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ARTICLE

An Analysis of Using Social Media Scenario Teaching to Enhance Students' Willingness to Learn Research

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ABSTRACT

The rapid development of information technology has brought about the explosive growth of online learning resources, and the emergence of new media as well as self-media has strengthened the learning advantages of the Internet, and the media characteristics of remote communication, discussion and collaboration, and interaction and sharing of social media have become more prominent in the context of the globalised knowledge society era. The learning mode with Face-book, B station and other social media as the e-learning platform is changing the form of expanding college students' knowledge acquisition. Online teaching context in the mechanism of positive regulation, they according to their own cognitive level, interest needs, with the help of the Internet intelligent mobile terminal, in the massive information resources to choose to meet the individual will of the learning content, anytime, anywhere, on-demand to carry out learning activities.

1. Introduction

Social media learning, as a new type of informal learning mode, fits the 'mobile and social' media habits of college students; the characteristics of content richness, form diversity, contextualised learning field and convenient operation on social media learning platforms have expanded the space and time of college students' learning, and reconstructed the way and process of knowledge learning. The social media learning platform has expanded the space and time of college students' learning and reconstructed the way and process of college students' knowledge learning. However, social media learning inevitably brings the negative effects of fragmentation, superficiality and inefficiency in knowledge acquisition, and unreasonable use of social media will make college students deviate from the original purpose of interpersonal communication and knowledge acquisition, and even become dependent on social media, which will in turn reduce their own learning ability and learning efficiency, and impede the development of the whole process of individual learning. This paper focuses on online learning and the path to improve the effectiveness of social media learning for college students in the network era, and builds a social media learning model for research.

2. Research hypothesis

Social media learning, as a new informal learning mode, fits the media use habits of college students; the characteristics of content richness, form diversity, learning field contextualisation and convenient operation on social me-

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dia learning platforms have expanded the space and time of college students' learning and reconstructed the way and process of college students' knowledge learning. [1]. In fact, the use of social media in higher education institutions is believed to increase the interaction between teachers and students. In addition, the use of social media for communication and collaboration helps learners to interact more actively. Face-book is recognised in foreign studies as a low-risk and versatile learning communication tool that can positively contribute to collaborative learning and strengthen the bond between students and lecturers in a rather engaging way [2].

This leads to the hypothesis:

H1:Social media interaction between instructors and students has a positive effect on students' perceived usefulness.

H2:Social media interaction between instructors and students has a positive effect on students' perceived ease of use.

Among the many variables that may influence people's acceptance or rejection of IT use, perceived usefulness is considered particularly important and refers to the extent to which people tend to use or not use an application, and whether or not they believe that IT will help them do their job better [2]. Furthermore, even if potential users believe that an application is useful, they may at the same time believe that the system is too difficult to use, and that the performance benefits of using it are weighed down by the effort expended in using the application. That is, in addition to usefulness, IT use is theoretically influenced by perceived ease of use [3].

This leads to the hypothesis:

H3: Students' perceived ease of use of an online learning platform has a positive effect on perceived usefulness.

The transformation of students from 'passive acceptance' to 'active teaching' is not only reflected in the practice of offline classroom interaction, but also in the practice of online learning modes, which also realises a modification of the traditional process model of 'use and satisfaction'. This shift also achieves a modification of the traditional 'use and satisfy' process model, which gives new value to the improvement of the effectiveness of social media learning. [4].

This leads to the following hypothesis:

H4: Students' perceived ease of use of e-learning platforms has a positive effect on satisfaction with e-learning.

H5:Students' perceived usefulness of online learning platforms has a positive effect on online learning satisfaction.

It has been suggested that teaching satisfaction has a significant mediating effect between perceived external environment, perceived usefulness, perceived ease of use, and willingness to continue using [5]. In other words, pedagogical satisfaction positively influences learners' continued use of the instructional platform. Therefore the hypothesis is proposed:

H6: Students' satisfaction with online learning has a positive effect on the willingness to use the platform for continuous online learning.

Recent research has shown that online users' usage behaviour is directly influenced by perceived usefulness. In the context of research on e-texts, Baker and Stone also pointed out that student satisfaction and perceived usefulness of e-textbooks are the main factors influencing students' willingness to continue using e-textbooks [6].

Therefore the hypothesis is proposed:

H7:Students' perceived usefulness of e-learning platforms has a positive effect on the willingness to continue using e-learning platforms.

The audience of professional learning platforms in social media based on clear learning objectives, to achieve the feasibility and proximity of information acquisition and then complete the knowledge to meet the formation of positive feedback; at the same time, personalised learners with a close cognitive level, similar interests and needs to obtain the knowledge to meet the knowledge of the next learning behaviours in the further reaction, the learning path of the various key nodes interact with each other, and the cycle repeats itself. An important task for teachers is to help students recognise the need for online teaching and learning.

This leads to the following hypothesis:

H8:Online teaching context plays a positive moderating role in the relationship between students' satisfaction with online learning and their willingness to use the online learning platform continuously.

H9:Online teaching context plays a positive moderating role in the relationship between students' perceived usefulness of online learning platforms and their willingness to use continuous online learning platforms.

3. Research Methods

3.1 Subjects of the study

The study used questionnaires to collect data, first conducting a small-scale pre-test, and then making appropriate adjustments to poorly understood statements before forming a formal questionnaire. All the formal questionnaires were distributed and filled in online to a financial university from August to September 2021, and a total of 318 valid questionnaires were finally recovered. Among the valid samples collected, 161 (50.5%) were male and

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157 (49.5%) were female; the grades of the students were 69 (21.6%) in freshmen, 96 (30.1%) in sophomores, 105 (33.2%) in juniors, and 48 (15.05%) in seniors; the majority of the students had owned a mobile device for more than one year (272, 85.3%), and the time spent online was more than one hour per day (272, 85.3%). online for more than one hour a day (299, 93.7%); 98 students (30.7%) had online learning experience of less than 4 months, while all other fillers had online learning experience of more than 5 months (220, 69.3%).

3.2 Research instruments

The variables involved in the study were measured using Likert 5-level scales. Among them, the scale of social media interaction was referred to Liu's study, perceived ease of use and perceived usefulness were measured using the classical scale of Davis [2], online satisfaction was referred to Moore4]'s scale, willingness to use continuous online learning platform was referred to Chintalapati and Daruri's study, and online teaching and learning context was measured using Hamidi and Chavoshi [7]'s scale. Meanwhile, online learning experience, academic qualification and years of mobile device ownership were selected as control variables to avoid the interference of other factors in hypothesis testing.

