Research on the Application of Multimedia in the Teaching of 'Electrical Machinery'

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ABSTRACT

This study aims to explore the specific application modes, practical effects, and existing challenges of multimedia technology in the teaching of Electrical Machinery, a core course in engineering disciplines. Guided by the Dual Coding Theory and Cognitive Load Theory, an analytical framework was constructed, and a sequential explanatory mixed-methods research design was adopted. A controlled experiment was conducted with two classes (n=92) of electrical engineering majors from a university, and both quantitative and qualitative data were collected through questionnaires, in-depth interviews, and classroom observations. The key findings are as follows: (1) The systematic application of multimedia resources such as 3D animations and simulation software significantly improved students' performance in understanding complex electromagnetic concepts and cognizing spatial structures ($p < .01$); (2) Multimedia effectively stimulated students' learning interest by creating contextualized scenarios, but improper design could increase extraneous cognitive load; (3) The in-depth integration of multimedia with traditional blackboard writing and physical models is the key to achieving effective teaching outcomes. Based on these findings, a "complementary integration" teaching framework was established, which provides theoretical references and practical pathways for optimizing the instructional design of engineering professional courses.

Keywords: Multimedia-assisted teaching; Electrical Machinery; Mixed-methods research; Cognitive load; Teaching optimization

INTRODUCTION

Electrical Machinery serves as an indispensable cornerstone in the curriculum system of Electrical Engineering and Automation. With electromagnetic field theory at its core, its knowledge system integrates physics, materials science, and dynamics, exhibiting high levels of abstraction, systematicness, and practicality (Li, Y., Wu, Y., & Liu, X., 2016). Specifically, this course covers complex internal structures of electrical machines, electromagnetic processes with temporal and spatial variations, and nonlinear energy conversion relationships—content that often proves difficult for students lacking engineering practical experience to grasp intuitively, thereby posing significant challenges to traditional teaching models (Yang, G., Xiao, Y., & Wang, Y., 2018). The teaching quality of Electrical Machinery directly impacts students' understanding and mastery of subsequent professional courses (e.g., Power System Analysis, Electrical Control Technology), making it a crucial link in cultivating qualified electrical engineers.

The in-depth development of educational informatization has provided an opportunity to address this teaching dilemma. Multimedia technology, by integrating multiple media forms such as text, graphics, animations, simulations, and videos, can visualize abstract principles, materialize dynamic processes, and three-dimensionally represent complex structures—aligning with the comprehensive requirements of engineering courses for intuitive cognition and logical thinking (Tayirova, 2023). For instance, 3D electrical machine models constructed using SolidWorks allow students to observe internal structures from any angle; animations developed via Flash or VB can clearly demonstrate the formation of rotating magnetic fields and the commutation process of DC motors; and virtual simulation experiments can overcome limitations of venues and equipment, providing students with a safe exploratory experimental environment. These applications have significantly enhanced the intuitiveness and interest of teaching (More Valencia, Nizama Reyes, Lizana Puelles, & Sandoval Valdiviezo, 2023).

Nevertheless, there are notable divergences and misunderstandings in the current application of multimedia technology in teaching practice. On one hand, some applications merely remain at the level of simple "digitalization" of textbook content, failing to touch upon the educational essence of multimedia technology in supporting in-depth cognitive construction. On the other hand, some fall into the blindness of "technology supremacy," excessively pursuing the richness of media forms without deep integration with teaching objectives. This may lead to information overload, which instead distracts students' attention and increases their extraneous cognitive load (Sankaranarayanan, Yang, & Kwon, 2024). Therefore, research on the application of multimedia technology in the teaching of Electrical Machinery must not stop at generalized assertions of "effectiveness"; instead, it is essential to conduct an in-depth analysis of the internal mechanism regarding "why it is effective" and "how to optimize it."

Against this backdrop, this study aims to move beyond superficial verification of instructional effectiveness and focuses on addressing three core research questions: for typical learning difficulties in Electrical Machinery—such as motor structure, rotating magnetic fields, and characteristic curves—how can a systematic and refined multimedia teaching design and application scheme be constructed based on principles from the learning sciences? What specific effects does this scheme have on students' depth of knowledge construction, disciplinary interest and engagement, and cognitive load, and what cognitive mechanisms underlie these effects? And how can an optimized multimedia teaching framework be developed to maximize positive instructional outcomes while effectively avoiding potential risks, particularly by clarifying the complementary integration between multimedia approaches and traditional teaching tools such as blackboard writing and physical models?

