findings should be interpreted as evidence of the instructional potential of hypermedia, rather than as evidence that the specific technology remains optimal today. Recent research similarly emphasizes that digital-learning effects are context-dependent and influenced by instructional design, teacher support, infrastructure, and implementation conditions [38], [41]. Future research should therefore replicate the intervention using larger and more diverse samples, randomized or stronger quasi-experimental designs, delayed posttests, and measures of higher-order reasoning to determine whether the observed benefits can be sustained and generalized across physics topics and contemporary digital learning environments.

4. CONCLUSION

This study concludes that the use of hypermedia significantly improved students' physics learning outcomes on Newton's Law of Universal Gravitation compared with conventional instruction. The experimental group achieved a higher posttest mean (78.07) than the control group (68.50), with a significant difference between groups ($t = 4.57 > t\text{-critical} = 2.00$). The improvement was evident across the C1–C4 cognitive levels, with the largest comparative advantage at the application level (C3), while the advantage at the analysis level (C4) was comparatively smaller. These findings suggest that hypermedia can support physics learning by integrating textual explanations, visual representations, animations, structured navigation, and interactive exercises to help students understand abstract gravitational concepts. In practice, physics teachers can integrate hypermedia into instruction to facilitate conceptual understanding and the application of physics principles, while complementing it with analytical reasoning and problem-solving activities to strengthen higher-order thinking skills. Future studies should involve larger and more diverse samples across multiple schools and employ more rigorous experimental designs to strengthen the generalizability of the findings. Further research should also develop more advanced interactive features and place greater emphasis on analytical tasks to improve students' C4-level learning outcomes.

ACKNOWLEDGEMENTS

The authors thank the school, teachers, and students for their support and participation in this study. No specific funding was received for this research.

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