4. .RESULTS OF THE STUDY

4.1 Data quality analysis

The data were processed and analysed using the software AMOS 21.0 and SPSS 25.0. The results of the reliability test showed that the overall Cronbach's alpha value was 0.973,and the value was not greatly improved by removing any question items. The lowest value of combined reliability for each variable was 0.84>0.6. The test value of KMO for the overall sample was 0.983,and the chi-square value of spherical Bartlett's test was 6511.615 ($p<0.001$). The effect of homoscedasticity bias was examined using the latent error variable control method. The results showed that the indicators of the factor analysis model with the addition of common method bias were x^2ld.f=1.247,RMSEA=0.029,which were larger than those of the original model, indicating that the fitting indicators of the model did not become better after the addition of the common method bias latent variable. Therefore the influence by the co-method bias is within the acceptable range.

4.2 Hypothesis testing

The test of the indicators in the structural equation model yielded the fit indices:CMIN/DF=1.293<3.0,GFI=0.936,AGFI=0.918>0.9,RMSEA=0.030<0.05,TLI=0.988,CFI=0.990,IFI=0.990,all of them are greater than 0.9.The results of the hypothesis test show that social media interaction ($\beta=0.769,p<0.001$) has a significant positive effect on perceived usefulness, and Hypothesis H1 is supported; social media interaction ($\beta=0.920,p<0.001$) has a significant positive effect on perceived ease of use, hypothesis H2 is supported; perceived ease of use ($\beta=0.245,p=0.021$) has a significant positive effect on perceived usefulness, hypothesis H3 is supported; perceived ease of use ($\beta=0.428,p=0.010$) has a significant positive effect on online satisfaction, hypothesis H4 is supported; perceived usefulness ($\beta=0.550,p<0.001$) has a significant positive effect on online satisfaction, hypothesis H5 is supported; perceived usefulness ($\beta=0.420,p=0.009$) has a significant positive effect on the willingness to use the continuous online learning platform, hypothesis H6 is supported; perceived Perceived usefulness ($\beta=0.581,p<0.001$) has a significant positive effect on the willingness to use continuous online learning platform, hypothesis H7 is supported.

Using the path coefficient identity test to analyse and compare the two groups of samples, the test results show that in the low online teaching context group, 'perceived usefulness→continuous online willingness' ($\beta=-1.366,p=0.517$) and 'online satisfaction→continuous online learning platform use willingness '($\beta=2.544,p=0.266$) have insignificant standardised path coefficients; in the high online teaching context group, 'perceived usefulness → willingness to continue online' ($\beta=0.631,p<0.001$) and 'online satisfaction → continued willingness to use the online learning platform' ($\beta=0.370,p=0.004$) are statistically significant standardised path coefficients; Restricted Model 1 (Restricted Path Perceived Usefulness→Continued Willingness to be Online) compared to the unrestricted model with $\Delta x^2=9.949$ ($p=0.020$), Hypothesis H8 is supported; Restricted Model 2 (Path Online Satisfaction→Continued online willingness) compared to the unrestricted model, $\Delta x^2=6.329$ ($p=0.012$), assuming that H9 is supported.

Conclusion: In traditional classroom teaching, the teacher has the absolute dominant power in the classroom, affected by the allocation of class time and the uneven level of students' knowledge, the interaction between teachers and students is limited, and the starting point of teachers' teaching under the 'one-to-many' mode is to consider the average acceptance of the students in the class, and cannot take into account the two extremes of the students with good and weak academic performance, let alone personalised teaching for each individual. The starting point of teaching in the 'one-to-many' mode is to consider the average acceptance of the students in the class, which cannot take into account the students with the best and weakest academic performance, nor can it realise personalised teaching for everyone.

As a new informal learning mode derived from the mobile Internet environment, social media learning is not limited by the teaching method, teaching content, and teaching time and space, and brings a new experience of freedom and diversity to college students. At the same time, its instant interactivity can also assist students to quickly master professional academic knowledge and learn by touch. Social media learning is a highly interactive learning process that enables learners at different levels to get corresponding knowledge satisfaction. Based on the learning of mobile terminals with instant messaging, students can interact and communicate with teachers instantly, and each communication object is a unique learning individual, which promotes the differentiation of education and the personalised development of students.

Another commonly recognised shortcoming of social media learning is that users are easily distracted when studying in the more relaxed cyberspace, and there is no effective monitoring mechanism. However, the learning platforms that college students are keen to choose have actually built an invisible monitoring system in the highly interactive Internet learning atmosphere. The 'user groups' using the same learning platform for similar learning content will upload their own learning results in a timely manner to motivate and urge their learning partners to learn and interact with each other, and this kind of learning behaviour with social attributes strengthens the sense of presence among the learners and makes them satisfied with such a pleasant and efficient learning process, so that their knowledge reserves and application abilities are continuously improved. The knowledge reserve and application ability are continuously improved.

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ARTICLE

The Design and Practice of a "Dual Mainlines" School-Based Scientific Inquiry Curriculum System

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ABSTRACT

This study explores the construction and implementation of a scientific inquiry curriculum system. Centered on cultivating students' interest in science and emphasizing the decisive role of science education in shaping scientific literacy, the curriculum proposes a "dual mainlines" instructional model. This framework integrates scientific knowledge, thinking, methods, and ethos into teaching materials and classroom practices. Through project-based teaching and a "learning-practice- reflection" framework, the curriculum guides students to progressively deepen their understanding of the nature of science. Grounded in real-life scientific phenomena and practical applications, the course sparks student engagement while prioritizing scientific inquiry as a core learning approach. By encouraging questioning and experimentation, it fosters students' capacity for autonomous exploration.

1. The Guiding Philosophy of Scientific Inquiry Curriculum System Framework Development

1.1 Cultivating a Universal Passion for Science

The rapid advancement of science and technology serves as the cornerstone driving comprehensive societal progress. It profoundly shapes the trajectory of social development by revolutionizing human modes of production, lifestyles, and cognitive frameworks. The objectives of science education extend far beyond equipping students with foundational scientific concepts and their interconnections. More crucially, it aims to cultivate students' skills and methodologies in scientific inquiry, enhance collaborative competencies and communication proficiency, while fostering a scientific mindset characterized by critical thinking, innovative exploration, and evidence-based reasoning. As the decisive catalyst in shaping individual scientific literacy, science education embodies the fundamental mission of elevating the scientific capabilities of every learner.

