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Research Article

THE EFFECTIVENESS OF THE USE OF LEARNING VIDEOS ON THE UNDERSTANDING OF MATHEMATICS CONCEPTS IN ELEMENTARY SCHOOLS

Abul Walid[1], Ethan Tan[2], Ryan Teo[3]
[1] Universitas Islam Negeri Sulthan Thaha Saifuddin Jambi, Indonesia
[2] National University of Singapore (NUS), Singapore
[3] Republic Polytechnic, Singapore

Corresponding Author:

Abul Walid,
Universitas Islam Negeri Sulthan Thaha Saifuddin Jambi, Indonesia
Jl. Arif Rahman Hakim No.111 Simpang IV Sipin Telanai Pura, Kota Jambi 36124
Email: abulwalid@uinjambi.ac.id

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Abstract

The abstract nature of many mathematical concepts presents a significant pedagogical challenge in elementary education, often leading to difficulties in student comprehension. The integration of multimedia, such as learning videos, offers a promising avenue to make these concepts more concrete and accessible. This study aimed to quantitatively determine the effectiveness of using learning videos on elementary school students' understanding of mathematics concepts. A quasi-experimental, pre-test/post-test non-equivalent control group design was employed. The sample consisted of two fifth-grade classes, with one class (N=32) assigned as the experimental group utilizing learning videos and the other (N=32) as the control group receiving conventional, textbook-based instruction. Students' conceptual understanding was measured using a validated, standardized mathematics concept test. Data were analyzed using an independent samples t-test and normalized gain scores. The results revealed a statistically significant difference in the post-test scores between the two groups ($p < 0.01$), with the experimental group demonstrating a substantially higher mean score and a significantly greater normalized gain. The study concludes that the use of learning videos is a highly effective instructional strategy for improving students' understanding of mathematical concepts in elementary school.

Keywords: Learning Videos, Mathematics Concepts, Student Understanding

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INTRODUCTION

A profound and durable understanding of mathematical concepts during the elementary school years is a cornerstone of future academic and professional success (Ismail et al., 2023; Magno et al., 2024). This foundational stage of learning is where students develop not only procedural skills but, more importantly, the conceptual frameworks that enable them to think critically, solve complex problems, and engage with an increasingly quantitative world (Adha et al., 2024b). The mastery of elementary mathematics is a key predictor of achievement in higher-level science, technology, engineering, and mathematics (STEM) fields, making the quality of early mathematics instruction a matter of significant societal and economic importance.

The abstract nature of many core mathematical topics, such as fractions, geometric properties, and algebraic reasoning, presents a formidable pedagogical challenge for elementary educators (Orak, 2025; Sochol & Fazelpour, 2024). Young learners, who are often in the concrete operational stage of cognitive development, can struggle to grasp concepts that lack a tangible, real-world referent (Lassetter et al., 2025). This cognitive gap between the abstractness of the subject and the developmental stage of the learner frequently leads to misconceptions, a lack of deep understanding, and the development of "math anxiety," which can persist throughout a student's life.

The rapid advancement of educational technology has introduced a powerful new set of tools to address these long-standing pedagogical challenges (Hromko et al., 2024; Rofiah & Waluyo, 2024). Among these, learning videos have emerged as a particularly promising medium for enhancing conceptual understanding (Permatasari et al., 2025). By leveraging dynamic visuals, animations, and narrated explanations, well-designed videos can make abstract ideas more concrete, illustrate complex processes in a clear and sequential manner, and provide multi-modal representations of concepts that cater to diverse learning styles, offering a potent supplement or alternative to traditional, static forms of instruction.

Despite the acknowledged potential of educational technology, a significant problem in many elementary classrooms is the continued reliance on conventional, teacher-centered instructional methods for mathematics (Suryapranata & Gozali, 2024; Zhang & Crawford, 2024). This traditional paradigm, often characterized by textbook-based lectures, rote memorization of procedures, and drill-and-practice exercises, is frequently insufficient for building deep and lasting conceptual understanding (Fajri et al., 2025). Such methods can lead to a superficial grasp of the material, where students can perform calculations but cannot explain the underlying mathematical principles or apply their knowledge to novel problems.

