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HTML5-Powered Causal Explanations: Fueling Deep Science Learning

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Abstract: ***With the advancement of information technology, HTML5 has emerged as a robust, interactive, and cross-platform web technology increasingly adopted in education. In China's current science classrooms, the emphasis often lies in factual outcomes over conceptual processes, limiting students' opportunities to develop deep understanding. This study, grounded in constructivist theory, integrates a causal explanation strategy with HTML5 technology to design an online science learning system focused on the "lever principle." A quasi-experimental design involving 42 middle school students was conducted. Results indicate that the HTML5-based system significantly improved students' science performance and metacognitive skills, offering empirical support for the effective integration of strategy and technology in science education.***

Keywords: Science Education; HTML5; Causal Explanation Strategy; Metacognition.

1. INTRODUCTION

As the "Internet Plus Education" policy continues to be implemented, digital technology is increasingly being integrated into the basic education system, emerging as a key driver of educational innovation. In this process, HTML5 technology, with its features such as no plugin requirements, excellent cross-platform compatibility, and superior interactive performance, has gradually become one of the core tools for developing educational resources and building interactive learning environments (Yang et al., 2018). Compared to traditional Flash technology, HTML5 not only supports multimedia embedding, animation display, and interactive feedback but also runs smoothly on both personal computers and mobile devices, significantly enhancing the accessibility of educational content and student engagement.

In the field of science education, teachers and researchers have begun to apply HTML5 to various teaching practices, such as experimental simulations, simulation platforms, and science games. Ramos-Quintana et al. (2016) utilized HTML5 to achieve efficient visual interaction in a particle dynamics simulation project. While these applications have made progress in terms of operability and visual presentation, they largely remain at the "technology-driven" level, lacking systematic guidance on students' cognitive processes and thinking structures. Particularly in secondary science classrooms, there has long been an issue of "emphasizing conclusions over processes," where teachers focus on presenting knowledge outcomes but rarely guide students to understand the causal mechanisms behind scientific phenomena. Students' mastery of knowledge remains at the stage of memorization and imitation, lacking deep construction (Zhou Qiang, 2014). This phenomenon has prompted researchers to begin exploring the role of cognitive strategies in science education.

Among these, causal explanation strategies have garnered significant attention in recent years, being regarded as a key pathway connecting knowledge phenomena with conceptual understanding. Paulo et al. (2004) proposed a four-stage model of causal explanation — "awareness, association, dissociation, and conceptualization" — which emphasizes the use of contextual stimulation and structured guidance to help students extract scientific laws from their life experiences, providing a clear operational framework for instructional design. de Carvalho (2004) found that explanatory learning tasks promote knowledge integration, problem transfer, and reflective behavior in science. Explanation not only deepens students' mastery of content but also enhances their ability to identify patterns and construct causal models in problem-solving. Flavell (1979) noted that the development of metacognitive abilities is closely linked to strategy use. Explanatory activities activate students' metacognitive dimensions such as self-monitoring and self-assessment, forming an important foundation for the development of higher-order thinking. Domestic research also indicates that incorporating causal explanation strategies into science education can effectively enhance students' causal reasoning abilities and scientific literacy (Zheng Hao, 2024). However, this strategy is currently primarily applied in traditional classrooms, such as paper-and-pencil tasks and teacher-student question-and-answer sessions, with limited implementation pathways in modern digital learning platforms.

HTML5 technology offers the possibility of programmatically implementing causal explanation strategies: its clear modular design and support for dynamic feedback and user behavior tracking enable real-time guidance and strategy embedding in the teaching process. However, current research in this area remains largely unexplored. Most HTML5 platforms focus on functional development and interface beautification, lacking strategic cognitive structures, which results in learners being able to complete tasks but struggling to form deep understanding. Therefore, how to organically integrate causal explanation strategies into HTML5 web platforms, so that technology serves not only as an information carrier but also as a tool for cognitive support, is an urgent research question that needs to be explored. This paper takes the “lever principle” in middle school physics as its theme and designs and develops an HTML5 science learning system embedded with a causal explanation model. The system constructs a complete causal chain learning path through life-oriented guiding videos, diagrammatic concept construction, interactive virtual experiments, and real-time feedback mechanisms, aiming to address the issue of “adequate content presentation but insufficient cognitive support.”