1.2 Developing a "Dual Mainlines" Framework for Teaching Content and Classroom Structure

The science curriculum design proposes a complementary "Dual Mainlines" model through the deep integration of content and pedagogical design. By systematically embedding scientific knowledge, thinking paradigms, methodologies, and ethos into both instructional materials and classroom practices, we establish dual distinctive pathways: content innovation and teaching process optimization. Guided by the "Dual Mainlines" framework, the scientific inquiry curriculum employs project-based teaching as its operational vehicle. The content framework revolves

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around a "learning- practice-reflection" progression, while the instructional design adopts an "observe- reflect-articulate-apply" cycle for holistic classroom integration. This structured approach enables students to gradually unravel the essence of science, fostering intellectual curiosity, scientific passion, and civic responsibility. Simultaneously, it equips learners with science-informed problem-solving strategies applicable to academic challenges and daily life contexts.

1.3 Constructing a Knowledge Framework Anchored in Everyday Scientific Phenomena

Science education must be rooted in students' cognitive development patterns and lived experiences, allowing them to recognize the significance of scientific principles through familiar life contexts. This pedagogical approach enables learners to progressively acquire skills in analyzing and addressing practical scientific issues. Instructional content is systematically integrated with real-world examples that illuminate scientific phenomena, guiding students to discover science in daily life. Through this design, learners experience both the intellectual wonder and practical relevance of science, fostering enduring engagement and curiosity.

1.4 Positioning Scientific Inquiry as the Central Learning Paradigm

Scientific inquiry, as the essential characteristic of scientific research, holds profound educational significance. Guiding students through authentic investigative processes not only safeguards their innate curiosity but also ignites proactive engagement in scientific learning. Within the "Dual Mainlines" curriculum framework, inquiry-based pedagogy manifests through intentional classroom design.

Pre-class engagement: Stimulating interest via science anecdotes aligned with lesson themes.

Exploratory learning: Resisting premature conclusion delivery; instead, posing strategic questions to scaffold hypothesis formulation and experimental reasoning.

Application bridging: Connecting theoretical findings to real-world problem- solving scenarios through multi-stage exploration.

This structured yet flexible approach diversifies learning modalities while sustaining student engagement, ultimately cultivating scientific habits of mind that transcend disciplinary boundaries.

1.5 Developing a Project-Based Guided Scientific Inquiry Curriculum System with a Progressive Structure

Grounding the curriculum in project-based learning, the program selects 16 core concepts per semester across domains including physical sciences, life sciences, earth sciences, physics, and chemistry, commencing from Grade 1. Aligned with developmental readiness, a spiral progression approach organizes these concepts through hierarchical design.

Conceptual decomposition: Each core concept is deconstructed into age- appropriate sub-concepts with scaffolded complexity levels.

Competency development: Students progress from conceptual understanding to applied mastery through iterative cycles of exposure and practice.

These systematically structured concepts constitute essential scientific literacy for lifelong learning and modern societal adaptation, while simultaneously serving as vehicles for cultivating scientific competencies and nurturing evidence-based mindsets.

2. Specific Design Approach

In our school's efforts to support the distinctive development of primary and secondary education, we have designed and implemented a dual mainlines school-based curriculum for scientific exploration, tailored to the psychological characteristics of students across different age groups and aligned with the practical needs of elementary school specialty programs. Living in an era of rapid scientific and technological advancement, we are constantly surrounded by the profound impacts of science and technology. The scientific exploration curriculum aims to cultivate scientific literacy among primary school students, with a focus on hands-on experimentation and inquiry-based learning. By integrating foundational disciplinary knowledge essential to students, the curriculum fosters scientific thinking skills and problem-solving abilities.

In the design of instructional content, the curriculum follows a "Learn—Practice— Reflect" framework. The instructional process begins with scientific storytelling to introduce concepts, followed by theoretical explanations of principles and guided observation and analysis of experimental phenomena to deepen understanding. It culminates in hands-on experimentation for students to actively explore and validate the principles. In classroom instruction, inquiry-based teaching and learning activities are organized around the ORDE framework (Observe—Reflect—Discuss— Experiment). Observation can direct students to actively investigate scientific phenomena, fostering intuitive understanding. Reflection can encourage students to connect scientific knowledge with daily life, identifying applications of science and technology, stimulating critical thinking by questioning "how" and "why."

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Discussion can facilitate teacher-student and peer interactions, summarizing and reflecting on acquired knowledge and methods. Experiment can guide students to cultivate a spirit of scientific inquiry.

The instructional content is designed to align with the cognitive development patterns of primary school students, leveraging post-class reflection tasks to deepen understanding and broaden knowledge horizons. Divided by grade level and semester, the curriculum adopts a spiral progression model centered on core scientific concepts. Each semester integrates 16 science experiments that synchronize with classroom instruction, with complexity and depth increasing progressively across grades. Students not only acquire discrete scientific facts but also develop holistic problem-solving skills by analyzing interdisciplinary challenges.

3. Case Analysis of the “ Dual Mainlines “ Scientific Exploration Curriculum

The scientific exploration curriculum is designed around tangible and engaging topics from four domains: physical science, life science, earth and space science, and technology and engineering. These topics are selected for their accessibility and ability to spark students’ curiosity, with a focus on cultivating primary school students’ interest in scientific inquiry, scientific thinking skills, and effective learning habits. Across each lesson, we systematically integrate four dimensions: scientific knowledge, scientific reasoning, scientific methods, and scientific ethos. Below, we illustrate the “Dual- Mainlines “ scientific exploration model using the example of the “Dancing Paper Snippets” project.

3.1 Emphasizing Curriculum Design to Establish a Holistic Knowledge Framework

In the experimental project design, to stimulate student interest, the lesson begins with a scientific story—the Magdeburg Hemispheres Experiment—to introduce the core concept: atmospheric pressure. To deepen students’ understanding of atmospheric pressure, the curriculum connects to familiar daily life experiences and practical applications, guiding students to solve simple real-world problems. The content emphasizes the application of scientific principles in everyday contexts, using examples related to atmospheric pressure to scientifically analyze and explain phenomena caused by it. Through case studies, students gain familiarity with atmospheric pressure and related concepts, culminating in hands-on experiments where they practice scientific inquiry methods, observe phenomena, and apply systematic approaches to explore scientific questions.

3.2 Emphasizing Inquiry-Based Pedagogy and Scientifically Structured Instructional Design

The design of classroom content forms the foundation for acquiring scientific knowledge and cultivating scientific literacy. Scientific teaching methods and instructional design serve as critical pathways for students to internalize and master scientific concepts—both are indispensable. Defined as a pedagogical approach where, under the guidance, organization, and support of teachers, students actively engage in hands-on, minds-on exploration to experience authentic scientific inquiry processes. Students are the central agents of the classroom, driving discovery through experimentation, observation, and collaboration. The teacher serves as the organizer (structuring inquiry tasks), guide (scaffolding critical thinking), and promoter (fostering curiosity and reflection).