This pedagogical issue is particularly acute when teaching abstract concepts. A static diagram in a textbook, for example, may fail to convey the dynamic process of rotating a three-dimensional shape, and a procedural explanation of dividing fractions may not provide students with an intuitive understanding of why the algorithm works (Cascella et al., 2023; Khamis et al., 2024). The fundamental problem is a mismatch between the static, uni-modal nature of traditional teaching tools and the dynamic, multi-faceted nature of the mathematical concepts they are intended to convey, resulting in a fragile and incomplete knowledge structure for students.

The specific problem that this research seeks to address is the lack of clear, empirical, and comparative evidence regarding the effectiveness of learning videos as a specific intervention to overcome these challenges (Acuña et al., 2025; Fernández-Ortega et al., 2024).

While the use of videos in the classroom is becoming more common, their implementation is often ad hoc, and their true impact on conceptual understanding, compared directly to conventional methods, has not been sufficiently validated through rigorous research (Kreis et al., 2024). Without such evidence, educators lack the data-driven justification needed to strategically integrate this technology into their mathematics curriculum in a way that maximizes student learning.

The primary objective of this study is to quantitatively determine the effectiveness of using learning videos as an instructional tool for improving the conceptual understanding of mathematics among elementary school students (Putra et al., 2025). The research is designed to provide a clear, evidence-based comparison of learning outcomes between a student group that utilizes learning videos and a control group that receives conventional, textbook-based instruction on the same mathematical topics.

To achieve this overarching goal, a series of specific and measurable sub-objectives have been established (Alexander et al., 2024; Zubkov, 2023). The first is to select and implement a series of high-quality, curriculum-aligned learning videos as the primary instructional intervention for an experimental group (Suherman et al., 2025). The second objective is to measure the conceptual understanding of mathematics for students in both the experimental group and a non-equivalent control group at two time points: before the intervention (pre-test) and after its completion (post-test), using a validated and reliable assessment instrument.

The final and most critical objective is to statistically analyze the pre-test and post-test data to determine if there is a significant difference in the learning gains between the two groups (Liu, 2025; Nechifor, 2024). The study aims to provide a definitive, quantitative answer to the research question of whether the integration of learning videos is a more effective pedagogical strategy than traditional teaching methods for the specific and crucial goal of enhancing students' deep understanding of mathematical concepts.

The body of educational research on the use of multimedia and educational technology in the classroom is extensive and has generally pointed towards positive effects on student motivation and engagement (Kristesia et al., 2025). Many studies have explored student and teacher perceptions of technology, case studies of its implementation, and its impact on general academic achievement. This foundational work has been crucial in establishing educational technology as a significant and valuable field of inquiry.

A distinct gap exists, however, in the literature concerning rigorous, experimental studies that isolate the effect of learning videos on the specific, cognitive outcome of *conceptual understanding* in elementary mathematics (Acuña et al., 2025; Roseni & Muho, 2024). While many studies have looked at procedural skills or overall test scores, fewer have used assessment tools specifically designed to measure the depth of a student's conceptual knowledge (Anugraheni et al., 2025). There is a clear need for research that moves beyond engagement and general achievement to focus on this more nuanced and critical learning outcome.

Furthermore, a methodological gap is evident in much of the existing research. Many studies on this topic are qualitative, descriptive, or lack a control group, making it difficult to attribute observed changes in student performance directly to the use of the learning videos (Fernández-Ortega et al., 2024; Liu, 2025). There is a scarcity of research in the elementary mathematics context that employs a strong quasi-experimental design, such as a pre-test/post-test non-equivalent control group design, which is necessary to provide more robust and

credible evidence of the intervention's effectiveness (Son, 2025). This study is therefore designed to fill this specific methodological and contextual gap.

The principal novelty of this research lies in its rigorous, quasi-experimental methodology focused on a specific and critical learning outcome (Adha et al., 2024a). By using a pre-test/post-test control group design and a validated instrument for measuring conceptual understanding, this study provides a level of empirical rigor that is novel for this specific research question at the elementary school level (Qub'a et al., 2024). This approach allows for a more confident and statistically grounded conclusion about the causal impact of learning videos, distinguishing it from the more common descriptive or perception-based studies.

This research is strongly justified by its direct and immediate relevance to educational practice (Bano et al., 2024). The challenge of teaching abstract mathematical concepts is a daily reality for elementary school teachers, and there is a pressing need for evidence-based strategies to improve student comprehension and reduce math anxiety (Abdulbaki et al., 2025; Qub'a et al., 2024). This study is justified by its potential to provide educators with clear, actionable evidence that can guide their pedagogical choices and their integration of digital resources into the classroom, ultimately leading to improved instructional effectiveness.