The theoretical value of this study lies in promoting the transfer of causal explanation strategies from traditional classrooms to modern digital platforms, verifying their adaptability and effectiveness in new interactive environments; its practical value lies in providing a teaching model that integrates strategy and technology, offering a theoretical foundation and operational demonstration for the design of future science education platforms. To test the effectiveness of this system, this study employs a quasi-experimental design, with 42 students from two first-year high school classes at a certain middle school in Fujian Province as the research subjects. An experimental group (using a strategy-supported HTML5 platform) and a control group (using an HTML5 platform without a strategy structure) were established to compare students' performance in scientific achievement and metacognitive abilities.

This study focuses on two core research questions:

1) Can the HTML5 web-based learning method based on causal explanation strategies effectively enhance students' mastery of scientific knowledge?

2) Can the HTML5 web-based learning method based on causal explanation strategies effectively enhance students' metacognitive ability levels?

2. LITERATURE REVIEW

Research has shown that HTML5-based education can offer students experiential opportunities, enhance hands-on skills, promote knowledge learning, and develop problem-solving abilities. This has driven explorations into its application across various educational disciplines, including language subjects like English (卢昊 等, 2023) and Chinese (陈鑫明, 2020), as well as science fields.

In the realm of virtual laboratory development, multiple studies have leveraged HTML5's capabilities. Tsinghua University in China has been building a simulated physics experiment platform using HTML5 since 2020, completing 32 different physics experiments by the time of publication (顾晨 等, 2022). Similarly, domestic scholar Yu Sheng et al. proposed an HTML5-based virtual laboratory that virtualizes electronic components, enabling users to construct circuits and input data for results. This setup allows students to conduct experiments anytime and anywhere, boosting convenience and efficiency (Sheng et al. 2016). Internationally, earlier research also utilized HTML5 for virtual laboratories, with a case study on the "pendulum experiment" showing that HTML5-assisted simulated experiments help students understand physical concepts, cultivate digital age skills, and enhance autonomous learning abilities (Aveleyra et al. 2016).

In terms of online education systems, Zhang Yifan (2014) analyzed the limitations of traditional systems—such as uneven resource distribution and weak interactivity—and designed an HTML5-based online learning system. Testing confirmed that this system facilitates students' scenario comprehension and knowledge absorption.

Within scientific simulation applications, HTML5 has been employed to design algorithms for particle dynamics, allowing learners to observe particle collision phenomena through simulations rather than just studying mathematical formulas, thereby deepening understanding of mass and momentum roles in collisions. In South Korea, scholars used HTML5 to simulate the Monte Carlo algorithm, which students can easily learn and implement. This algorithm supports perimeter simulation calculations in e-learning and distance education, with empirical results showing that HTML5's accessible graphic context enables most students and teachers to create simulation programs, making it suitable for middle school physics education to explain complex dynamic systems.

Despite these explorations—spanning educational software platforms, educational game integration, and specific curriculum cases—existing studies have exposed limitations. HTML5 often functions merely as an auxiliary teaching tool, failing to fully integrate into the entire teaching process. While it aids understanding of certain physical concepts, such comprehension remains superficial. Additionally, screen capture-based HTML5 teaching may induce passive learning, hinder innovative thinking, and result in fragmented knowledge acquisition (Pettit, 2018).