Through a rigorous mixed-methods empirical study, this research will systematically explore the aforementioned questions. It aims to provide solutions with both theoretical depth and practical validity for the teaching innovation of Electrical Machinery and related engineering courses, thereby promoting the paradigm shift from "the application of technical tools" to "intelligent teaching design.

THEORETICAL FRAMEWORK

Multimedia-assisted teaching

In an academic context, this concept has two interpretations: broad and narrow. In the broad sense, multimedia-assisted teaching refers to "the combined application of multiple single-function teaching media"—for instance, the integrated use of blackboards, wall charts, slides, projectors, and other media in the teaching process (Ying, 2009). However, with the rapid development of information technology, the narrow interpretation is now widely accepted in both academic and practical fields: it specifically refers to the use of multimedia computers to comprehensively process and control various media information (including symbols, language, text, sound, graphics, images, and videos), organically integrate this information according to teaching requirements, present it via screens or projection equipment, and supplement it with audio and human-computer interaction to complete the teaching or training process (Peng, 2020). It is often regarded as synonymous with computer-assisted instruction.

Building on this, this study provides the following operational definition of multimedia-assisted teaching: it is a type of instructional system design that aims to promote learners' in-depth cognitive construction. Based on the principles of learning sciences (especially cognitive theories of multimedia learning), it systematically designs, develops, and applies digital media (such as animations, simulations, and interactive models), and organically integrates these media with traditional teaching methods (including teachers' lectures, blackboard-based deductions, and physical demonstrations) in a sequential manner. Its essence is not the simple accumulation of multiple media, but rather the emphasis on the alignment between media and teaching objectives, as well as the synergy of various teaching elements in the cognitive process; its ultimate goal is to optimize the teaching process (Scheiter et al., 2017).

It is particularly important to note that the key to successful multimedia-assisted teaching lies in "organic integration." It should play a "supporting" role, aiming to compensate for the limitations of traditional teaching in presenting abstract and dynamic knowledge—rather than replacing the leading role of teachers or the subjective status of students.

Review of Related Studies and Identification of Research Gaps

A review of existing domestic and international literature reveals that the educational value of multimedia technology in science and engineering education has been widely acknowledged. However, the focus and depth of relevant studies have continued to evolve alongside technological advancements and developments in learning sciences. In the past five years, research has shifted significantly from merely validating the effectiveness of multimedia tools to exploring underlying cognitive mechanisms and constructing integrated learning ecologies (Mayer, 2020).

1. Deepening and Expansion of Recent Research Themes

Recent studies have moved beyond the simplistic comparison between multimedia instruction and traditional teaching methods, delving into more nuanced dimensions.First, in terms of research themes, scholars have begun to systematically investigate the influence of *emotional design* on learning outcomes. Studies have shown that incorporating emotionally positive design elements—such as warm colors and anthropomorphic characters—into multimedia learning materials can elicit learners' positive emotions, thereby enhancing their intrinsic motivation and sustained engagement. However, such effects are moderated by the complexity of learning materials and learners' prior knowledge (Plass & Kaplan, 2016; Schneider et al., 2022).

Second, *individual differences* have become another prominent research focus. Empirical findings consistently indicate that learners' characteristics—such as prior knowledge, working memory capacity, and cognitive style—significantly influence their receptivity to various forms of multimedia presentation and their corresponding learning outcomes (Kalyuga, 2021; Mayer, 2021). This challenges the "one-size-fits-all" design paradigm and underscores the necessity for *personalized adaptive instruction* (Sweller et al., 2019).

Furthermore, with the maturity of immersive technologies such as *Virtual Reality (VR)* and *Augmented Reality (AR)*, research has evolved from mere feasibility studies to exploring their unique advantages in creating high-fidelity learning contexts and fostering *embodied cognition*, as well as the potential cognitive load challenges they may introduce (Pellas et al., 2021; Radianti et al., 2020). For instance, the development and application of *virtual laboratories* have been shown to effectively address the scarcity of physical laboratory resources, providing safe, accessible, and efficient learning experiences in science education (Potkonjak et al., 2016).