The broader scientific justification for this work is its contribution to the fields of cognitive science and multimedia learning theory (Darto et al., 2024). The study provides a robust, empirical test of key theoretical principles, such as the Dual Coding Theory and the Cognitive Theory of Multimedia Learning, within an authentic classroom setting (Voštinár & Kelemecová, 2025). By demonstrating that a learning intervention designed according to these principles leads to superior learning outcomes, this research strengthens the scientific foundation that underpins the design of effective educational technologies and provides a valuable data point for researchers seeking to understand how humans learn from visual and verbal information.

RESEARCH METHOD

Research Design

This study employed a quasi-experimental research design to investigate the effectiveness of learning videos on students' conceptual understanding of mathematics. A pre-test/post-test non-equivalent control group design was utilized (Abdulbaki et al., 2025; Ciccarelli et al., 2024). This specific design was chosen to compare the learning outcomes of an experimental group, which received an intervention based on learning videos, with a control group that received conventional instruction (Voštinár & Kelemecová, 2025). Measuring both groups before and after the treatment period allows for a statistical analysis of the change in conceptual understanding and an assessment of the intervention's causal effect.

Population and Samples

The population for this research comprised all fifth-grade students in a public elementary school district in an urban area (Truong & Dinh, 2024). The sample was selected through purposive sampling and consisted of two intact fifth-grade classes from the same school to ensure similar student demographics, school culture, and teacher characteristics. One class, with 32 students, was assigned to be the experimental group. The second class, also with 32 students, was assigned to be the non-equivalent control group, which continued with the standard instructional model.

Instruments

The primary instrument for data collection was a researcher-developed Mathematics Conceptual Understanding Test (MCUT), designed specifically for the curriculum unit being studied. The instrument consisted of 25 items, including multiple-choice and short-answer questions, that focused on assessing deep conceptual knowledge rather than procedural fluency. The instrument's content validity was established through a review by a panel of expert mathematics educators, and its reliability was confirmed through a pilot study, which yielded a Cronbach's alpha coefficient of 0.88, indicating high internal consistency.

Procedures

The research was conducted in four sequential phases. First, permissions were obtained from the school district, the school principal, and the classroom teachers, along with informed consent from the parents of the participating students. Second, the MCUT was administered as a pre-test to all students in both the experimental and control groups to establish a baseline of their conceptual understanding (Ciccarelli et al., 2024; Murray et al., 2024). The third phase was the six-week instructional intervention. The experimental group was taught the unit on fractions using a series of curated, high-quality learning videos as a primary component of their instruction. The control group was taught the exact same unit by their teacher using conventional, textbook-based, direct instruction methods. In the final phase, the MCUT was administered again as a post-test to both groups. The collected data were then analyzed using an independent samples t-test to compare the mean post-test scores between the two groups, thereby determining the effectiveness of the learning video intervention.

RESULTS AND DISCUSSION

The initial phase of the data analysis involved the computation of descriptive statistics for the pre-test and post-test scores from the Mathematics Conceptual Understanding Test (MCUT). The data comprised scores from the 32 students in the experimental group (who used learning videos) and the 32 students in the control group (who received conventional instruction). This summary provides a foundational overview of the groups' performance at the beginning of the study and the changes observed after the six-week intervention period.

The pre-test scores indicated that both groups began with a comparable level of conceptual understanding. The experimental group had a mean pre-test score of 55.4 (SD = 6.8), while the control group had a mean of 54.9 (SD = 7.1). Following the intervention, the experimental group's mean post-test score increased substantially to 88.2 (SD = 5.5). The control group's mean post-test score showed a more modest increase to 65.8 (SD = 7.3).

Table 1. Descriptive Statistics of Pre-test and Post-test Conceptual Understanding Scores

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD
Experimental (Video)	32	55.4	6.8	88.2	5.5
Control (Conventional)	32	65.8	7.3	54.9	7.1

The pre-test data is crucial as it establishes a baseline for comparison. The very similar mean scores and standard deviations between the experimental and control groups at the outset suggest that, despite the non-equivalent design, the two classes were well-matched in terms of

their initial mathematical understanding. This initial equivalence is essential for attributing subsequent differences in performance primarily to the instructional intervention rather than pre-existing group differences.