3. METHODOLOGY

To investigate the role of an HTML5 science learning platform based on causal explanation strategies in enhancing students' scientific understanding and metacognitive abilities, this study employs a quasi-experimental design and constructs a learning system that integrates strategy embedding and interactive feedback. The specific research methods are as follows:

3.1 System Architecture

This study developed an online web-based learning system using HTML5 technology. Figure 1 shows the system architecture. The system primarily consists of three modules: a learning materials database, an interaction database, and an experiment database. Module one is the learning materials database, which houses various learning resources, including text, images, and video materials. Therefore, the system's web pages not only present text-based materials but also incorporate various video, image, and other media resources, fully leveraging the advantages of HTML5 to make the entire learning process engaging and interactive. Module two is the interactive database, where the system records students' operational behaviors and has designed a feedback system for this purpose. The feedback system provides corresponding feedback on the recorded operational behaviors, effectively showcasing the high interactivity of HTML5 technology. For example, the system has designed numerous question-and-answer interactive sessions, and students must complete these sessions before proceeding to the next learning phase. After students complete the corresponding content, the system will have them conduct a scientific experiment on the principle of levers, which is the final experimental database module. The experimental platform used in this study is CrackGod, which includes experimental content for various subjects in primary and secondary schools, including science, physics, biology, and chemistry. The platform provides various experimental equipment for students to choose from and complete experiments on the experimental bench. The platform also records students' operational processes. The system also incorporates an instant feedback mechanism, which records students' behavioral data in real-time, such as clicks, drag-and-drop paths, and response content, and automatically generates prompts and suggestions based on learning behavior to enhance their metacognitive awareness and learning regulation abilities (Clark & Mayer, 2023).

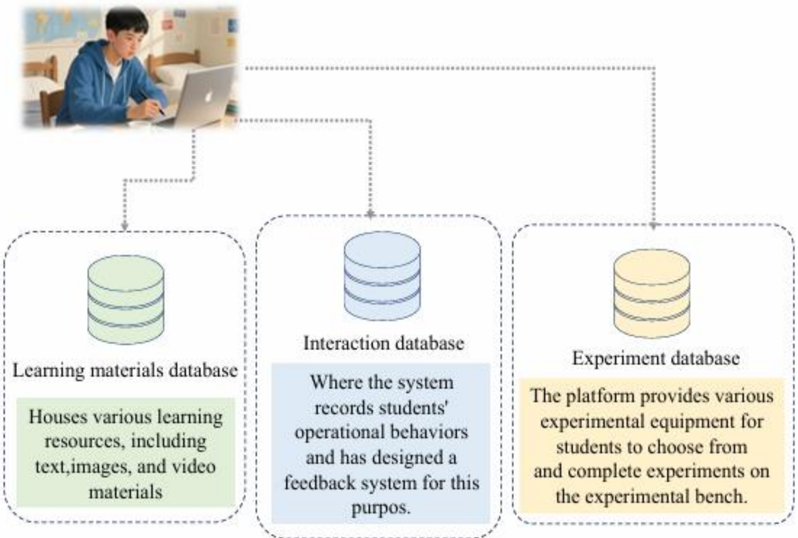

Figure 1: The system architecture.

3.2 Experimental Design

The study employed a quasi-experimental design, selecting two parallel freshman classes (totaling 42 students) from a high school in Fujian Province, which were randomly divided into an experimental group (20 students) and a control group (22 students). Specifically: the experimental group used an HTML5 system incorporating causal explanation strategies; the control group used standard HTML5 web-based learning resources, which were identical in content but lacked strategic structure and interactive support. The entire instructional intervention spanned four class periods, with pre- and post-tests administered before and after the intervention to assess the impact of platform use on students' mastery of scientific knowledge and metacognitive abilities. At the end of the experiment, five students in each group were randomly selected for one-on-one and half structured interviews. Figure 2 shows the experimental flow picture.