2. Refinement and Diversification of Research Methods

In terms of methodology, recent empirical research exhibits an increasing level of *refinement and methodological pluralism*.On one hand, physiological measurement techniques—such as *eye-tracking*, *electroencephalography (EEG)*, and *galvanic skin response (GSR)*—are increasingly employed to objectively assess cognitive load and cognitive processes. These methods complement subjective measures, such as the NASA-TLX scale and self-reported cognitive load questionnaires (Antonietti et al., 2022; Brünken et al., 2020), thereby providing richer and more direct evidence for understanding the cognitive mechanisms underlying multimedia learning.

On the other hand, research designs have become more rigorous, with *mixed-method approaches* that combine true experiments, quasi-experiments, and qualitative investigations gaining prominence. Such designs enhance both internal validity and ecological validity, allowing for more meaningful interpretations within authentic educational contexts (Creswell & Plano Clark, 2017). For example, some studies have integrated eye-tracking data with retrospective interviews to uncover learners' cognitive strategies and difficulties when processing complex scientific animations (Liu et al., 2022).

3. Progress and Limitations of Domestic Research

In China, scholars have actively drawn upon leading international theories—such as *Cognitive Load Theory* and the *Cognitive Theory of Multimedia Learning*—while emphasizing localized practices and applied research (Jia et al., 2024; Wang et al., 2023). Many domestic studies focus on specific disciplinary challenges (e.g., physics, chemistry), developing multimedia resources tailored to these difficulties and evaluating their pedagogical effectiveness.

Nevertheless, several limitations remain in domestic research when viewed within the context of global academic discourse.First, *theoretical grounding* is sometimes insufficient, as some studies fail to situate their investigations firmly within well-established theoretical frameworks, thereby limiting the explanatory depth of observed phenomena.Second, research *timeframes* are often short, focusing primarily on immediate learning outcomes without tracking long-term retention or knowledge transfer.Third, the *exploration of cutting-edge technologies* remains limited—empirical studies on AI-driven adaptive learning systems and the application of *generative AI* in education are still in their nascent stages (Zhang et al., 2024).

4. Research Gaps Addressed by the Present Study

Based on a systematic review of recent literature, the present study aims to address the following research gaps that remain insufficiently explored:

a. From "Media Combination" to "Cognitive Sequencing":While many studies emphasize the importance of integrating multiple media types, few have systematically examined how to design the *optimal sequence and functional distribution* of media presentations according to different *knowledge types* (declarative, procedural, conceptual) and *cognitive goals*. This indicates a lack of empirically validated principles for constructing *cognitively optimal instructional sequences* (Mayer, 2020; Renkl & Scheiter, 2017). The proposed *"Complementary Integration Framework"* in this study seeks to fill this theoretical gap.
b. Fine-Grained Measurement of Cognitive Load:Although the significance of cognitive load is well recognized, many studies remain limited to assessing *overall cognitive load*. Insufficient attention has been paid to how multimedia instruction differentially affects the *intrinsic*, *extraneous*, and *germane* components of cognitive load and their dynamic interrelations (Leppink et al., 2020). This study employs a *multi-method measurement strategy* that integrates subjective ratings with performance-based indicators to reveal these mechanisms more precisely.
c. Long-Term Learning Outcomes and Affective Engagement:Existing studies predominantly focus on immediate learning achievements, paying limited attention to the long-term retention, knowledge transfer, and the development of *deep learning motivation* and *disciplinary emotions* (Bates et al., 2021; Plass & Kaplan, 2016). The present research addresses this gap by incorporating *delayed post-tests* and *in-depth interviews* to explore the sustained cognitive and affective impacts of multimedia learning.
d. Validation in Authentic and Complex Course Contexts:Many tightly controlled laboratory studies yield results that may lack applicability in authentic, dynamic classroom environments (Hattie & Zierer, 2019). This study conducts *empirical interventions within a full-scale engineering course*, aiming to provide evidence with high *external validity* for real-world educational settings.