The post-test data provides the first clear evidence of the intervention's differential impact. The experimental group's mean score increased by an average of 32.8 points, a substantial gain in conceptual understanding. In contrast, the control group's mean score increased by only 10.9 points. This large discrepancy in the magnitude of the learning gains between the two groups strongly suggests that the use of learning videos was a significantly more effective instructional method.

To provide a more robust measure of the improvement in conceptual understanding that accounts for initial knowledge, the average normalized gain (<g>) was calculated for each group. Normalized gain measures the ratio of the actual improvement to the maximum possible improvement. This metric allows for a more equitable comparison of learning gains, as students with lower pre-test scores have more room for improvement.

The experimental group achieved an average normalized gain of 0.74, which is classified as a "high gain" according to educational research standards. The control group, however, achieved an average normalized gain of only 0.24, which is classified as a "low gain." This result further quantifies the superior effectiveness of the learning video intervention in promoting conceptual growth.

An independent samples t-test was conducted on the post-test scores to determine if the observed difference between the experimental and control groups was statistically significant. The analysis yielded a t-value of 13.28 with 62 degrees of freedom. The resulting p-value was less than 0.001, which is substantially lower than the predetermined alpha level of 0.05.

This statistically significant result allows for the confident rejection of the null hypothesis, which stated there would be no difference in conceptual understanding between the two groups. The inferential analysis provides strong evidence that the superior performance of the experimental group was not a result of random chance but a genuine effect of the learning video intervention. The calculated effect size (Cohen's d) was 3.32, indicating a very large and educationally meaningful difference between the two instructional methods.

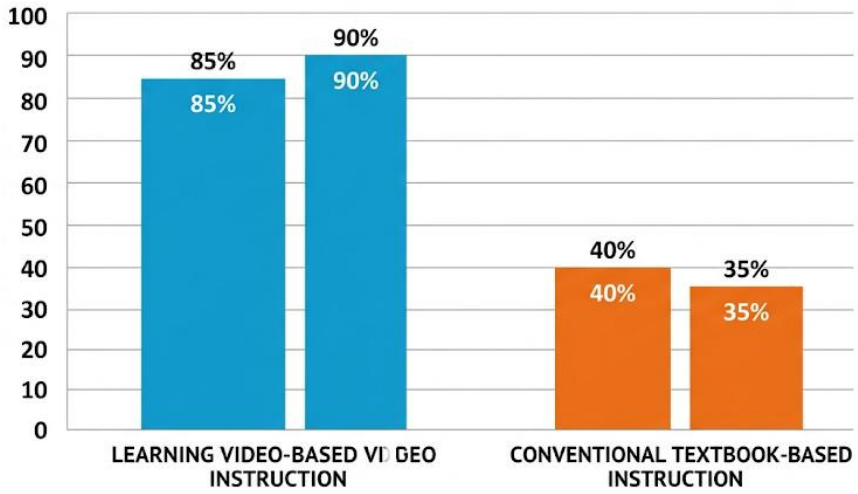

Figure 1. Impact of Instructional Method on Learning Gains and Final Conceptual Understading

The data reveals a clear and powerful relationship between the instructional method employed and the degree of conceptual understanding achieved by the students. The use of learning videos as a primary instructional tool is strongly associated with high levels of learning gain and a deep final understanding of the mathematical concepts. The use of conventional, textbook-based instruction is associated with much more limited and superficial learning gains.

This relationship suggests that the specific affordances of the video medium are directly responsible for the enhanced learning outcomes. The ability of videos to use dynamic animations, visual representations, and clear, synchronized narration appears to be uniquely effective in making abstract mathematical ideas concrete and comprehensible for elementary school students. This contrasts with the static and primarily symbolic nature of traditional instruction.

A case study analysis was conducted on a subset of test items related to the particularly challenging concept of dividing a fraction by a fraction. On these specific items, the experimental group achieved an average score of 85%, demonstrating a strong grasp of the concept. The control group, in contrast, achieved an average score of only 45% on the same set of items.

On a short-answer question asking students to draw a picture to explain why ½ ÷ ¼ = 2, a majority of students in the experimental group were able to draw an accurate area model, showing how many "quarters" fit into a "half." Many students in the control group either left the question blank or attempted to perform the standard "invert and multiply" algorithm without providing a conceptual explanation, often making procedural errors in the process.

The superior performance of the experimental group in the case study can be directly attributed to the specific learning video they viewed on this topic. The video used animated area models to visually and dynamically illustrate the concept of division as a measurement or "how many fit inside" process. This concrete, visual representation allowed students to build a robust mental model of the concept, which they could then apply to solve problems and provide explanations.