3.3 Emphasizing Differentiated Instruction and Gradual Progression in Teaching

Grades 1–2 focus on cultivating imagination and developing manual dexterity. Grades 3–4 focus on enhancing imagination, observation skills, hands-on operational abilities, and foundational technical writing skills. Grades 5–6 focus on fostering creative skills, innovative thinking, advanced hands-on practical skills, and lab report writing. Education Courses are systematically integrated into the core curriculum for all students. Tailored projects and elective modules ensure individual talents and interests are nurtured, such as robotics clubs or environmental innovation labs.

4.Concluding Remarks

In this era of rapid technological advancement, cultivating scientific literacy is paramount for students. Through the establishment of the “Dual- Mainlines” scientific exploration curriculum, we have not only built a comprehensive knowledge platform for students but also prioritized nurturing their interest in scientific inquiry, critical thinking, and practical competencies. By grounding learning in real-world scientific phenomena and guiding students through project- based learning, we empower them to experience the wonders of science through hands-on practice while enhancing their scientific literacy through reflection. Our tiered pedagogical approach addresses the developmental needs of each age group, progressively unlocking their potential.

Looking ahead, we remain committed to refining curriculum design and exploring innovative teaching methodologies. Our unwavering goal is to nurture a new generation equipped with scientific rigor and creative problem-solving skills, ensuring that the seeds of science take root and flourish in every child’s mind. Together, we pave the way for a future where curiosity and innovation drive meaningful progress.

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ARTICLE

Socratic Scaffolding in AI Education: A Framework for Critical Thinking

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ABSTRACT

The integration of artificial intelligence (AI) into education has created unprecedented opportunities for personalized learning, yet students often engage with AI tools through superficial, fact-driven inquiries, limiting their potential to foster critical thinking. This study addresses this gap by proposing a tripartite Socratic questioning framework (cognitive scaffolding, metacognitive reinforcement, and technological enablement) to enhance critical thinking in AI-mediated education. Findings suggest that structured questioning strategies and reflective practices significantly improve the depth and coherence of student inquiries, transforming passive AI interactions into iterative, reflective dialogues. While the framework demonstrates potential in fostering intellectual rigor, challenges such as AI's inherent biases and the need for pedagogical adaptation persist. Future research should explore long-term cognitive outcomes and contextual adaptations across diverse learning environments.

1. Introduction

1.1 Contextualizing the Problem

The rapid integration of artificial intelligence (AI) into educational ecosystems has ushered in transformative opportunities for personalized and adaptive learning. AI-powered tools, such as ChatGPT and Khanmigo, demonstrate unprecedented capabilities in generating instant, context-aware responses, enabling learners to engage in dynamic dialogues that transcend traditional classroom boundaries (Zhao et al., 2025; Khan Academy, 2024). However, while AI holds promise for fostering intellectual growth, its pedagogical efficacy remains contingent on the quality of human-AI interactions. Current research reveals a critical gap: students often approach AI with superficial, fact-driven inquiries (e.g., "What is photosynthesis?") rather than leveraging its potential to scaffold higher-order thinking (Li, 2023). This tendency toward low-cognitive engagement not only limits the utility of AI as a "thought partner" but also perpetuates passive learning behaviors, wherein students prioritize answer retrieval over critical inquiry (Zhao et al., 2025).

The cultivation of critical thinking—marked by analysis, evaluation, and creation (Anderson & Krathwohl, 2001)—has emerged as a cornerstone of 21st-century education, particularly in an era dominated by generative AI. Yet, existing pedagogical frameworks often fail to equip students with the metacognitive strategies necessary to navigate AI's dual role as both a guide (providing structured reasoning pathways) and a provocateur (challenging assumptions through counterarguments). This deficiency underscores the urgency to reimagine AI-augmented learn-

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ing environments through evidence-based instructional designs that prioritize dialogic depth over transactional exchanges.

1.2 Research Gap

Existing AI-edtech solutions predominantly focus on efficiency (e.g., automated grading) rather than epistemological development. Major platforms like Khanmigo and Quizlet employ predefined Q&A protocols that mirror traditional drill-and-practice methods, failing to leverage AI's unique capacity for adaptive dialogue (Mollick, 2023). Socratic questioning, a millennia-old pedagogical practice rooted in structured inquiry and iterative reflection (Paul & Elder, 2016), offers a compelling solution. By systematically guiding learners to clarify concepts, probe causality, and confront contradictions, Socratic methods align seamlessly with AI's capacity to simulate dialectical reasoning.

1.3 Research Question

This study addresses these challenges by proposing a tripartite strategy framework designed to operationalize Socratic questioning within AI-mediated learning contexts. Through a synthesis of pedagogical theory, technological innovation, and empirical validation, the research seeks to answer two pivotal questions:

- *How can Socratic questioning strategies be systematically integrated into AI interactions to enhance the depth and coherence of student inquiries?*
- *What design principles ensure these strategies foster critical thinking across diverse disciplinary and cognitive contexts?*

By bridging the gap between classical pedagogy and cutting-edge technology, this work aims to advance both theoretical discourse and practical implementations in AI-enhanced education. Its findings hold implications for educators seeking to harness AI as a catalyst for intellectual rigor and for developers aiming to create tools that transcend mere content delivery to nurture lifelong learners.

2. Educational Relevance of Socratic Questioning

Socratic questioning originated as a dialectical tool to expose contradictions in reasoning and stimulate epistemic humility. Through iterative dialogues, Socrates guided interlocutors to interrogate assumptions, evaluate evidence, and refine beliefs—a process Plato documented in works such as The Republic (Paul & Elder, 2016). Over millennia, this method has evolved into structured pedagogical practices.

2.1 Core Principles of Socratic Questioning

The enduring relevance of Socratic questioning in modern education lies in its capacity to cultivate intellectual rigor and self-directed inquiry. Rooted in ancient Greek philosophy, Socratic methods transcend temporal boundaries, offering a timeless framework for nurturing critical thinking—a competency increasingly vital in an era dominated by AI-driven information overload.

Central to this approach are five question categories:

Clarification (e.g., "What do you mean by 'fairness' in this context?"),

Causal exploration (e.g., "What evidence supports this hypothesis?"),

Consequence analysis (e.g., "If this policy is implemented, what long-term effects might follow?"),

Comparative critique (e.g., "How does this theory contrast with alternative viewpoints?"),

Reflective synthesis (e.g., "How has this discussion altered your initial perspective?") (Paul & Elder, 2016).