In summary, this study does not seek to merely replicate previous validations of multimedia "effectiveness." Instead, grounded in prior research, it adopts a rigorous *mixed-method design* to explore *why* and *how* multimedia technologies function effectively in higher engineering education. By doing so, it aspires to construct a theoretically informed and practically meaningful framework that can guide the *deep integration of information technology and pedagogical practice* in contemporary education.

Theoretical Foundations

1. Mayer's Cognitive Theory of Multimedia Learning (CTML)

This is the core theory guiding multimedia instructional design. Mayer (2024) points out that effective multimedia learning occurs when learners can coordinate two types of representations: verbal (text or audio) and visual (images or animations). The theory is based on three core assumptions: **Dual channels:** Humans possess separate processing channels for visual and auditory information; **Limited capacity:** Each channel can only process a limited amount of information at one time; **Active processing:** Learners actively construct knowledge models.

Based on these assumptions, Mayer proposed a series of multimedia instructional design principles, which directly guided the design of multimedia materials in this study:

a. **Coherence principle:** Remove interesting but irrelevant text, sounds, or images that do not align with core objectives to avoid distracting learners. In this study, all animations and simulations were strictly designed around the core principles of "three-phase asynchronous motors" to eliminate interference from irrelevant elements.
b. **Spatial and temporal contiguity principles:** Corresponding text explanations should be placed adjacent to their related graphics (spatial contiguity); narrations should be played simultaneously with corresponding animations (rather than sequentially) (temporal contiguity). Both principles aim to reduce the cognitive load on learners when integrating information. The courseware design in this study strictly adhered to these principles.
c. **Redundancy principle:** On-screen text should not fully duplicate the content of the teacher's narration, to prevent information redundancy and cognitive overload within the visual channel.

2. Cognitive Load Theory (CLT)

This theory provides a key framework for evaluating the effectiveness of multimedia-assisted teaching. Sweller (as cited in Kirschner, 2002) categorized cognitive load into three types: intrinsic, extraneous, and germane. The advantage of multimedia-assisted teaching lies in its ability to effectively reduce intrinsic cognitive load (caused by the high interactivity of complex knowledge) by visualizing and dynamizing complex knowledge. However, improperly designed multimedia (e.g., cluttered interfaces or information overload) can generate significant extraneous cognitive load. An ideal design should, under the premise of controlling total cognitive load, maximize germane cognitive load— which contributes to schema construction and knowledge automation. In this study, a cognitive load scale included in the post-test was used to accurately assess the actual impact of the designed multimedia materials on the three types of cognitive load.

3. Dual Coding Theory (DCT) and Constructivism Learning Theory (CLT)

Dual Coding Theory (Clark & Paivio, 1991) explains why multimedia-assisted teaching can enhance memory and understanding: when the structure of an electrical machine (imagery) is presented simultaneously with its professional terminology and principle descriptions (verbal information), students are more likely to form stable memory connections.

From a macro perspective, Constructivism Learning Theory (Rosana & Handayaningrum, 2024) clarifies the role of multimedia-assisted teaching: it should not be a tool for one-way knowledge transmission, but rather a "cognitive tool" that enables students to actively explore and construct meaning. For example, the virtual simulation software used in this study allowed students to independently adjust parameters and observe changes in motor characteristics—creating a constructive environment where students could actively conduct "experiments" and make "discoveries."

METHOD

Research Design

A sequential explanatory mixed-methods design was employed in this study. In the first phase, quantitative research was conducted: data were collected via questionnaires and tests to understand the current status of multimedia application and its macro-level relationship with academic performance. In the second phase, qualitative research was carried out: in-depth interviews and classroom observations were used to further explain and supplement the quantitative results, and explore the underlying causes of the observed phenomena.

Research Participants and Data Sources

Participants

Two natural classes were randomly selected from second-year undergraduate students majoring in Electrical Engineering who took the Electrical Machinery course at a university, serving as the control class (n=45) and the experimental class (n=47), respectively. The two instructors had comparable teaching experience and competence. Additionally, 5 teachers from the course team were invited to participate in interviews.

