



Enhancing Students' Deep Conceptual Understanding in Physics through Video Demonstrations: A Systematic Literature Review

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ABSTRACT

This systematic literature review investigates the effectiveness of video demonstrations in enhancing students' deep conceptual understanding in physics education. Adopting the PRISMA 2020 guidelines, a comprehensive search was conducted on the Scopus database for articles published between 2015 and 2025. A final selection of 20 high-impact empirical studies involving high school and university students was analyzed using thematic synthesis. The results reveal that video interventions successfully foster deep understanding only when designed to trigger active cognitive processing. Key effective strategies include leveraging cognitive conflict to correct misconceptions, utilizing video analysis tools (e.g., Tracker) for mathematical modeling, and employing simulations for abstract quantum concepts. Conversely, passive video consumption proves insufficient for conceptual change. The study concludes that video demonstrations function as effective cognitive scaffolds when coupled with interactivity, such as embedded questions and inquiry-based tasks. These findings imply that physics educators should transition from using videos as static illustrations to utilizing them as tools for active scientific analysis.

Keywords: Deep conceptual understanding, Physics education, Systematic literature review, Video analysis, Video demonstration.

Meningkatkan Pemahaman Konseptual Mendalam Siswa dalam Fisika Melalui Demonstrasi Video: Tinjauan Literatur Sistematis

ABSTRAK

Tinjauan literatur sistematis ini menyelidiki efektivitas video demonstrasi dalam meningkatkan pemahaman konsep mendalam siswa dalam pendidikan fisika. Dengan mengadopsi pedoman PRISMA 2020, pencarian komprehensif dilakukan pada pangkalan data Scopus untuk artikel yang diterbitkan antara tahun 2015 hingga 2025. Seleksi akhir terhadap 20 studi empiris berdampak tinggi yang melibatkan siswa sekolah menengah dan mahasiswa dianalisis menggunakan sintesis tematik. Hasil penelitian menunjukkan bahwa intervensi video berhasil menumbuhkan pemahaman mendalam hanya jika dirancang untuk memicu pemrosesan kognitif aktif. Strategi efektif utama meliputi pemanfaatan konflik kognitif untuk memperbaiki miskonsepsi, penggunaan perangkat analisis video (seperti Tracker) untuk pemodelan matematis, dan penerapan simulasi untuk konsep kuantum yang abstrak. Sebaliknya, konsumsi video secara pasif terbukti tidak memadai untuk memfasilitasi perubahan konsep. Studi ini menyimpulkan bahwa video demonstrasi berfungsi sebagai scaffolding kognitif yang efektif ketika dipadukan dengan interaktivitas, seperti pertanyaan yang disematkan (embedded questions) dan tugas berbasis inkuiri. Temuan ini menyiratkan bahwa pendidik fisika perlu beralih dari penggunaan video sekadar sebagai ilustrasi statis menjadi memanfaatkannya sebagai alat untuk analisis ilmiah aktif.

Kata kunci: Analisis video, Pemahaman konsep mendalam, Pendidikan fisika, Tinjauan literatur sistematis, Video demonstrasi.

INTRODUCTION

Physics, as a discipline rich in abstract concepts such as force, magnetic fields, and quantum phenomena that cannot always be observed directly, is often considered difficult by students (Irvani, Rustaman, et al., 2024; Nautiyal et al., 2025; Syahdah & Irvani, 2023; Wulff, 2024). This poses a fundamental challenge in the learning process. The main problem that often arises is the tendency for students to get stuck in a rote learning pattern, which is memorizing formulas or mathematical procedures without really understanding the physical meaning behind them (Astra et al., 2025; Irvani, Rochintaniawati, et al., 2024; Ulfa et al., 2024). This condition ultimately hinders the achievement of conceptual understanding. To overcome this, a study approach is needed that deliberately distinguishes between algorithmic solving, which focuses on the application of mechanical steps, and conceptual understanding, which requires a deep understanding of basic principles and the relationships between concepts. Students should not only be able to solve problems, but also truly understand the world of physics they are learning.

