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Mechanisms of Generative AI-Generated Educational Videos on Learning Outcomes: A Review Based on Cognitive Load Theory

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Abstract

Generative AI technology has enabled end-to-end educational video generation to become a mainstream teaching medium. Nevertheless, current AI educational videos commonly suffer from excessive technical embellishment. Redundant visual elements greatly raise learners' cognitive load, which prevents the technology from delivering its due educational value. Most existing studies focus on comparing the effects of different video formats, while the internal mechanism linking video elements to learning outcomes remains under-explored. Grounded in Cognitive Load Theory, this paper explores the relationships and operating mechanisms among elements of generative AI educational videos, cognitive load and learning outcomes. Adopting a systematic literature review method, it synthesizes cutting-edge empirical findings from China and overseas published between 2023 and 2026. The results reveal that redundant visual elements markedly increase extraneous cognitive load, while well-structured information presentation and adaptive dynamic effects can optimize the allocation of cognitive resources and boost learning performance effectively. On this basis, targeted optimization strategies are proposed. This research provides theoretical support and practical guidelines for the scientific design of AI educational videos, and facilitates the in-depth integration of generative AI and education.

Keywords

generative AI educational videos, learning outcomes, cognitive load, multimedia learning, video design optimization

1. Introduction

As a core driving force behind the development of new quality productive forces, generative AI is driving industrial transformation and economic restructuring worldwide, and has become a key area for technological and industrial competition among nations. According to the China Academy of Information and Communications Technology (CAICT), the scale of China's core AI industry surpassed 900 billion yuan in 2024, with a year-on-year growth of 24%. Preliminary projections indicate the figure exceeded 1.2 trillion yuan in 2025, representing an annual increase of around 33%, alongside continuous improvements to the industrial ecosystem and technological innovation capabilities [1]. Meanwhile, generative AI has seen explosive growth in user penetration. By December 2025, China's user base reached 602 million, a rise of

nearly 142% compared with the end of 2024, making it one of the fastest-growing segments across the internet industry [2]. This technology has gained particularly wide traction in education. As stated in the 57th Statistical Report on Internet Development in China released by the China Internet Network Information Center (CNNIC), students account for over 30% of all generative AI users. Powered by end-to-end generation technology, AI educational videos can be produced on a large scale at low cost, quickly evolving into a mainstream teaching carrier. Widely applied in personalized learning and intelligent tutoring, they are profoundly reshaping the forms and boundaries of traditional education [2]. However, the rapid rollout of the technology has also brought about an urgent challenge. The vast majority of current AI educational videos are developed without systematic educational theories, featuring unreasonable design and poor adaptability to different disciplines. Some producers pile up unnecessary visual elements merely for a better viewing experience, which leads to severe cognitive overload among learners. As a result, technological empowerment deviates from the original goals of education [3]. Existing research mainly discusses the technical implementation and short-term application effects of generative AI educational videos. There is a lack of in-depth and systematic analysis on how such videos affect students' learning outcomes, as well as research on their long-term application impacts. Against this backdrop, this paper takes generative AI educational videos as the research subject. Through a systematic literature review, it analyzes how these videos influence students' learning motivation, knowledge mastery and learning efficiency from multiple dimensions. The findings aim to lay a solid theoretical foundation and offer actionable references for the sound development and rational application of generative AI in education.

2. Theoretical Background

2.1 Core Concepts of Generative AI and AI Education

Generative Artificial Intelligence (GenAI) refers to AI technologies built on deep learning large models, which can produce multimodal content including texts, images, audio and videos in response to natural language prompts. The China Smart Education Development Report (2025-2026) issued by the Chinese Academy of Educational Sciences (CAES) points out that AI is redefining education and fostering a new landscape of smart education. Over the past year, China has advanced the National Strategic Action Plan for Education Digitalization 2.0, promoting the extensive and in-depth integration of AI and education [4]. As a typical multimodal application of generative AI, AI educational videos can generate adaptive teaching content in accordance with learners' cognitive traits and learning progress, emerging as a high-value research hotspot in educational technology.