Data Sources

The data for this study were collected from multiple sources to ensure comprehensive analysis and triangulation. These sources included students' pre-test and post-test transcripts to measure academic performance, questionnaires assessing students' learning interest and cognitive load, transcripts of audio-recorded interviews with both students and teachers, and systematic classroom observation records documenting teaching and learning processes.

Research Tools and Materials

Teaching Materials

For the core chapter on *three-phase asynchronous motors*, a set of multimedia teaching materials was developed and implemented in the experimental class, including a 3D interactive model of motor structure, animations illustrating the formation of rotating magnetic fields, simulation software for generating mechanical characteristic curves, and a database of virtual fault diagnosis cases. In contrast, the control class received instruction using conventional PPT-based courseware.

Measurement Tools

The research instruments included self-developed academic performance pre-test and post-test papers, whose content validity was verified by experts from the course team. Students' learning interest was measured using a five-point Likert-scale questionnaire, while cognitive load was assessed through a simplified version of the NASA-TLX scale to evaluate students' mental load under different teaching methods. In addition, semi-structured interview outlines were separately designed for students and teachers to obtain in-depth insights into their perceptions, experiences, and suggestions regarding multimedia-assisted teaching.

Research Procedures

a. Preliminary Preparation (Weeks 1–2): The multimedia teaching material package was developed; a pilot experiment was conducted; and the measurement tools were revised.
b. Pre-test (Week 3): A basic knowledge test and a pre-test of learning interest were administered to students in both classes to ensure the homogeneity of the two groups.
c. Teaching Intervention (Weeks 4–9): The control class was taught using the traditional teaching model. For the experimental class, the developed multimedia materials were systematically integrated into the teaching process based on traditional lectures. Researchers conducted and recorded classroom observations.
d. Post-test and Data Collection (Week 10): A post-test of academic performance was conducted, and questionnaires on learning interest and cognitive load were distributed. Eight students with different academic performance levels were purposefully selected from the experimental class for semi-structured interviews; interviews with the 5 teachers were also conducted.
e. Data Analysis (Weeks 11–12): Quantitative data were statistically analyzed using SPSS (including independent samples t-test, analysis of covariance, etc.); qualitative interview data were coded and subjected to thematic analysis.

Data Analysis Methods

For quantitative data analysis, descriptive statistics and inferential statistics (t-test, ANOVA) were mainly used to compare differences between the two groups of students. For qualitative data, thematic analysis was adopted: core themes were extracted through open coding, axial coding, and selective coding. These themes were used to explain and supplement the quantitative results, collectively supporting the research conclusions.

FINDINGS AND DISCUSSION

Promoting Effect of Multimedia Application on the Deepening of Knowledge Construction

As shown in Table 1, the results of analysis of covariance (ANCOVA) indicated that after controlling for the influence of pre-test scores, the post-test academic performance of students in the experimental class (M=82.5, SD=6.8) was significantly higher than that in the control class (M=75.3, SD=8.1), with $F(1, 89) = 25.73$ and $p < .001$. The effect size ($\eta^2 = 0.224$) suggested that multimedia teaching intervention could explain 22.4% of the variance in academic performance, and this difference held important practical significance.

This finding aligns with the current development trend of educational informatization, which emphasizes using information technology to transform people's cognitive methods—shifting learning from being education-led to learner-led, and from passive reception to active exploration.

Table 1. Descriptive Statistics and ANCOVA Results of Pre-test and Post-test Scores Between Experimental Class and Control Class (N=92)

Group	Sample Size (n)	Pre-test Score (M±SD)	Post-test Score (M±SD)	Adjusted Post-test Mean (Madj)	Standard Error (SE)	F Value	Degrees of Freedom	p Value	Effect Size (η²)
Experimental	47	72.15 ± 8.23	82.51 ± 6.78	82.45	0.92	25.73	(1, 89)	< .001	0.224
Control	45	71.89 ± 7.95	75.32 ± 8.12	75.38	0.94				

Dynamic visualization technology transforms abstract electromagnetic concepts into intuitive images, helping students establish accurate physical representations. For example, when describing the animation of rotating magnetic fields, one student commented: "The three-dimensional process of magnetic field synthesis, which originally required strong spatial imagination, becomes clear at a glance through animation demonstrations." This dual coding of visual representations and verbal symbols aligns with constructivist learning theory, which posits that learners acquire knowledge and skills through meaning construction in specific contexts.