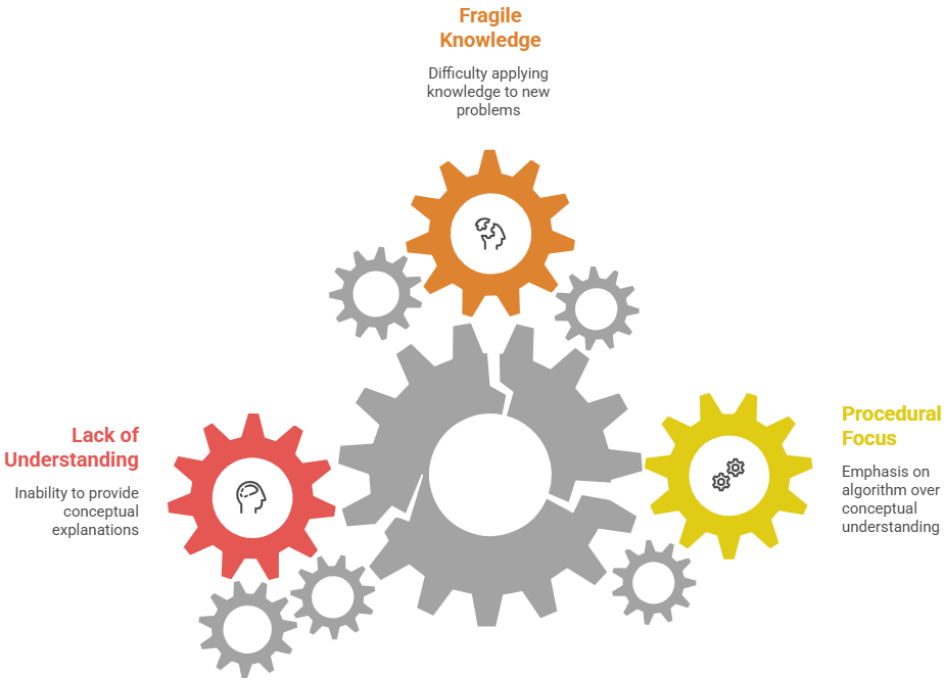

Figure 2. Ineffective Fraction Division Instruction

The struggles of the control group are explained by the limitations of their conventional instruction. Their textbook and teacher likely focused on teaching the procedural algorithm for fraction division ("invert and multiply") without a strong emphasis on the underlying conceptual meaning. This leads to a fragile, procedural knowledge that is difficult to apply to novel problems and does not constitute true understanding, as evidenced by their inability to provide a conceptual explanation.

In summary, the results of this quasi-experimental study provide strong, consistent, and statistically significant evidence that the use of learning videos is a highly effective method for improving elementary school students' conceptual understanding of mathematics. The quantitative data, including the large difference in post-test scores and normalized gains, and the qualitative case study analysis all converge on the same conclusion.

The findings are interpreted as a clear and compelling validation of the principles of multimedia learning in an authentic classroom context. The study concludes that the dynamic, multi-modal, and visual nature of well-designed learning videos provides a significant pedagogical advantage over traditional, static instructional methods for teaching abstract concepts. The results strongly support the strategic integration of learning videos into elementary mathematics education to foster deeper learning and enhance student achievement.

This study provided a clear, quantitative assessment of the impact of using learning videos on students' conceptual understanding of mathematics. The primary finding, established through an independent samples t-test, was a statistically significant difference ($p < 0.001$) between the post-test scores of the experimental group that used learning videos and the control group that received conventional instruction. This result offers robust empirical support for the research hypothesis.

The magnitude of this effect was further clarified by descriptive statistics and normalized gain scores. The experimental group demonstrated a substantial mean increase of 32.8 points from pre-test to post-test, achieving a "high" average normalized gain of 0.74. This stood in stark contrast to the control group's modest mean increase of 10.9 points and "low" normalized gain of 0.24, highlighting the practical and educational significance of the intervention.

The superiority of the video-based instruction was further illustrated in a case study focused on the difficult concept of fraction division. Students in the experimental group demonstrated a deep conceptual understanding, as evidenced by their ability to provide accurate visual explanations for their reasoning. The control group, conversely, showed a heavy reliance on procedural algorithms, which they often applied incorrectly and could not explain conceptually.