Video technology offers an important solution in overcoming difficulties in understanding abstract physics concepts, as visualization serves as a bridge between theoretical ideas and observable real phenomena (Mulvia & Lestari, 2023; Munfaridah et al., 2021; Qolbi et al., 2024). The development of video media has undergone significant evolution, from passive documentary videos to interactive learning tools, slow motion analysis such as that offered by tools like Tracker, to virtual simulations that allow for safe and controlled exploration of phenomena (Chernetsky et al., 2021; Navarrete et al., 2025; Rana, 2024). Demonstration videos are particularly useful for bringing into the classroom phenomena that are impractical or dangerous

to show directly, such as collision processes on a macro scale, atomic particle motion, or radioactive activity, so that students can witness and analyze the dynamics of physics that previously could only be imagined or calculated mathematically.

The effectiveness of videos in physics learning is not merely a matter of technological innovation, but is based on a strong psychological foundation (Cai et al., 2021; Piloto et al., 2022). One of the main theories that explains this is Mayer's Cognitive Theory of Multimedia Learning, which states that humans learn better when information is conveyed through a combination of words and images, rather than words alone (Mayer, 2024). This principle is known as Dual Coding (Clark & Paivio, 1991). Additionally, the Cognitive Load Theory also provides an important explanation: well-designed demonstration videos can reduce students' cognitive load, allowing them to shift their focus from processing information to deeply understanding concepts, rather than merely imagining phenomena in their minds (Sweller, 2011). Thus, the use of videos is not merely an entertainment tool or supplement, but a scientifically proven pedagogical strategy to enhance students' conceptual understanding.

Considering the conceptual challenges in physics learning, the role of video technology as a visualization tool, and the theoretical basis supporting its effectiveness, this article aims to answer the following three research questions.

RQ1: How effective are demonstration videos in improving students' deep conceptual understanding of physics concepts?

RQ2: What characteristics of demonstration videos are most effective in facilitating conceptual change in students?

RQ3: What challenges hinder the effectiveness of demonstration videos in building such deep understanding?

METHOD

This study is a systematic literature review (SLR) that aims to analyze and synthesize empirical evidence regarding the effectiveness of demonstration videos on students' deep conceptual understanding in physics learning. To ensure transparency, validity, and replicability of the review process, this study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and protocol (Henukh et al., 2025; Rohman et al., 2025; Ye et al., 2023). This approach was chosen to minimize bias in literature selection and provide a comprehensive overview of current research trends.

A comprehensive literature search was conducted in December 2025 using the Scopus database. Scopus was selected based on its reputation as the largest citation database covering high-quality, globally indexed education journals. The search strategy used a combination of specific keywords with Boolean operators to find articles relevant to the variables of media (video), context (physics education), and learning outcomes (understanding). The search string used was: TITLE-ABS-KEY ((“multimedia” OR “digital media” OR “video”) AND (“demonstration” OR “experiment”) AND (“physics”) AND (“understanding” OR “student achievement” OR “learning outcome”)).

To ensure that the analyzed literature was relevant to the research objectives, eligibility criteria were established based on the PICOS framework (Population, Intervention, Comparison, Outcomes, Study Design). The inclusion and exclusion criteria used are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criterion	Inclusion Criteria	Exclusion Criteria
<i>Time Period</i>	<i>2015 – 2025 (Last 10 years)</i>	<i>Published before 2015</i>
<i>Language</i>	<i>English</i>	<i>Non-English languages</i>
<i>Document Type</i>	<i>Peer-reviewed Journal Articles (Empirical Studies)</i>	<i>Conference proceedings, book chapters, systematic reviews, editorials, dissertations, or white papers</i>
<i>Population</i>	<i>Students at any formal educational level (Primary, Secondary, or Undergraduate) engaged in Physics learning</i>	<i>Non-student populations or pure science research without educational subjects</i>
<i>Intervention</i>	<i>Use of video demonstrations, video analysis, video modeling, real-world experiments recorded on video, or interactive video simulations</i>	<i>Static media, Augmented/Virtual Reality (AR/VR) without a specific video component, or text-based instruction</i>
<i>Outcome</i>	<i>Cognitive outcomes related to Deep Understanding: Conceptual understanding, mental models, scientific reasoning, critical thinking, or remediation of misconceptions</i>	<i>Studies focusing solely on affective domains or technical skills without measuring conceptual grasp</i>
<i>Context/Topic</i>	<i>Physics Education (Mechanics, Optics, Thermodynamics, Electromagnetism, Modern Physics, etc.)</i>	<i>Pure Physics research, Engineering, or medical applications not related to Physics Education</i>
<i>Accessibility</i>	<i>Full-text available</i>	<i>Full-text not available or only abstract accessible</i>