The interactive exploration function allows students to independently adjust parameters and observe continuous changes in motor characteristics. This experiential learning fosters in-depth cognition, making otherwise tedious knowledge vivid and understandable.

Notably, the appropriate application of multimedia technology can create diversified learning contexts, turning teaching activities into a process filled with intellectual enjoyment. This "education through entertainment" approach not only improves learning efficiency but also cultivates students' intrinsic interest in the discipline of electrical machinery. Meanwhile, this study also found that to achieve such effects, it is essential to ensure the close alignment between multimedia content and teaching objectives, avoiding the trap of formalistic application.

The Duality of Learning Motivation Stimulation and Cognitive Load

Data from the learning motivation scale, as presented in Table 2, showed that the increase in intrinsic motivation among students in the experimental class was significantly greater than that in the control class ($p < 0.01$). Students generally reported that interactive simulations and virtual cases "brought the joy of exploration"—this positive emotional experience is consistent with the "education through entertainment" concept supported by information technology. By providing a ubiquitous learning environment, modern information technology offers learners experiences that engage their intellect, senses, and emotions, thereby stimulating their intrinsic learning motivation.

Table 2. Comparison of Post-test Results of Learning Motivation (Intrinsic Motivation Dimension) Between Experimental Class and Control Class (N=92)

Group	Sample Size (n)	Posttest Intrinsic Motivation Scores (M)	Standard Deviation (SD)	Statistical Test Value (t)	p Value
Experimental	47	4.25	0.58	3.42	< 0.01
Control	45	3.71	0.62		

However, the measurement results of cognitive load showed complexity, as presented in Table 3. Although the average extraneous cognitive load of the experimental class was not significantly higher than that of the control class, the large within-group standard deviation indicated obvious individual differences. In-depth interviews revealed that when the presentation speed of animation information was too fast or the interface elements were overly complex, some students reported feeling "overloaded with information and unable to grasp the key points." This finding confirms the Cognitive Load Theory in multimedia teaching—improper instructional design will increase extraneous cognitive load, thereby affecting learning effects.

Table 3: Comparison of Post-test Results of Extraneous Cognitive Load Between Experimental Class and Control Class (N=92)

Group	Sample Size (n)	Post-test External Cognitive Load Score (M)	Standard Deviation (SD)	Statistical Test Value (t)	p Value
Experimental	47	5.10	2.45	0.35	0.73
Control	45	4.95	1.80		

Further analysis showed that the duality of cognitive load is reflected in two aspects: well-designed multimedia materials can increase germane cognitive load by integrating information and highlighting key points, thereby promoting schema construction; while poorly designed multimedia presentations will introduce a large amount of harmful extraneous cognitive load, interfering with learning. This duality suggests that teachers need to reasonably design multimedia teaching content based on students' cognitive characteristics, ensuring that it can not only stimulate learning interest but also avoid cognitive overload.

Key to Teaching Effectiveness: Sequential Integration of Multimedia and Traditional Methods

Results from classroom observations and teacher interviews indicated that the key to the success of multimedia teaching lies in achieving sequential integration with traditional methods. A senior teacher emphasized: "The logical deduction process of blackboard writing is an irreplaceable thinking training, while the advantage of multimedia lies in the intuitive presentation of conclusions." This view is consistent with existing teaching practice research, suggesting that modern media and traditional media should complement each other rather than replace one another.

This study proposes a "complementary integration" framework, which emphasizes designing teaching sequences based on the characteristics of different knowledge types, as shown in Figure 1. For declarative knowledge, the sequence of "multimedia intuitive presentation → lecture on precise definitions" is adopted; for procedural knowledge, the path of "blackboard deduction → multimedia verification" is more appropriate; and for conceptual knowledge, the sequence of "problem context → thinking guidance → multimedia deepening" is applicable. This distinction is consistent with the concept of personalized learning supported by information technology, enabling teaching to adapt to the characteristics and needs of different learners.