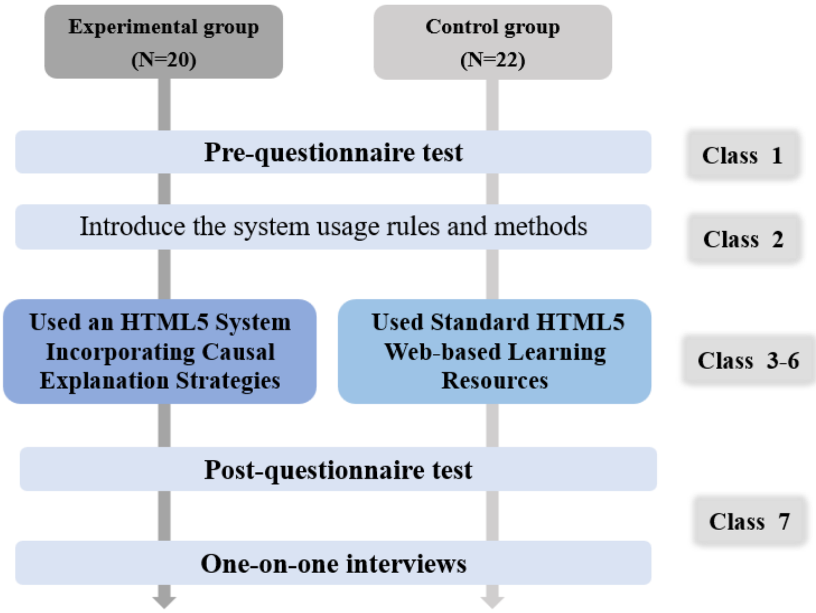

Figure 2: The experimental flow picture.

Causal reasoning enables students to predict, infer, and explain the events or phenomena they encounter and observe, which are essential skills for conceptual understanding and problem-solving. This study combined the four stages of causal explanation proposed by foreign scholars: awareness awakening → establishing connections → detachment → conceptualization to design the HTML5 web system. Figure 3 shows the learning process picture. The learning process involves four stages, through which students construct causal explanations of lever phenomena and gain a deeper understanding of related scientific concepts. To align with the “learning by doing” philosophy of science education and reinforce students' scientific knowledge, after completing the four stages of self-directed web-based learning, the system will arrange for students to use the aforementioned CrackGod experimental platform to conduct experiments on lever balance.

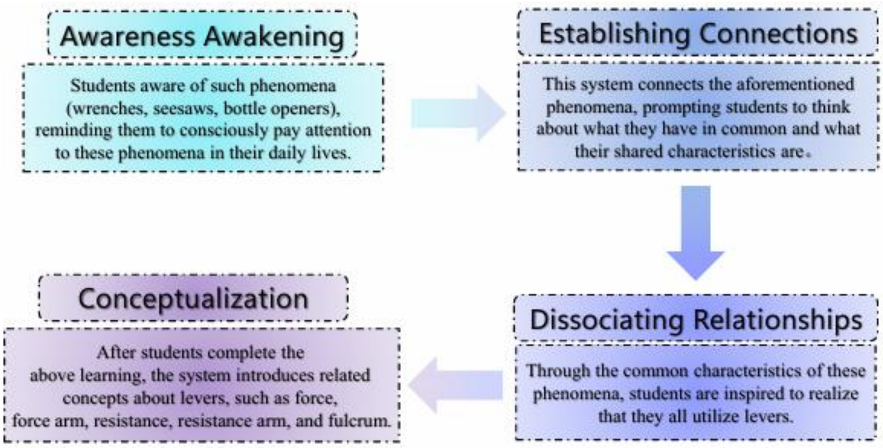

Figure 3: The learning process picture.

Stage One: Awareness Awakening. Paulo defines this stage as arousing students' attention to phenomena and helping them establish a shared memory of these phenomena. In this system, short videos relevant to daily life are used to make students aware of such phenomena (wrenches, seesaws, bottle openers), reminding them to consciously pay attention to these phenomena in their daily lives.

Stage Two: Establishing Connections. Paulo explains that establishing connections involves helping students establish causal relationships between phenomena and guiding them to think about the relationships between phenomena. This system connects the aforementioned phenomena, prompting students to think about what they have in common and what their shared characteristics are.

Stage Three: Dissociating Relationships. Paulo points out that the purpose of this stage is to help students connect the causal relationships between phenomena with specific physical properties or results, further deepening their understanding of causal relationships. Through the common characteristics of these phenomena, students are inspired to realize that they all utilize levers.