The selection process was carried out in three main stages according to the PRISMA flow chart. In the identification stage, the initial search yielded 210 documents. The next stage was screening based on metadata (year of publication and type of document), which left 145 articles. The second stage of screening was carried out by manually reading the titles and abstracts to separate irrelevant articles. From this process, 74 articles were declared eligible for the eligibility stage. The final stage involved reading the full text to ensure the availability of data related to in-depth understanding. A total of 20 articles met all the criteria and were included in the final analysis. These deeply analyzed articles were viewed based on High Impact Articles.

RESULT AND DISCUSSION

Based on the rigorous screening process outlined in the methodology, a final set of 20 articles was identified as highly significant for the current review. These studies were selected due to their explicit focus on fostering and measuring deep conceptual understanding in physics education,

moving beyond general academic performance to capture cognitive processing and reasoning skills. The selected literature encompasses a diverse range of physics domains and employs various video-based interventions, including real-experiment video analysis (tracker), interactive simulations, and neuroscientific approaches. A summary of these selected studies, along with their primary contributions to the analysis of this review, is presented in Table 2.

Table 2. Summary of Selected Studies Included in the Analysis

<i>No.</i>	<i>Author, Year</i>	<i>Article Title</i>	<i>Main Focus & Contribution to Analysis</i>
1	(Mufit et al., 2022)	<i>Cognitive Conflict-Based E-Book with Real Experiment Video Analysis Integration to Enhance Conceptual Understanding of Motion Kinematics</i>	<i>Core Strategy: Integrates Video Analysis with Cognitive Conflict strategies. Provides strong evidence on how video can be used to correct misconceptions and foster deep understanding.</i>
2	(Jose et al., 2021)	<i>Instructional Videos, Conceptual Understanding and Self-Efficacy in the Time of COVID</i>	<i>Quantitative Data: Directly measures the impact of instructional videos on "Conceptual Understanding" specifically, rather than just general exam scores.</i>
3	(Poonyawatponkul et al., 2025)	<i>Effectiveness of Online Experiments for Conceptual Understanding of Simple Pendulum by Physics Student-Teachers</i>	<i>Latest Evidence (2025): Recent research specifically measuring conceptual understanding in Mechanics (Pendulum) using online video experiments.</i>
4	(Rachniyom et al., 2019)	<i>The projectile tube experiment for improving high-school physics conceptual understanding</i>	<i>Visualization Tool: Focuses on Projectile Motion. Demonstrates how video experiments help visualize trajectories that are difficult to observe with the naked eye.</i>
5	(Kestin & Miller, 2022)	<i>Harnessing active engagement in educational videos: Enhanced visuals and embedded questions</i>	<i>Video Design: Addresses "what makes a video effective." Findings on embedded questions are crucial for explaining how to trigger active thinking processes.</i>
6	(Ma et al., 2025)	<i>Spatial proximity effects on cognitive processing of multimedia learning among college students: evidence from functional near-infrared spectroscopy</i>	<i>Neuroscience Evidence: Uses fNIRS (brain scanning) to observe cognitive load during multimedia learning. Provides "hard" empirical data on cognitive processing.</i>
7	(Flegr et al., 2023)	<i>How to foster STEM learning during Covid-19 remote schooling: Combining virtual and video experiments</i>	<i>Media Comparison: Compares the effectiveness of Real Experiment Videos vs. Virtual Simulations. Essential for the discussion on media types.</i>