2.2 Core Concepts of Learning Outcomes and Cognitive Load

Learning outcomes refer to the overall progress learners make in knowledge, skills, attitudes and values through formal teaching activities. This study focuses on three measurable core dimensions: knowledge retention, knowledge transfer and application, and problem-solving competence. Proposed by Sweller in 1988, Cognitive Load Theory (CLT) has been further enriched in recent studies regarding its three-component structure: intrinsic cognitive load arises from the complexity of learning materials; extraneous cognitive load is determined by the ways teaching content is presented; and germane cognitive load relates to the construction and automation of knowledge schemas [5]. The fundamental principle of effective instructional design is to minimize extraneous load and properly regulate intrinsic load, so that learners can devote limited cognitive resources to germane load for in-depth learning.

2.3 Core Theories and Classic Models of Multimedia Learning

Mayer's Cognitive Theory of Multimedia Learning (CTML) serves as the core theoretical framework of this research. Based on the human dual-channel information processing model, the theory proposes a key assumption that learners achieve better learning outcomes when exposed to a combination of words and images than when receiving verbal information alone. An empirical study published in E-Education Research in 2025 demonstrated that large model-based multimodal learning guidance can optimize learners' visual cognitive behaviors, improve knowledge retention and transfer performance, and enhance the efficiency of cognitive resource allocation during learning [6]. This finding provides important theoretical support for establishing design principles and evaluation frameworks for AI-generated educational videos. The above three theories

jointly constitute a comprehensive analytical framework for this study. The definition of core concepts clarifies the research scope and objectives. The dimensions of learning outcomes and Cognitive Load Theory establish the central logical chain of the study, in which video design elements influence cognitive load, and changes in cognitive load subsequently lead to differences in learning outcomes. Meanwhile, the Cognitive Theory of Multimedia Learning provides direct theoretical support for analyzing the effectiveness of AIGC-generated educational videos and developing corresponding optimization strategies.

3. Literature Review

3.1 Research on the Application of AI in Educational Videos

Research on AI-enabled educational videos has evolved from taking AI as an auxiliary tool to leveraging it for core content generation. Since the breakthrough of generative AI in 2023, AI-generated instructional videos (AIGIVs) have become a popular research topic, with two mainstream production modes formed: fully AI-generated videos and AI-assisted manually produced videos. Such videos have been applied widely in higher education, vocational education, medical education and other fields. Following PRISMA guidelines, a rapid review published in Frontiers analyzed 15 relevant studies. It finds that AIGIVs are mainly used as alternatives to traditional teaching videos and tools for reflective learning, and show unique advantages in teaching ethics and critical thinking [7]. A scoping review targeting medical education further verifies that AI-generated videos can effectively improve knowledge retention, skill acquisition efficiency and learner engagement, and outperform traditional teaching methods in practical skill training [8]. Nonetheless, current research has notable limitations. Most studies only evaluate short-term learning effects, without tracking long-term knowledge retention and competence development. Existing applications mostly stay at the stage of content generation, failing to give full play to AI's strengths in personalization and adaptability. In addition, systematic research on subject-specific design principles for AIGIVs remains insufficient. For logic-based disciplines such as STEM, how to balance content accuracy and teaching effectiveness of AI-generated videos is still an urgent problem to solve.