Stage Four: Conceptualization. Paulo notes that the purpose of this stage is to help students connect causal relationships with existing knowledge and experience, forming a more systematic understanding. Therefore, after students complete the above learning, the system introduces related concepts about levers, such as force, force arm, resistance, resistance arm, and fulcrum.

3.3 Measurement Tools

This study used scales for data collection:

Science Knowledge Test: Developed based on the “Compulsory Education Science Curriculum Standards (2011 Edition)” and current textbooks, it consists of 27 questions, including multiple-choice, true/false, fill-in-the-blank, and open-ended short-answer questions, comprehensively assessing students' understanding and application of the lever principle, with a Cronbach's alpha of 0.84; Metacognitive Ability Scale: Adapted from Flavell’s (1979) classic metacognitive theory, it covers three dimensions: planning, monitoring, and regulation, with 8 items. It uses a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). This scale has been validated for reliability and validity in multiple domestic studies (Li Ping, 2020).

4. RESULTS

To examine the impact of an HTML5 learning platform incorporating causal explanation strategies on students' scientific learning outcomes, this study conducted a comparative analysis of the experimental and control groups' performance in two dimensions—scientific knowledge mastery and metacognitive ability—using pre- and post-test data and relevant statistical analyses. The results are as follows:

4.1 The Impact of Science Instruction Incorporating Causal Explanation Strategies in HTML5 on Students' Scientific Achievement

To ensure the reliability of the research results and control for irrelevant variables, this study conducted a one-way analysis of variance on the pre-test data of the two experimental groups. Based on the obtained p-values, there were no significant differences in scientific knowledge levels and metacognitive abilities between the experimental group and the control group, thereby ruling out the interference of irrelevant variables on the experimental results.

After eliminating the aforementioned interference, this study proceeded to conduct an independent samples t-test analysis on the post-test data. First, in terms of science performance, science performance was used as the dependent variable, and the experimental and control groups within the groups were used as the grouping variable. As shown in Table 1, the mean science performance scores for the experimental and control groups were 76.90 and 71.23, respectively; the standard deviations were 8.065 and 7.886, respectively; and the mean errors were 1.803 and 1.681, respectively. As shown in Table 2, the observed value of the F statistic for this test is 0.451, with a corresponding probability p-value of $0.506 > 0.05$, indicating that there is no significant difference in variance between the two populations. Therefore, the subsequent t-test data values should be read from the “Assume equal variance” row, specifically the values in the “Significance (two-tailed)” column. The p-value in this column is $0.027 < 0.05$, so it can be concluded that there is a significant difference in science scores between the experimental group and the control group.

Table 1: Statistics for the science achievement group

Group	N	Mean	S.D.	S.D. Mean
Experimental group	20	76.90	8.065	1.803
Control group	22	71.23	7.886	1.681

Table 2: Independent samples t-test for science scores

	F	Significance	t	df	Significance (two-tailed)	Mean Difference	S.D.Difference
Assumption of equal variance	0.451	0.506	2.303	40	0.027	5.637	2.463
No assumption of equal variance			2.301	39.431	0.027	5.637	2.465

4.2 The Impact of Science Instruction Incorporating Causal Explanation Strategies in HTML5 on Students' Metacognition

In terms of metacognitive abilities, metacognitive performance was used as the dependent variable, and the experimental and control groups within the experimental design served as the grouping variable. As shown in Table 3, the mean metacognitive performance scores for the experimental and control groups were 3.970 and 2.991, respectively; the standard deviations were 0.7954 and 1.1604, respectively; and the mean errors were 0.1779 and 0.2474, respectively. As shown in Table 4, the observed value of the F statistic for this test is 1.740, with a corresponding probability p-value of 0.195 > 0.05, indicating that there is no significant difference in variance between the two populations. Therefore, the subsequent t-test data values should be read from the "Assumed Equal Variance" row, specifically the values in the "Significance (Two-tailed)" column. The p-value in this column is 0.003 < 0.05, so it can be concluded that there is a significant difference in metacognitive performance between the experimental group and the control group.