<i>No.</i>	<i>Author, Year</i>	<i>Article Title</i>	<i>Main Focus & Contribution to Analysis</i>
8	(Becker et al., 2020)	<i>Using mobile devices to enhance inquiry-based learning processes</i>	<i>Student Independence: Focuses on Inquiry-Based Learning assisted by video on mobile devices. Relevant for "Student-Centered Learning" arguments.</i>
9	(Sundstrom et al., 2020)	<i>Problematizing in inquiry-based labs: How students respond to unexpected results</i>	<i>Scientific Reasoning: Explores student reasoning when video experiment results deviate from theoretical predictions. Core to forming deep scientific reasoning.</i>
10	(Nyirahabimana et al., 2024)	<i>University student's dataset related to achievement, classroom practices, perceptions and attitudes of multimedia-based learning quantum physics</i>	<i>Quantum Physics: Rare research using multimedia for abstract Quantum Physics topics. Valuable for demonstrating applicability across physics domains.</i>
11	(Pratidhina, Dwandaru, et al., 2020)	<i>Exploring Fraunhofer diffraction through Tracker and spreadsheet: An alternative lab activity for distance learning</i>	<i>Optics & Tracker: Specific example of using Video Analysis (Tracker) for Waves/Optics concepts, broadening the scope beyond Mechanics.</i>
12	(Harjono et al., 2020)	<i>An interactive e-book for physics to improve students' conceptual mastery</i>	<i>Media Integration: Demonstrates that video is not standalone but integrated into interactive E-books to achieve conceptual mastery.</i>
13	(Swandi et al., 2020)	<i>Harnessing technology-enabled active learning simulations (TEALSim) on modern physics concept</i>	<i>Modern Physics: Focuses on active simulations for Modern Physics concepts that are invisible and abstract.</i>
14	(Marçal et al., 2020)	<i>Learning physics through online video annotations</i>	<i>Interactive Features: Discusses "Video Annotation" (students adding notes to video timelines). A unique strategy to ensure active rather than passive viewing.</i>
15	(Putri et al., 2023)	<i>Design and Prototype Testing of the Video Tracker Analysis-Based Uniformly Varied Rectilinear Motion Tool</i>	<i>Tool Development: Technical focus on developing Video Tracker-based tools for Kinematics, showing the technological readiness in the field.</i>
16	(Tóthová & Rusek, 2025)	<i>Eye Tracking in Science Education Research: Comprehensive Literature Review</i>	<i>Methodology: Review on Eye Tracking. Serves as a theoretical reference for measuring visual attention and cognitive focus in video learning.</i>
17	(Leshko et al., 2025)	<i>The Principle of Historicism and Ways of Its Implementation in a Physics Course</i>	<i>Historical Context: Alternative use of historical documentary videos to build conceptual understanding through the context of discovery.</i>

<i>No.</i>	<i>Author, Year</i>	<i>Article Title</i>	<i>Main Focus & Contribution to Analysis</i>
18	(Pratidhina, Rizky Yuliani, et al., 2020)	<i>Relating simple harmonic motion and uniform circular motion with tracker</i>	<i>Concept Linking: Uses video analysis to visually connect two distinct concepts (Simple Harmonic Motion and Uniform Circular Motion).</i>
19	(Herwinarso et al., 2020)	<i>Development of android app to assist high school students in learning physics quantities and measurement principles</i>	<i>Mobile Learning: Android application containing visual content for fundamental topics (Quantities & Measurement).</i>
20	(Bramley et al., 2018)	<i>Intuitive experimentation in the physical world</i>	<i>Cognitive Psychology: Fundamental research on how humans perform "intuitive experiments" mentally. Provides a strong theoretical foundation for the study.</i>

Cognitive Mechanisms: From Visualization to Deep Understanding

The review identifies that video demonstrations promote deep conceptual understanding not merely through visualization, but by triggering specific cognitive mechanisms. A critical finding is the role of Cognitive Conflict. As demonstrated by Mufit et al. (2022), integrating real experiment videos that contradict students' intuition can effectively destabilize misconceptions, creating a fertile ground for conceptual change. This aligns with the psychological foundations of learning where "seeing" a discrepancy is more powerful than being told about it.

Furthermore, recent neuroscientific evidence provided by Ma et al. (2025) using fNIRS technology offers biological validation to these pedagogical claims. Their study reveals that the cognitive load and brain processing patterns during multimedia learning are significantly influenced by how visual information is presented. This implies that for a video to foster "deep understanding," it must be designed to optimize working memory, preventing cognitive overload while stimulating active processing. Similarly, Bramley et al. (2018) suggest that humans possess an innate ability for "intuitive experimentation," and video demonstrations act as a scaffold that bridges this intuition with formal scientific reasoning.