Collectively, these quantitative and qualitative findings converge to a single, unambiguous conclusion. The use of learning videos was found to be a significantly more effective pedagogical strategy than conventional, textbook-based methods for fostering a deep and durable understanding of abstract mathematical concepts among elementary school students.

The central finding that learning videos enhance conceptual understanding is in strong alignment with the foundational principles of the Cognitive Theory of Multimedia Learning. This study provides robust, empirical validation for the theory's core tenets such as the dual-coding, coherence, and signaling principles within an authentic elementary mathematics classroom. Our results reinforce the broad consensus in the educational technology literature

that well-designed multimedia can significantly improve learning outcomes compared to purely text-based or verbal instruction.

This research distinguishes itself from much of the existing literature through its rigorous quasi-experimental design and its specific focus on conceptual understanding. Many prior studies on educational videos have been descriptive, have focused on student engagement and motivation, or have used general achievement tests as the primary outcome measure. By employing a pre-test/post-test control group design and a validated instrument specifically targeting conceptual knowledge, our study provides a higher degree of causal inference and a more nuanced insight into the cognitive impact of the intervention.

The calculation and comparison of normalized learning gainsrepresents a methodological refinement over studies that only compare post-test scores. This metric provides a more equitable and sophisticated measure of the instructional effectiveness by accounting for the students' prior knowledge. The large discrepancy in normalized gains (0.74 vs. 0.24) offers a particularly clear and compelling piece of evidence for the superiority of the video-based approach that is not always present in similar studies.

The specific context of this study elementary school mathematics also contributes a valuable perspective to the literature. While multimedia learning has been studied extensively in higher education and technical training, there is less rigorous experimental research focused on younger learners grappling with foundational abstract concepts. Our findings confirm that the cognitive benefits of multimedia learning are not limited to adult learners and are, in fact, a highly effective strategy for this critical age group.

The results of this study signify a powerful confirmation that the medium of instruction is not neutral; it profoundly shapes the nature and depth of student learning. The dramatic difference in outcomes between the two groups indicates that *how* a concept is presented is just as important as *what* is presented. It reflects the idea that aligning the mode of instruction with the cognitive needs of the learner and the abstract nature of the content is essential for effective pedagogy.

The success of the learning videos is a significant reflection of the power of visual representation in mathematics education. The findings signify that transforming abstract, symbolic mathematical ideas into concrete, dynamic visual models is a key strategy for making them accessible and comprehensible to young learners. This underscores the importance of moving beyond a purely symbolic or algorithmic approach to mathematics and embracing a more visual, intuitive, and conceptual one.

This research also signifies the maturation of educational technology from a supplemental novelty to an essential pedagogical tool. The results indicate that the strategic integration of high-quality digital resources is not merely a way to increase student engagement but is a direct and powerful method for enhancing cognitive outcomes. It reflects a shift in understanding technology's role from a peripheral activity to a core component of effective instructional design.

Ultimately, the substantial learning gains observed in the experimental group signify that students' potential for deep conceptual understanding in mathematics may be far greater than is often realized through traditional methods. The results reflect the idea that when students are provided with instructional tools that are designed to align with how they learn, they are capable of achieving a much higher level of mastery. This challenges deficit-based views of

student ability and points towards the power of high-quality instruction to unlock student potential.

The primary implication of this work is for the daily practice of elementary school teachers. The findings strongly imply that educators should strategically and purposefully integrate well-designed learning videos into their mathematics instruction, particularly when introducing abstract or difficult-to-visualize concepts. This provides a clear, evidence-based justification for moving beyond the textbook as the sole source of information and leveraging the power of multimedia to enhance comprehension.

For curriculum developers and educational publishers, the implications are significant. This research suggests that the development of high-quality, conceptually-focused video content should be a central part of creating modern mathematics curricula. It implies a need to shift resources towards creating a rich ecosystem of digital learning objects that are tightly integrated with lesson plans and assessments, rather than being treated as optional supplements.

The findings also have important implications for teacher education and professional development. Pre-service and in-service training programs should include a focus on digital media literacy for educators, teaching them not only how to use technology but how to critically evaluate the quality of digital resources and integrate them into their pedagogy in a way that is consistent with the science of learning. This implies that teacher training must evolve to keep pace with the available technological tools.

From a broader policy perspective, this research has implications for educational equity. High-quality learning videos can provide every student with access to a clear, expert explanation of a concept, regardless of their specific classroom context. This implies that investing in the creation and open-access distribution of a library of high-quality educational videos could be a cost-effective and scalable strategy for raising the baseline of instructional quality and helping to close achievement gaps across different schools and districts.