Table 3: Statistics for metacognitive achievement groups

Group	N	Mean	S.D.	S.D. Mean
Experimental group	20	3.970	0.7954	0.1779
Control group	22	2.991	1.1604	0.2474

Table 4: Independent samples t-test for metacognitive performance

	F	Significance	t	df	Significance (two-tailed)	Mean Difference	S.D.Difference
Assumption of equal variance	1.740	0.195	3.157	40	0.003	0.9791	0.3101
No assumption of equal variance			3.213	37.304	0.003	0.9791	0.3047

4.3 Interview Analysis Results

The interviews were audio-recorded, transcribed into text, and analyzed by counting key words.

Results showed that experimental group students often used words like "figure out the whole process" (15 times), "think step by step" (12 times), "understand why" (11 times), and "connect things" (15 times). They said the causal explanation strategy helped them "go through each part of how levers work, not just jump to the answer." One student mentioned, "It made me think about why moving the fulcrum changes things, instead of just remembering the rule." Another noted, "I could link what I saw in daily life (like seesaws) to the science part, which made it stick better." In contrast, control group students more often used phrases like "do the steps" (18 times) and "remember the result" (13 times). They rarely talked about deep thinking. These findings match the test results, showing that the causal explanation strategy really helps students think through the learning process and develop deeper understanding.

5. DISCUSSION

5.1 Causal Explanation and Interaction in Boosting Science Achievement

The results of this study indicate that an HTML5 learning system based on causal explanation strategies can significantly improve students' science grades. This effect stems from the system design's deep alignment with cognitive principles: by guiding students to explore the causal relationships behind phenomena, it encourages them to form more logical and systematic structures in their knowledge construction. For example, when learning about the principle of levers, students must explain why changing the fulcrum position affects the effort-saving effect. This process forces them to connect scattered concepts such as “fulcrum, lever arm, and applied force” into a causal chain, rather than relying on rote memorization. This learning approach aligns closely with Williams and Lombrozo's (2010) conclusion that explanatory learning promotes deep understanding—when students actively engage in constructing causal relationships, knowledge transforms from isolated symbols into transferable cognitive tools. Additionally, the interactive design incorporating feedback and guidance further reinforces this process: when students' explanations of the “conditions for lever balance” deviate, the system immediately presents counterexamples (e.g., “why increasing the force without changing the lever arm may still result in imbalance”), sparking critical thinking and deepening their mastery of scientific concepts through cognitive revision.

The technical advantages of HTML5 provide multi-dimensional support for the implementation of causal explanation strategies. The system transforms abstract principles into visual dynamic processes through text and animation: when dragging the fulcrum, changes in lever arm length are displayed in real time through color contrast and numerical annotations, transforming the abstract definition of “the lever arm is the perpendicular distance from the fulcrum to the line of action of the force” into perceptible visual information; Multimedia experiments allow students to perform extreme operations (such as moving the fulcrum to the end of the lever) in a safe environment, observing causal relationships under non-conventional conditions—something that is often difficult to achieve in traditional laboratories due to safety or equipment limitations; Interactive tasks guide inquiry through a progressive series of questions (from “describing phenomena” to “explaining causes” to “predicting outcomes”), with each operation result immediately generating a causal relationship diagram to help students intuitively grasp variable associations. This inquiry-centered learning approach not only activates students' life experiences (such as using a crowbar) but also promotes knowledge transfer (Mayer, 2008). For example, students can transfer the causal analysis method of the lever principle to the explanation of using a claw hammer to pull out nails. Additionally, this design fully aligns with Merrill's (2002) “First Principles Instructional Design” framework of “Demonstration — Application — Integration”: establishing conceptual understanding through dynamic demonstrations, applying principles through virtual operations, and integrating knowledge systems through causal explanations, enabling abstract physical knowledge to transition from ‘knowing’ to “understanding” through technological empowerment.