These categories scaffold learners' progression from superficial comprehension to evaluative and creative thinking—a trajectory mirrored in Anderson and Krathwohl's (2001) revised taxonomy of cognitive domains.

2.2 Bridging Socratic Principles and AI-Enhanced Learning

While AI tools like ChatGPT excel at generating answers, their pedagogical value hinges on users' ability to formulate incisive questions. Current studies reveal a paradox: despite AI's interactive potential, students frequently default to low-cognitive inquiries (e.g., factual recall or procedural guidance), neglecting opportunities for deeper engagement (Zhao et al., 2025; Li, 2023). This tendency stems from two interrelated factors:

- Cognitive passivity: Students often perceive AI as an authoritative "answer engine," inhibiting curiosity-driven exploration (Khan Academy, 2024).
- Structural limitations: AI responses, while rapid, may lack logical coherence or contextual nuance, discouraging iterative inquiry (Zhao et al., 2023).

Socratic questioning counteracts these limitations by reframing AI interactions as collaborative dialogues rather than transactional exchanges. For instance, when students pose clarifying questions (e.g., "How does your definition of 'bias' account for cultural differences?"), they compel AI to articulate implicit assumptions, thereby exposing gaps in reasoning. Similarly, comparative questions (e.g., "How would a sociologist versus an economist interpret this data?") encourage interdisciplinary synthesis, mitigating AI's tendency toward siloed responses. Empirical ev-

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idence from Zhao et al. (2025) demonstrates that students using Socratic scaffolds exhibit a 63% increase in high-order questions (analysis, evaluation, creation) during AI interactions, alongside enhanced ability to identify logical inconsistencies in AI outputs.

3. Designing Socratic Strategies for AI-Enhanced Critical Thinking

The integration of Socratic questioning into AI-mediated education demands a systematic framework that harmonizes pedagogical theory, technological affordances, and learner-centered design. This section presents a three-tiered strategy model—cognitive scaffolding, meta-cognitive reinforcement, and technological enablement —tailored to address the dual challenges of fostering critical thinking and optimizing AI interactions. Grounded in scaffolding theory (Van de Pol et al., 2010) and prompt engineering principles (Zhao et al., 2023), the framework emphasizes adaptability across disciplines and learner proficiency levels.

3.1 Cognitive Scaffolding: From Templates to Deep Inquiry

Central to cognitive scaffolding is the use of Socratic question banks, which provide learners with predefined templates categorized by inquiry type: clarification, causal analysis, consequence exploration, comparative critique, and reflective synthesis (Paul & Elder, 2016). These templates reduce cognitive load while modeling effective questioning patterns. For example, in a biology class examining genetic engineering ethics, students might begin with clarification questions ("How does CRISPR-Cas9 differ from traditional gene-editing methods?") before progressing to consequence analysis ("What long-term ecological risks arise from gene-drive technologies?"). Empirical studies demonstrate that such scaffolds increase the proportion of high-order questions by 63% in AI interactions (Zhao et al., 2025).

To further deepen reasoning, depth assessment tools offer real-time feedback on question quality. A quantifiable rubric—ranging from factual recall (0.5 points) to creative synthesis (3.0 points)—allows students to self-evaluate their inquiries. Visualizations, such as Sankey diagrams, map transitions between question types, revealing patterns like overreliance on clarification or underutilization of comparative critique. In a university ethics course, students using these tools exhibited a marked shift from isolated factual questions ("What is algorithmic bias?") to interconnected analytical sequences ("How do socioeconomic factors amplify bias in AI hiring tools?" → "What counterarguments exist against regulating these tools?") (Zhao et al., 2025).

3.2 Metacognitive Reinforcement: Cultivating Reflective Dialogues

Metacognitive strategies aim to transform sporadic questioning into disciplined intellectual habits. Reflective dialogue journals serve as a cornerstone, requiring learners to document their inquiry cycles: initial questions, AI responses, follow-up critiques, and cognitive revisions. For instance, a student exploring AI's role in creative writing might begin by asking, "Can AI produce original poetry?" After receiving an AI-generated sonnet, they might reflect: "Does algorithmic 'originality' lack emotional intentionality? How might cultural context influence this assessment?" Such reflections not only expose gaps in AI's reasoning but also train students to recognize their own cognitive biases. Studies show that learners maintaining these journals achieve 32% higher retention of critical concepts compared to peers relying solely on unstructured interactions (Hsu et al., 2022).

Complementing individual reflection, collaborative questioning circles foster peer-driven Socratic dialogues. In these sessions, small groups analyze AI-generated arguments—for example, a ChatGPT essay on renewable energy policies—using structured protocols: one student poses a clarification question, another challenges assumptions, and a third proposes alternative viewpoints. This collaborative process mirrors Socratic seminars, where collective inquiry uncovers nuances often missed in solo interactions. Such circles reduce AI dependency effectively as students learn to critique outputs rather than accept them uncritically.

3.3 Technological Enablement: Optimizing AI for Socratic Dialogue

To maximize AI's pedagogical potential, dynamic prompt engineering tailors interactions to align with Socratic principles. A nested prompt architecture ensures AI responses provoke deeper inquiry rather than terminate discussions. For example:

- Role-setting: "Act as a Socratic mentor. Respond with clarifying questions rather than direct answers."
- Question-type directives: "Challenge the student's assumption that all technological progress is inherently beneficial."
- Domain constraints: "Base your response on peer-reviewed studies about AI ethics published post-2020."

This approach transforms generic AI exchanges into structured dialectics. In a pilot study, students using dy-

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namic prompts engaged in 5–7 dialogue turns per session—compared to 1–2 turns with standard prompts—demonstrating sustained engagement (Zhao et al., 2023).

Additionally, visual thinking tools mitigate AI's textual dominance by mapping logical relationships. Concept maps, for instance, convert abstract dialogues into visual frameworks, such as linking "AI bias" to "training data limitations" and "mitigation strategies." Collaborative platforms like Miro enable real-time co-construction of these maps, with AI flagging inconsistencies (e.g., "Your map links 'transparency' to 'trust' but lacks empirical evidence"). Engineering students using such tools identified 20% more logical flaws in AI-generated designs than text-only groups (Hwang et al., 2020).