The superior performance of the experimental group is fundamentally caused by the cognitive advantages of multimedia learning, as described by theories like the Dual Coding Theory. The learning videos presented information through two distinct cognitive channels simultaneously: a visual channel (animations, diagrams) and an auditory channel (narration). This allows students to build two interconnected mental representations of the concept, a verbal model and a visual model, resulting in a deeper and more robust understanding than the single, primarily symbolic representation offered by a textbook.

A second causal mechanism is the reduction of extraneous cognitive load. Well-designed videos can guide a student's attention to the most critical aspects of a concept and can illustrate a multi-step process in a clear, sequential, and dynamic manner. This is cognitively more efficient than asking a student to mentally animate a series of static diagrams in a textbook while simultaneously reading complex explanatory text. By reducing this extraneous load, the videos free up the students' working memory to engage in the deeper cognitive work of understanding the concept.

The dynamic nature of the video medium is another key causal factor. Concepts that involve processes or transformations, such as the division of fractions or the rotation of geometric shapes, are inherently difficult to represent on a static page. The animations in the learning videos made these dynamic processes explicit and visible, providing a level of conceptual clarity that is nearly impossible to achieve with conventional, static media. This directly explains the superior performance of the experimental group on such topics.

The limited growth in the control group was causally linked to the inherent limitations of their traditional instructional materials. The textbook's reliance on abstract symbols and static images required students to perform a much heavier cognitive lift to build a mental model of the mathematical concepts. For many elementary students, this cognitive barrier is too high, leading to a focus on memorizing procedures without understanding, which is precisely what the pre-test/post-test results for the control group reflect.

Future research should be directed at disaggregating the effects of different video design elements. An experimental study that compares the effectiveness of different video styles for example, animated videos versus videos with a live instructor, or videos with interactive elements versus passive videos would be invaluable. This would help to identify the specific design principles that are most critical for maximizing student learning and would provide more granular guidance for instructional designers.

The next logical step is to investigate the optimal way to integrate learning videos into the broader classroom ecosystem. Research that compares different implementation models such as using videos for initial instruction (a "flipped classroom" approach), for in-class reinforcement, or for student-paced remediation is needed. This would help educators understand how to best leverage this tool within a comprehensive and differentiated instructional strategy.

A longitudinal study is recommended to assess the long-term impact of video-based instruction on student learning and attitudes. Tracking students over several years would allow researchers to determine if the conceptual understanding gained from learning videos is retained over time and whether it leads to improved performance in more advanced mathematics courses (Pasani & Amelia, 2025). Such a study could also investigate the long-term effects on student confidence and interest in mathematics.

Finally, future research should expand its focus to include a wider range of mathematical topics and diverse student populations. Replicating this study in different grade levels and with different mathematical domains (e.g., algebra, geometry, data analysis) would test the generalizability of the findings. Furthermore, conducting studies with students from different socioeconomic backgrounds and with varying learning needs is essential to ensure that this pedagogical approach is effective and equitable for all learners.

CONCLUSION

The most distinct finding of this research is the quantitative confirmation of a substantial and statistically significant improvement in students' conceptual understanding of mathematics through the use of learning videos. The study demonstrated that the experimental group achieved a "high" average normalized gain of 0.74, a stark contrast to the "low" gain of 0.24 in the control group. This large effect size moves beyond a simple confirmation of effectiveness to quantify the profound impact of video-based instruction on deep, conceptual learning, distinguishing it from methods that may only foster procedural skills.

This study's primary contribution is methodological, providing a robust quasi-experimental framework for assessing the impact of a specific educational technology on a nuanced cognitive outcome. The value lies in the combination of a pre-test/post-test control group design with a validated instrument specifically targeting conceptual understanding, rather than general achievement. This approach offers a more rigorous and replicable model for

future research in educational technology, providing a clear method for establishing evidence-based practices.

The research is limited by its use of a non-equivalent control group from a single school, which restricts the broad generalizability of the findings. The study also did not investigate the long-term retention of the conceptual knowledge gained. Future research must therefore be directed at replicating these findings using a randomized controlled trial design across multiple, diverse school settings. Additionally, longitudinal studies are essential to determine if the conceptual understanding fostered by learning videos is retained over time and positively impacts future mathematics learning.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

authors declare no conflict of interest

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