5.2 System Design's Role in Enhancing Metacognition

From the perspective of cognitive processing, explanatory tasks serve a dual function of reinforcing memory and restructuring knowledge frameworks. Lombrozo (2006) noted that actively explaining learned content enhances attribution judgments and structural thinking, thereby promoting the construction of long-term memory. This is particularly evident in the performance of the experimental group students: in the open-ended question “Design a lever device to reduce effort and explain its principles,” the experimental group not only accurately drew diagrams but also systematically explained the principles from angles such as “the influence of the fulcrum position on the lever arm ratio” and “the causal relationship between the direction of force and resistance”; in contrast, the control group mostly remained at the level of simply describing the device's structure. This difference confirms the promotional effect of causal explanation strategies on deep processing — when students need to explain “why,” they must mobilize their knowledge reserves, organize logical relationships, and even correct misconceptions. This process essentially involves the recoding and structural reorganization of knowledge, which is far more conducive to the formation of long-term memory than passively receiving information.

At the metacognitive level, the system's feedback mechanisms and task path design create an “explicit cognitive monitoring environment,” enabling students to continuously self-monitor and regulate their learning. Flavell (1979) argued that the core of metacognitive ability lies in the awareness and control of one's own cognitive processes, and such awareness often requires external tools for guidance. This study's system achieves this through multiple designs: The operation recording function automatically saves experimental parameter adjustments, enabling students to trace back to “the reason for initially choosing that fulcrum position”; Task feedback not only evaluates the correctness of results but also highlights “potential cognitive biases” (e.g., “Did you overlook the effect of force direction on the lever arm?"); the prompt mechanism provides "scaffolding guidance" when students stall (e.g., "Compare the ratio of changes in lever arm and applied force between the two experiments"). These designs prompt students to continuously test, reflect on, and adjust their strategies during learning, ultimately resulting in significant improvements in monitoring and regulation dimensions for the experimental group. This aligns with the findings of Azevedo et al. (2004) — an explicit metacognitive environment supported by technology can effectively help students internalize external guidance into autonomous monitoring abilities.

This study further validates the necessity and effectiveness of integrating technology with instructional strategies. Previous research has shown that while many technological platforms are functionally advanced, when they lack integration with instructional strategies, students often engage in superficial operations (Zhao, 2020). For example, certain HTML5 physics experiment platforms only provide an operational interface, allowing students to drag sliders to change parameters, but they are not guided to think about the "causal logic of parameter changes," ultimately leading to learning that remains at the "playing with experiments" level. In contrast, the learning system in this study employs a structured guidance approach through causal explanation strategies, forming a "operation — explanation — feedback — revision" cognitive loop: after adjusting lever parameters (operation), students must explain the underlying principles (explanation), the system provides targeted feedback based on the quality of the explanation (feedback), and students then adjust their cognition or operations based on the feedback (revision). This loop effectively prevents" technological idling," ensuring that HTML5's interactive advantages truly serve cognitive objectives. Clark and Mayer (2023) further point out that only when multimedia design is deeply integrated with learning strategies can learning outcomes be maximized.

5.3 Comparison with Related Studies

The findings of this study form a beneficial contrast with related domestic and international research. For example, the HTML5 experimental platform developed by Gu Chen et al. (2022) excels in interactivity and simulation realism, allowing students to observe physical phenomena intuitively. However, due to the lack of embedded cognitive strategies, students' operations often involve random trials, making it difficult to form systematic understanding. In contrast, this system embeds causal structures into task chains, such as a mechanism in virtual experiments requiring students to first explain the purpose of an operation before proceeding to the next step. This forces students to think before acting, shifting learning focus from "observing experimental results" to "understanding the essence of principles." This difference validates the design philosophy that "technology is the medium, and strategy is the soul" — only when technological tools resonate with cognitive principles can the true potential of digital learning be unlocked.