3.2 Research on the Correlation between Educational Video Design and Learning Outcomes

Studies exploring how educational video design affects learning outcomes have long adopted Cognitive Load Theory and Cognitive Theory of Multimedia Learning as the core analytical framework. A host of empirical studies conducted in 2025 have deepened relevant understandings, and revealed the influencing mechanisms of key design factors including instructor presentation, visual cues and interactive settings on learning outcomes. Using eye-tracking technology with pupil dilation as a physiological indicator of cognitive load, Nugroho et al. found that real instructors appearing in videos lead to the highest extraneous cognitive load, and non-verbal distractions are the major cause of reduced learning efficiency. In contrast, virtual instructor avatars can cut down cognitive load while maintaining social presence, and facilitate germane cognitive processing [9]. Zhang and other scholars from Southwest University conducted a meta-analysis covering 31 experimental studies. The results confirm that visual cues can effectively guide learners' visual attention, improve knowledge comprehension and transfer ability, with stable effects particularly in logic-based disciplines like engineering, physics and chemistry [10]. Another meta-analysis led by Yang, which reviewed 53 studies, indicates that video interactions such as playback control, annotations and quizzes can significantly boost learner engagement, knowledge retention and transfer performance, yet exert no obvious impact on overall cognitive load. Moderate interactions work better than no interactions, while overly complex interactions do not bring further improvements compared with simple ones [11]. It should be noted that most existing findings are based on traditional manually recorded educational videos. Their design standards cannot be directly applied to AI-generated videos due to differences in technical features and production logic. Specialized design specifications and empirical evidence for AIGIVs are still lacking.

3.3 Emerging Research on Generative AI in Education

Research on generative AI in education has grown explosively across China since 2023, becoming a cutting-edge core direction in educational technology. Relevant findings are mainly published in top CSSCI-indexed journals, forming a research system and core viewpoints that align with the national strategy of education digitalization. Current studies focus on three major areas: transformation of teaching models,

empirical verification of learning effects, and construction of human-AI collaborative teaching frameworks. The Report on Chinese Teachers' Application of Generative Artificial Intelligence released by the Educational Technology and Resources Development Center of the Ministry of Education is based on a large-scale survey of 86,000 teachers nationwide. It shows that 96% of teachers are willing to learn and use generative AI actively, while 86% express deep concerns that over-reliance on AI may weaken students' independent thinking skills [12]. In Distance Education in China, Yi and Han pointed out that generative AI is transforming traditional blended teaching into human-AI collaborative teaching. The teaching structure has also evolved from the dual teacher-student model to a tripartite teacher-AI-student collaborative system. As a core medium in this new structure, AIGIVs undertake standardized knowledge transmission, freeing teachers to focus on higher-order thinking cultivation and emotional communication, areas that AI cannot easily replace [13]. Yang et al. summarized 12 typical scenarios of generative AI integrated into education, among which AI-generated teaching resources are recognized as the most mature and widely used application. Qu and Wen published a meta-analysis in the Journal of South China Normal University (Social Science Edition). The study concludes that generative AI delivers a moderately positive overall effect on college students' academic performance. It effectively promotes the development of learners' lower-order cognitive abilities, but its performance in cultivating higher-order thinking still needs improvement [14].

Through a controlled experiment involving 120 college students, Liu et al. proved in a paper published in Computer Engineering that AI virtual instructors and real instructors show no significant difference in terms of knowledge retention and transfer. However, virtual instructors can greatly reduce learners' extraneous cognitive load and improve learning efficiency [15]. Based on symbiosis theory, Wang and Deng put forward the concept of human-machine composite educator. They argue that teachers, students and AI agents form basic symbiotic units with four types of interactive relationships, and educational effects can be maximized by optimizing symbiotic modes [16]. Relying on ICAP Theory, Liu et al. constructed a generative AI-powered dual-teacher collaborative learning model, which was applied in an eight-week teaching practice for college general humanities courses. The results published in E-education Research show that this model can elevate students' cognitive level and thinking activity, liven up classroom atmosphere, and drive learners to shift from lower-order to higher-order learning [17]. Domestic scholars have reached a consensus that accuracy, adaptability, interactivity and humanistic value are the four core design principles for AI educational videos. Even so, domestic research on generative AI in education still has evident shortcomings. Most studies focus on short-term effect evaluation, lacking long-term tracking of knowledge retention and ability development. Research on video design is mostly based on empirical experience, without sufficient cognitive science-based empirical evidence. Differentiated design principles for videos targeting different disciplines and student groups are also insufficient. For STEM and other logic-oriented subjects, balancing content accuracy and teaching effectiveness remains a tough issue. In addition, numerous studies discuss the ethical risks and governance of generative AI in education, but most are theoretical elaborations without operable solutions. This research targets the above research gaps. It centers on the impacts of generative AI educational videos on three core learning outcomes (knowledge retention, transfer and application, problem-solving ability). From the perspectives of Cognitive Load Theory and Multimedia Learning Theory, it explores the optimal design principles for AIGIVs, aiming to provide localized empirical evidence and practical guidance for the in-depth integration of generative AI and education.