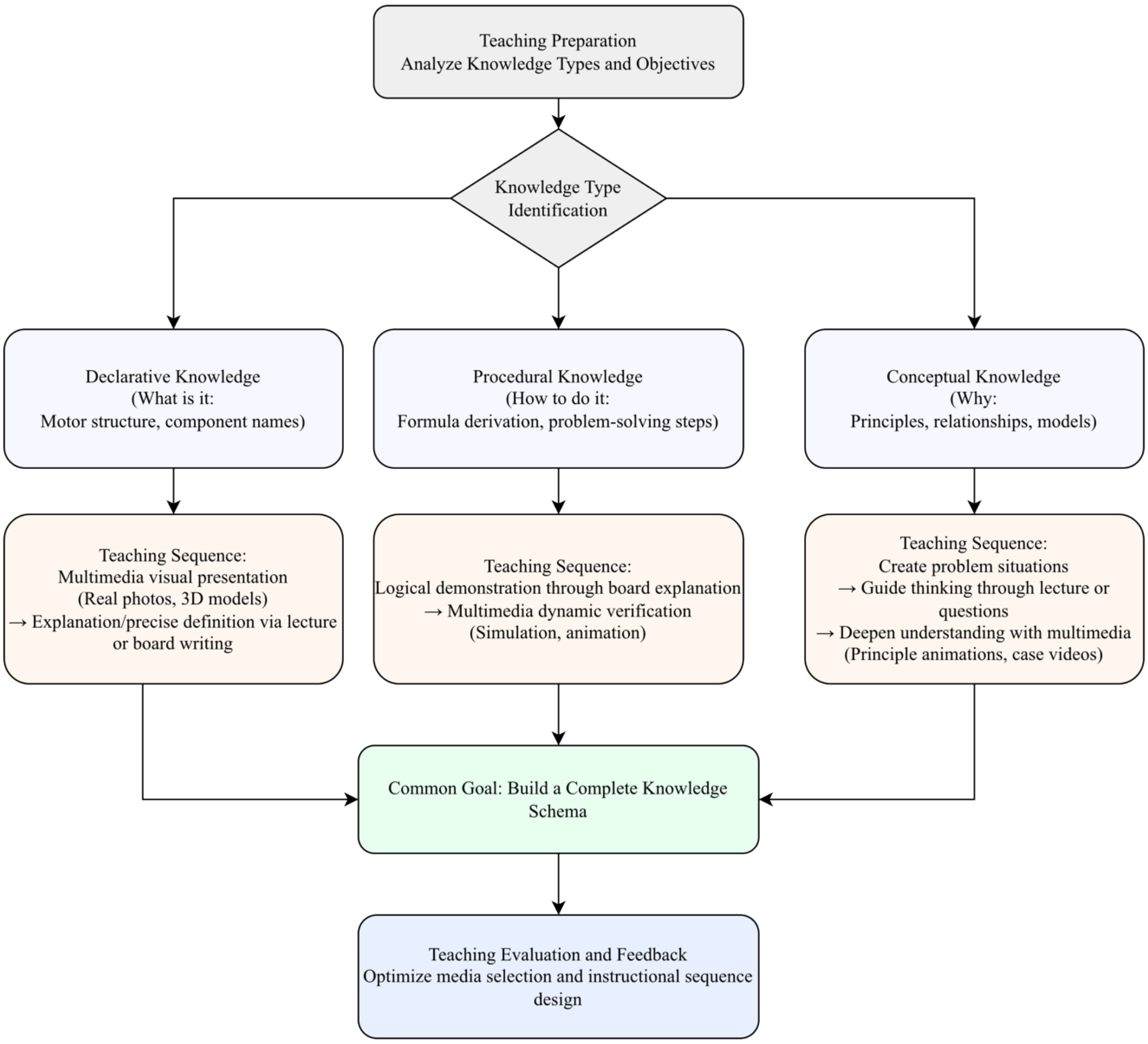

Figure 1. Teaching Framework Diagram for "Complementary Integration" in Electrical Machinery

It is worth noting that effective integration requires teachers to accurately grasp the characteristics of various teaching media. For example, in the teaching of motor structure, 3D models can intuitively display spatial relationships, but during principle deduction, step-by-step blackboard writing is more effective in guiding the development of thinking. This sequential integration embodies the "learner-centered" educational concept—by creating diversified learning contexts, it promotes students' active construction of knowledge. At the same time, teachers should avoid over-reliance on multimedia technology and ensure that their leading role in the teaching process is fully exerted.