3.4 Ethical and Practical Considerations

While these strategies offer significant promise, their implementation requires addressing ethical and logistical challenges. AI's propensity for bias amplification necessitates bias-aware protocols, such as prompting learners to interrogate training data diversity ("Which demographics are underrepresented in this dataset?") or cultural assumptions ("How might this conclusion differ in a non-Western context?"). Simultaneously, educators must balance scaffolded guidance with organic curiosity—overstructuring inquiries risks reducing Socratic dialogue to formulaic exercises. Professional development programs are critical to equip teachers as "questioning architects" capable of modeling nuanced inquiry (Long, 2025).

4. Conclusion

This study demonstrates that integrating Socratic questioning into AI-mediated education holds transformative potential for fostering critical thinking and elevating the quality of human-AI interactions. By designing a tripartite framework—cognitive scaffolding, metacognitive reinforcement, and technological enablement—educators can address the pervasive issue of superficial questioning, guiding students to engage in deeper, more reflective dialogues with AI tools. Key findings reveal that structured question banks and reflective journals significantly increase the prevalence of high-order inquiries (e.g., analysis, evaluation, creation), while dynamic prompt engineering and visual thinking tools enhance the coherence and depth of AI-supported reasoning chains (Zhao et al., 2025; Hsu et al., 2022). These strategies not only mitigate AI's limitations, such as fragmented logic and bias propagation, but also empower learners to transition from passive consumers to active co-inquirers in knowledge construction.

The implications of this research extend beyond pedagogical practice to inform the development of next-generation AI systems. By embedding Socratic principles into AI architectures—for instance, through bias-aware protocols or adaptive questioning prompts—developers can create tools that prioritize epistemic humility over authoritative answer delivery. However, the study also highlights critical challenges, including the need for teacher training in Socratic pedagogy and the risks of over-reliance on prescriptive scaffolds (Long, 2025). Future research should explore longitudinal impacts of these strategies on lifelong learning habits and investigate cross-cultural adaptations to ensure equitable access to AI-augmented critical thinking education.

Ultimately, this work underscores the symbiotic relationship between ancient philosophical traditions and modern technological innovation. As AI continues to reshape education, Socratic questioning offers a timeless framework for nurturing discerning minds capable of navigating an increasingly complex, algorithmically mediated world.

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ARTICLE

Implementation of Gamification Method in Lower Grade Mathematics Subject in China

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ABSTRACT

The implementation of the gamification method in lower-grade primary school mathematics teaching represents an important direction for exploring improvements in teaching effectiveness. This study focuses on the implementation effect of the gamification method. It explores its relationship with two categories of predictive variables: teacher-level independent variables (teachers' understanding of gamification method, attention to student subjectivity, and ability to create gamified environments) and student-level independent variables (students' interest level, classroom game participation, and knowledge comprehension). This study targeted 200 lower-grade primary school students and 200 mathematics teachers in Nanchong City, China. Regression analysis results show that for teacher-level variables, the coefficient of determination (R^2) with the implementation effect is 0.930, the F-value is 871.248 ($p<0.001$), indicating that each independent variable significantly predicts the implementation effect. For student-level variables, the R^2 is 0.929, the F-value is 854.972 ($p<0.001$), confirming that each variable also demonstrates significant predictive power for the implementation effect. The study indicates that strengthening teachers' cognition of gamification teaching, emphasizing student subjectivity participation, and stimulating students' intrinsic learning interest are core pathways to optimize the implementation effect of the gamification method. Based on these findings, the research provides improvement suggestions for the implementation of gamification method in lower-grade primary school mathematics teaching and provides a basis for optimizing the teaching method and enhancing teaching effectiveness.

1. Introduction

Learning mathematics in the primary years is essential for developing logical thinking, abstract reasoning, and problem-solving skills. However, teaching mathematics to young primary students presents teachers with unique educational challenges [1]. During this developmental stage, children are still exhibiting Piaget's "concrete operational" thought, which makes it difficult for them to understand theoretical concepts in mathematics, geometry, and reasoning. Consequently, conventional teaching methods often fail to engage these students, leading to diminished motivation, forgotten concepts, and weakened problem-solving skills. In response to these challenges, teachers have been attempting cooperative learning, project-based activities, and the integration of technology in

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their classes. Although these teaching approaches can be effective, they do not consistently provide young learners with the interactive experiences they most enjoy. Traditional lectures, lacking interactivity, are not ideal for engaging students in mathematics, and while group work can enhance meaningful learning, it may overlook the step-by-step fundamentals crucial for mathematical understanding. Due to a lack of effective teaching practices, gamification has garnered increased attention recently, utilising games and their rewarding elements to motivate students in education [2].

The application of gamification is particularly effective for young learners, who prefer to play, explore new ideas, and receive prompt feedback. Presenting students with mathematical puzzles in the form of interactive games allows them to easily connect theory to practice. This not only fosters greater interest and involvement among students but also enhances their ability to understand and apply mathematical concepts. Nevertheless, despite its potential benefits, the use of gamified teaching in primary schools remains relatively limited. Reports indicate that most teachers employ gamification primarily for the introductory activity of lessons, with little integration into other phases of the learning process. This research investigates the implementation of gamification in lower-grade mathematics teaching in the city of Nanchong, China. It examines the effectiveness of gamification as a pedagogical approach and explores its relation to two sets of factors: those associated with teachers (such as their understanding, emphasis on students' perspectives, and design skills) and those concerning students (including their interest, level of participation, and grasp of mathematical concepts). By applying multiple linear regression analysis to the results of a survey involving 200 teachers and 200 students, the study identifies the influences on the effectiveness of gamified learning [3,4,5].

The main theories behind this research are John Dewey's Pragmatist Theory of Education, Constructivist Learning Theory, and Cooperative Learning Theory. Using "learning by doing" as a guideline, Dewey would find that gamified teaching easily makes the classroom into a place where learning happens through experience. According to constructivist theory, students gain knowledge by being actively involved, and gaming helps them do this. Besides, Cooperative Learning Theory points out that learning is also social, and this aspect is well supported by games through planned group activities and group contests. This study has important consequences for teaching, making changes to the curriculum, and students' growth. For teachers or educators, it provides useful advice and steps for using gamification in their teaching. When used in curriculum development, it gives a way to switch from educational standards and cognitive goals to game design. It proves that gamification is helpful for students in stimulating their interest in math, helping them process knowledge better, and making them feel more engaged [6,7].

To conclude, this research tackles an unaddressed issue by researching how gamification has changed primary math education and what its outcomes are. By studying the issue with research and solid ideas, it provides advice to those in charge of education to help them improve and enhance children's learning through gaming [8].