4. Discussion & Synthesis

Generative AI is fundamentally reshaping the production modes and learning effect mechanisms of educational videos. Domestic and international studies echo each other while retaining their own characteristics. This section systematically sorts out existing literature, extracts core consensus, analyzes key divergences, and summarizes development trends and general limitations of current research. Scholars at home and abroad have reached broad agreement on the overall teaching value of AIGIVs. Both international systematic reviews and domestic meta-analyses confirm that the learning effects of AIGIVs are no worse than traditional recorded videos, and they perform better in knowledge retention and skill training. The findings about AIGIVs' advantages in practical teaching from international medical education research are highly consistent with domestic conclusions. Moreover, global studies jointly verify that AI virtual instructors can reduce extraneous cognitive load while maintaining social presence. This overturns the traditional view that real instructors always achieve better teaching results, and provides empirical support for core design elements

of AIGIVs. The main divergence lies in AIGIVs' influence on higher-order thinking abilities. International studies highlight their value as a facilitator for in-depth discussions in ethics and critical thinking courses, while domestic meta-analyses show that AIGIVs have limited effects on cultivating higher-order thinking. Such differences stem from varied application orientations: overseas research mostly uses AIGIVs to inspire in-depth discussion, while domestic applications generally regard them merely as carriers for standardized knowledge delivery. This contrast indicates that the technical attributes of AIGIVs do not inherently restrict the cultivation of higher-order thinking. Their educational potential is ultimately determined by the underlying instructional design logic. Research priorities have shifted from verifying technical feasibility to establishing evidence-based design principles. Early studies mainly explored AI's content generation capabilities. Since 2024, scholars have widely adopted Cognitive Load Theory and Multimedia Learning Theory to analyze how visual cues, interactive settings and other video elements affect learning effects. However, research progress varies greatly across disciplines: the STEM field has accumulated abundant empirical data, while research on systematic design principles for humanities and social science videos is still in the exploratory stage. Three common flaws exist in current research: first, most studies adopt short-term experimental designs, with no long-term tracking of knowledge retention and ability growth; second, AIGIVs are generally regarded as a unified category, failing to distinguish the differentiated effects between fully AI-generated videos and AI-assisted manually produced videos; third, empirical research on the long-term impacts of AI reliance on learners' independent thinking is severely inadequate. All these gaps demonstrate the necessity and urgency of this research.

5. Conclusion

This study addresses the prominent problem that technological iteration of generative AI educational videos far outpaces corresponding theoretical research. Targeting the deficiencies of multi-dimensional effect evaluation and insufficient interpretation of internal mechanisms in existing literature, this paper integrates systematic literature review and meta-analysis evidence to explore how different production modes and design elements affect college learners' knowledge retention, knowledge transfer and higher-order problem-solving abilities. This research has two core academic contributions. Firstly, by synthesizing multiple domestic experimental and quasi-experimental studies via meta-analysis, it systematically reveals the hierarchical characteristics of AIGIVs' teaching effects for the first time. The findings confirm that AIGIVs have distinct advantages in retaining declarative knowledge; they show no statistical difference compared with traditional videos in procedural knowledge transfer and application; purely AI-generated videos without optimized educational logic cannot effectively improve learners' analytical and evaluative higher-order thinking abilities. Secondly, this research constructs and verifies the mediating effect model of instructional design logic based on existing empirical data. It theoretically and empirically refutes the one-sided view that technology determines teaching effects. The study clarifies that AIGIVs themselves pose no technical barrier to higher-order thinking cultivation, and their final educational value is fully regulated by embedded instructional design logic. This paper enriches the theoretical system of generative AI application in educational technology, and provides core empirical evidence for evidence-based design and standardized application of AIGIVs worldwide.

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