5.4 Enlightenment to Teaching Practice and Future Research Direction

From a teaching practice perspective, the research findings offer two specific insights for frontline teachers: First, the development of technology platforms should prioritize strategy guidance and learning path design rather than merely pursuing functional richness. For example, when selecting or designing HTML5 teaching tools, teachers should focus on whether they include elements that guide students to explain causal relationships (such as question chains or explanatory evaluations); Second, scientific education should strengthen the cultivation of causal reasoning abilities. This can be achieved by designing tiered tasks using technological tools, progressing from "identifying simple causal relationships" (e.g., "What changes occur when the fulcrum is moved to the left?") to "analyzing complex causal networks" (e.g., "The interactive effects when both the fulcrum and the force are changed simultaneously"), enabling students to achieve cognitive integration and transfer during knowledge construction. This insight aligns with the contemporary demands of science literacy education for the development of higher-order thinking skills (NGSS, 2013) — scientific learning should not stop at knowledge memorization but should focus on the development of core competencies such as "evidence-based reasoning" and "causal relationship analysis."

This study still has limitations. In terms of research design, the sample size is small (42 students) and limited to first-year high school students at a certain high school in Fujian Province, which may affect the generalizability of the results. Cognitive characteristics vary among students in different regions and grade levels, and the effectiveness of the system requires further validation. The study duration was short (four class periods), making it difficult to reveal the long-term retention and transfer of learning outcomes (e.g., whether students can still apply causal explanation strategies to analyze other physical principles such as pulleys and inclined planes three months later), requiring long-term tracking data to support this. From a system design perspective, personalized support for learning paths is insufficient: the current system uses a uniform question chain and feedback model for all students, failing to adequately consider cognitive differences (e.g., some students require more concrete examples, while others can directly engage in abstract reasoning). Future research could incorporate learning analytics and AI technology to track data such as students' types of explanatory errors and experimental operation preferences, automatically adjusting question difficulty and feedback methods to achieve more precise monitoring of the learning process and dynamic feedback.

In summary, the HTML5 learning system integrating causal explanation strategies not only effectively enhances students' scientific knowledge mastery and metacognitive abilities in the short term but also establishes a positive feedback loop between "technological tools — cognitive strategies — learning outcomes." This model provides important reference for the design of digital teaching platforms: the value of technology lies not in the accumulation of functions, but in providing precise support for the implementation of cognitive strategies; the implementation of cognitive strategies also relies on technology to enable the visualization and externalization of abstract thinking. Future research could further explore the applicability of this system across broader scales (different regions, educational levels) and disciplines (e.g., chemistry "factors influencing reaction rates," biology "material cycles in ecosystems"), optimize instructional design (e.g., by incorporating interdisciplinary causal reasoning tasks) to address personalized learning needs, and drive the transformation of digital education from "tool application" to "cognitive empowerment."

6. CONCLUSION

This study took the "principle of leverage" as its teaching theme, based on constructivist theory, and integrated causal explanation strategies with HTML5 technology to develop a structured online science learning system. Through quasi-experimental research, it was found that the system significantly improved students' mastery of scientific knowledge and metacognitive abilities in the short term.

From the results, it can be seen that the introduction of causal explanation strategies can effectively guide students to focus on the logical relationships behind scientific phenomena, thereby enhancing their reasoning abilities and the systematic nature of their knowledge structures. The interactive features, multimedia presentation, and real-time feedback provided by the HTML5 platform also offer essential technical support for implementing these strategies. The combination of both facilitates students' active knowledge construction, enhances metacognitive monitoring, and strengthens strategy regulation abilities during the learning process. This teaching system design model, centered on the "cognitive pathway," provides a paradigm reference for addressing issues such as "technological isolation" and "shallow interaction" in digital learning platforms.

However, the study also has certain limitations, including a limited sample size, a short research period, and the need to enhance the platform's personalized functions. Future research could consider expanding the sample size, extending the experimental period, and combining learning behavior analysis with artificial intelligence technology to achieve precise identification and dynamic intervention of learning paths by the system.

In summary, this study not only validated the effectiveness of combining causal explanation strategies with HTML5 technology in teaching but also provided theoretical foundations and practical insights for future digital instructional design. Future research could further explore its potential for application across different disciplines and grade levels, while continuously optimizing the depth and breadth of strategy-technology integration.

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