2. Literature Review

2.1 Theoretical Foundations of Gamification in Education

Foundational theories used in the gamification of education are John Dewey's theory, the Constructivist theory, and the Cooperative Learning theory. Dewey (1916) believed that learning takes place through experiences, and he believed education should be focused on the students. Gamified teaching follows this vision by changing traditional instruction into something students participate in. According to constructivist ideas, Piaget and Vygotsky, students learn the most when they actively take part in learning activities (Piaget, 1972; Vygotsky, 1978). Gamification gives these opportunities by including learning objectives in problem-solving games. Cooperative Learning Theory, which was first suggested by Johnson and Johnson (1989), also has a significant impact. It stresses teamwork, joint targets, and learning together, all of which are usual in educational games made for groups[9,10,11].

2.2 Gamification in Mathematics Education

Many experts point out that gamification helps students brush up on their interest in mathematics and learn better. The author of Zhao Hai (2021) says that using mathematical games can quickly interest students and improve how they think. Huifen (2020) also believes that games improve a person's desire to learn and their understanding and proper use of knowledge. As explained by Pan Xingwei, games are suited for youths since they help young people engage and understand challenging math concepts.

In the past, China's education system relied heavily on rote learning and taking exams. Now, gamification provides a fair balance between having fun and doing challenging tasks. Because the Ministry of Education aims for quality education, the current policy environment promotes new methods in education. Even so, proper use of gamified methods in math classes has not been fully put into place and is still understudied at the beginning of

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students' education [12,13].

2.3 Strategies and Challenges in Gamification Implementation

There are several opportunities and difficulties described in the literature about gamifying math fields. Wang Fang (2023) disagrees with the way most current practices are pursued, due to their lack of new ideas, guidance toward learning MAIN, and relatedness to various subjects. In her opinion, games should have clearer objectives, be used more closely with school subjects, and have consistent classroom management for better results. In 2022, Liu Yang emphasised that for gamification to work well, rules need to be proper and the timing precise, since it should not be a rather temporary, spur-of-the-moment idea [14,15].

Li Mei (2023) advises that gamified learning should follow three main guidelines: matching games to the learning objectives, including different kinds of formats, and finding a suitable middle ground in terms of complex tasks and amounts of time spent. Wang Hao (2022) further states that students should have some independence and know how to cooperate within groups. In 2024, Zhang Liang points out that new ideas and creativity are essential to designing good games.

Even with these observations, there are difficulties in implementing the results. Many teachers don't have enough knowledge about both the principles and practices of gamification. As pointed out by Li (2022), because of cognitive biases, teachers sometimes use gamification for entertainment rather than for any educational purpose. In addition, the lack of proper management in classrooms, unequal involvement of students, and poor evaluation systems limit how well schools can function [16,17,18,19,20].

2.4 Empirical Gaps and Research Needs

International studies prove that educational games are useful, though research about lower-grade mathematics education for students in China is still not very common. Based on the data from CNKI (2024), just about 9% of research on gamification in education focuses on this age group. Moreover, previous studies tend to be weak scientifically since few uses large data sets to look at how teacher features and student characteristics affect each other.

This study highlights that we need extra studies to find out how gamification supports teaching effectiveness, keeps students interested, and can make them retain knowledge at the primary education level. It is necessary to create gamification strategies that focus on the unique features of Chinese students' culture, institutions, and intellectual processes [21].

3. METHODOLOGY

3.1 Research Design

This study employs a multiple linear regression research design, using quantitative survey methods to explore the relationship between the implementation effect of the gamification method in lower-grade primary school mathematics and teacher-student predictors. The reason for adopting the combination of questionnaire survey and multiple linear regression is that this approach can systematically describe the feedback characteristics of lower-grade primary school teachers and students (200 students and 200 mathematics teachers) regarding gamified teaching, while also analyzing the impact intensity of teacher predictors (degree of understanding of gamification methods, attention to student subjectivity, ability to create gamified environments) and student predictors (interest level, participation, degree of knowledge understanding) on the implementation effect through quantitative models. This provides data support and an inferential basis for optimizing teaching methods.

3.2 Population and Sampling

Nanchong City is one of the earliest regions in Sichuan Province, China, to explore the implementation of the gamification method in primary school mathematics teaching. This study takes lower-grade primary school students and primary school mathematics teachers in the city as research subjects. Considering that differences in teaching characteristics across different grade levels and between teachers and students may influence the research results, stratified sampling is adopted for primary school mathematics teachers in Nanchong City [22].

Teachers are stratified by the grade levels they teach. The sampling proportion of mathematics teachers in the first grade of primary school is set at 40%, and those in the second and third grades account for 30% each. Statistical analysis shows that the average age of the sampled teachers is 34 years, with male teachers comprising 43% and female teachers 57%. Meanwhile, stratified sampling is also implemented for lower-grade primary school students in Nanchong City. Students are stratified by grade level: the sampling proportion of first-grade students is 40%, and those in the second and third grades each account for 30%. The average age of the sampled students is 8 years, with male students representing 59% and female students 41%. Through scientific and reasonable stratified sampling, this study aims to ensure the representativeness of the samples, thus providing a reliable data foundation

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for subsequent research.

3.3 Instrument of Study

This study employs the questionnaire survey as the core instrument; a method widely used in social science research for its efficiency and universality. To comprehensively explore the implementation status of the gamification method in primary school mathematics in Nanchong City, special questionnaires are designed for primary school teachers and students of different grades in the city, investigating multiple dimensions such as teachers' and students' cognition, acceptance, usage experience, and influencing factors of gamified teaching.

In the process of questionnaire development, existing relevant scales are fully referenced, and questions are designed in combination with the research background and objectives. The questionnaire mainly consists of multiple-choice questions supplemented by open-ended questions to ensure comprehensive and objective feedback collection. It is divided into two versions: the student version, which adopts concise expressions to adapt to the cognitive characteristics of younger students, and the teacher version, which deepens the dimensionality of questions to obtain detailed information on teaching practices.

The questionnaire was officially distributed in January 2025, with a total of 400 copies distributed. After strict screening, all questionnaires were valid, with an effective recovery rate of 100%. The content validity was tested by a review panel composed of educational experts and frontline teachers to confirm the relevance of the questions to the research objectives and the comprehensiveness of coverage. The construct validity was ensured by designing different versions for teachers and students, and the empirical validity was verified by the 100% effective recovery rate, demonstrating the questionnaire's applicability. In addition, the test-retest method was used to examine reliability: the same group was retested after a two-month interval, and the Pearson correlation coefficient reached 0.9, indicating good reliability of the questionnaire. The specific content is shown in Table 1. The instrument is divided into five sections: Section A (personal details), Section B (experience of gamified teaching), Section C (influencing factors of teaching implementation), Section D (evaluation of acceptance by teachers and students), and Section E (improvement suggestions). The questions adopt a 1-5 Likert scale and open-ended response formats.