The Role of Active Engagement and Interactivity

A recurring theme across the selected studies is that "watching is not enough." The transition from passive viewership to active engagement is the key determinant of deep learning. Kestin and Miller (2022) provide compelling evidence that videos with embedded questions significantly outperform standard videos in retaining conceptual knowledge. This interactivity forces students to pause and retrieve information, transforming the video from a transmission medium into a cognitive tool.

Technological features such as Video Annotations, as highlighted by Marçal et al. (2020), further empower this active role. By allowing students to tag and comment on specific timeline events, students engage in a process of deconstructing the physical phenomenon. This supports the findings of Becker et al. (2020), who utilized mobile devices to facilitate inquiry-based learning.

In this context, video becomes a raw material for inquiry rather than a finalized lecture, encouraging students to take ownership of their learning process and develop self-efficacy (Jose et al., 2021).

Video Analysis as a Bridge for Kinematics and Optics

Specific attention must be given to Video Analysis tools (e.g., Tracker), which dominate the literature in Mechanics and Optics. Studies by Putri et al. (2023) and Pratidhina et al. (2020) illustrate that video analysis allows students to extract mathematical data (graphs/tables) directly from physical phenomena. This process bridges the gap between the concrete world (a moving ball) and the abstract representation (a position-time graph), which is often the source of student difficulty.

What makes video analysis unique in fostering deep understanding is its ability to visualize the invisible. For instance, Pratidhina et al. (2020) extended this application to Optics (Fraunhofer diffraction) and Simple Harmonic Motion, proving that video analysis is not limited to projectile motion but is effective for any phenomenon requiring precise spatiotemporal measurement. By analyzing frame-by-frame data, students are compelled to use scientific reasoning to interpret outliers and errors, as noted by Sundstrom et al. (2020), thereby simulating the authentic work of a physicist.

Visualizing the Abstract: Quantum and Modern Physics

While mechanics relies on real-world video, abstract domains like Quantum Physics require a different approach. Nyirahabimana et al. (2024) and Swandi et al. (2020) highlight the indispensability of multimedia and simulations (TEALSIm) in this domain. Since quantum phenomena cannot be observed directly, video simulations serve as the only access point for students to build mental models of concepts like wave-particle duality or electron probability. In these cases, the video does not just "demonstrate" reality; it "simulates" a theoretical reality, allowing students to manipulate variables that are impossible to control in a physical lab.

CONCLUSION

This systematic review elucidates that video demonstrations serve as powerful cognitive scaffolds for enhancing deep conceptual understanding in physics, provided they are designed to trigger active cognitive processing rather than passive consumption. The analysis of the selected studies confirms that video interventions are most effective when they facilitate cognitive conflict to challenge misconceptions and utilize visualization to bridge the gap between concrete phenomena and abstract mathematical models. Merely exposing students to video content is insufficient; the transformative potential of video lies in its ability to visualize the invisible and support scientific reasoning through data extraction and inquiry-based frameworks.

The pedagogical implications of these findings necessitate a shift in how physics educators integrate multimedia. Teachers and lecturers should move beyond using videos as static illustrations and instead employ them as tools for active inquiry. Strategies such as embedding questions to disrupt passive viewing, utilizing video analysis tools for kinematic modeling, and integrating simulations for unobservable quantum phenomena are essential for fostering deep

understanding. The evidence suggests that the effectiveness of video demonstrations is maximized when students are positioned as active analysts who must interpret, question, and derive data from the visual media, rather than passive observers.

Future research should expand the boundaries of this field by integrating neuroscientific methods, such as eye-tracking and fNIRS, to provide objective data on students' cognitive load and attention allocation during video learning. While current studies predominantly focus on short-term conceptual gains, longitudinal research is urgently needed to investigate the long-term retention of concepts acquired through video interventions. Additionally, further exploration is warranted in the domain of modern and quantum physics, where visualization is not just helpful but indispensable for conceptualizing abstract realities.

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