CONCLUSION

Summarize the main points of your study. Consider writing down the key takeaways, the contribution of your chapter to theory, policy, or practice, the limitations of the study. You can also offer suggestions for future research or application.

Through empirical analysis using a mixed-methods approach, this study confirms that in the teaching of Electrical Machinery—a course characterized by high abstraction and systematic complexity—systematic multimedia applications designed based on cognitive theories can significantly enhance students' understanding of abstract electromagnetic concepts and deepen their knowledge construction. Quantitative data shows that the post-test scores of the experimental class were significantly higher than those of the reference class ($p<0.001$), and the effect size ($\eta^2=0.224$) indicates that the intervention has important practical significance.

Qualitative analysis further reveals that this facilitating effect is mainly achieved through dynamic visualization (e.g., animations of rotating magnetic field formation) and interactive exploration (e.g., parameter adjustment in simulation software). These methods effectively lower students' cognitive thresholds, confirming the supporting role of visual representations for verbal/symbolic representations as proposed in the Dual Coding Theory.

However, the study also found that the effectiveness of multimedia teaching is highly dependent on scientific instructional design. Cognitive load measurement results show that if multimedia information is presented too quickly or the interface is overly complex, it will cause extraneous cognitive load, which negatively impacts learning outcomes. Therefore, the core of successful teaching lies not in the technology itself, but in the in-depth integration and sequential arrangement of multimedia and traditional teaching methods (such as blackboard deduction and physical demonstrations). The "complementary integration" framework, derived from classroom observations and teacher interviews, emphasizes that the timing and function of different media should be carefully determined based on knowledge types (declarative, procedural, conceptual), rather than simply replacing one with another. Based on the research findings, several teaching recommendations are proposed. In the development of multimedia resources, priority should be given to integrating scientific accuracy with educational value, ensuring that technological tools effectively serve instructional objectives rather than merely enhancing presentation. During classroom implementation, teachers are encouraged to flexibly select appropriate media combinations and presentation sequences according to different types of knowledge and students' learning characteristics. Furthermore, in terms of teacher professional development, greater emphasis should be placed on strengthening training in information-based teaching competencies so as to improve the overall quality of multimedia instructional design.

These recommendations provide important reference value for advancing the informatization reform of engineering education. In particular, for professional courses such as Electrical Machinery, which require a close integration of theoretical understanding and practical application, the scientific and rational use of multimedia technology can contribute to the cultivation of high-quality engineering talents with strong innovative awareness and practical abilities.

Nevertheless, this study has several limitations. First, the sample was drawn from a single institution; while this facilitated control of variables, the generalizability of the findings needs further verification through multi-center and large-sample comparative studies. Second, the research primarily focused on short-term instructional effects and did not include long-term follow-up data, making it difficult to determine whether multimedia teaching promotes long-term knowledge retention and transfer.

In conclusion, the application of multimedia technology in Electrical Machinery teaching is a systematic and comprehensive endeavor. Only by adhering to principles from the learning sciences, focusing on the enhancement of students' deep cognitive processing, and achieving creative integration between technology and pedagogy can the quality of higher engineering education be effectively improved.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my supervisors—Prof. ede Rasben Dantes, Prof. Dewa Gede Hendra Divayana, and Prof. Hery Santosa—for their invaluable guidance, consistent support, and profound insights throughout the entire development of this thesis, Research on the Application of Multimedia in the Teaching of "Electrical Machinery".

Their rigorous academic attitude, professional expertise, and sincere care for my research journey have been crucial to the completion of this work. Whenever I encountered challenges, their encouragement and advice gave me the confidence to move forward.

Words fall short of conveying my appreciation for their contributions. I will always cherish their teachings and continue to pursue exploration in the fields of educational technology and electrical engineering pedagogy.

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