3.4Data Collection Procedure

After obtaining permission from the local education authorities and schools, the data collection can be initiated. Following the completion of pre-tests for questionnaire reliability and validity that meet research standards, customised questionnaires will be adopted to carry out field surveys. On the data collection day, researchers distribute questionnaires to respondents, with independent versions designed for student and teacher questionnaires, both affixed with an informed consent form and filling guidelines on the first page. A total of 200 student questionnaires are distributed, with on-site supervision of the filling process to ensure each student submits only one valid questionnaire. Meanwhile, 200 teacher questionnaires are distributed synchronously using the same distribution and collection mechanism, with all questionnaires collected on the spot to guarantee data integrity. After questionnaire retrieval, the research team conducts piece-by-piece verification, eliminating invalid questionnaires with incomplete information, obvious logical contradictions, etc. Valid questionnaires are uniformly coded and input into the professional SPSS data processing system for quantitative analysis, ensuring the data processing process complies with academic norms.

3.5 Data analysis

All data were collected and processed using SPSS IBM Version 29.0. Statistical analysis via SPSS ensures the precision of calculations. The collected data were subjected to descriptive and inferential analyses using SPSS software. Descriptive statistics were first employed to outline the demographic profiles of respondents, presenting percentages, means, and standard deviations to interpret the findings of Objective (1). The core analysis adopted a multiple linear regression model to measure the impact intensity of teacher predictors (gamification teaching comprehension, student subjectivity attention, environmental creation ability) and student predictors (interest level, participation degree, knowledge understanding) on the implementation effect. This quantitative model analysis aims to provide data support and inferential basis for optimizing teaching methods, aligning with the research objectives of (2), (3) and (4).

Multiple linear regression analysis was used to evaluate the strength of the relationship between predictor variables and the dependent variable. The analysis followed a statistical framework where regression coefficients (β values) indicated the direction and magnitude of influence, with significance tested at $p < 0.05$. The overall goodness-of-fit of the model was assessed using the coefficient of determination (R^2). Effect sizes were interpreted according to Cohen's guidelines, where β values approaching 0.1, 0.3, and 0.5 represented small, medium, and large effects, respectively. This approach systematically inferred the contribution of each predictor to the implementation effect, providing empirical insights for instructional improvement.

Table 3.1: Cohen's Guidelines for Interpreting Effect Sizes of β Values

Effect Size	β Value Range	Interpretation
Small	≈0.1	Slight influence; minimal practical significance
Medium	≈0.3	Noticeable influence; moderate practical significance
Large	≈0.5	Substantial influence; strong practical significance

4. Results

This section outlines the results of data analysis collected from teachers and students in lower grades of primary schools in Nanchong. The main purpose of this study is to explore the relationship between the dependent variable (implementation effect of gamification method) and two categories of predictor variables: teacher-level factors (understanding of gamification method, attention to student subjectivity, environmental design ability) and student-level factors (interest level, participation degree, knowledge comprehension). Through multiple linear regression analysis, this study systematically describes the feedback characteristics of teachers and students on the gamification method, aiming to provide data support and inferential basis for optimizing teaching methods, and to address the research questions raised in the introduction.

4.1 Overview of Data Collection

This study distributed a total of 400 questionnaires to 200 students and 200 mathematics teachers in lower grades of primary schools in Nanchong. All questionnaires were formally administered in January 2025, and after strict screening, all were valid with a 100% effective recovery rate. The data collection process ensured scientific rigor through multiple reliability and validity tests: a review panel composed of educational experts and frontline teachers verified content validity to confirm the relevance and comprehensiveness of questions to research objectives; structural validity was ensured by designing separate questionnaires for teachers and students; the 100% recovery rate further validated empirical validity. Additionally, test-retest reliability was examined by administering the questionnaire to the same group with a two-month interval, yielding a Pearson correlation coefficient of 0.9, indicating good reliability of the questionnaire.

4.2 Profile of Respondent

Based on Table 4.1, the number of female teachers (n=114, 57%) was higher than that of male teachers (n=86, 43%). The respondent profile also indicated that respondents aged over 35 years (n=139, 69.5%) were slightly more than those under 35 years (n=61, 30.5%).

Table 4.1: Teachers' Profile

Demographic	Categories	Frequency	Percentage
Gender	Male	86	43%
	Female	114	57%
Age	≥35	139	69.5%
	<35	61	30.5%

Based on Table 4.2, male students (n=118, 59%) were more than female students (n=82, 41%) in the sample. The profile further showed that among student respondents, there were 7-year-old respondents (n=78, 39%), 8-year-old respondents (n=65, 32.5%), and 9-year-old respondents (n=57, 28.5%).

Table 4.2: Students' Profile

Demographic	Categories	Frequency	Percentage
Gender	Male	118	59%
	Female	82	41%
Age	7	78	39%
	8	65	32.5%
	9	57	28.5%

4.3 Descriptive Analysis

Descriptive analysis was conducted to investigate the relationships between the implementation effect of gamified teaching and variables at the teacher-level and student-level. Specifically, it focused on variables such as teachers' "ability to create a gamified environment", "degree of understanding of the gamification method", "degree of attention to student subjectivity", as well as students' "level of interest", "classroom game participation level", and "degree of knowledge understanding", and their impacts on the "implementation effect"[23].

4.3.1 Results Based on Research Questions

4.3.1.1 Implementation Effect Related to Variables

Regression analysis aimed to understand how the variables at the teacher-level and student-level affect the "implementation effect" of gamified teaching.

Based on Table 4.3, with an R-value of 0.964, it indicates a very strong correlation between the independent variables at the teacher-level (ability to create a gamified environment, degree of understanding of the gamification method, degree of student subjectivity) and the dependent variable (implementation effect). The coefficient of determination (R-square) value of 0.930 means that approximately 93% of the variation in the implementation effect

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can be explained by these independent variables. The adjusted R-square of 0.929, which considers the number of predictor variables, further validates the goodness-of-fit of the model.

The Table 4.4 ANOVA results show that the F - F-value is 871.248 and the significance level (Sig.) is less than 0.001. This indicates that the regression model is statistically significant, meaning that at least one independent variable has a significant relationship with the dependent variable.

The unstandardized coefficient (B) for "Degree of Understanding of the Gamification Method" is 0.354, which means that, with other variables held constant, for every - unit increase in the degree of understanding, the implementation effect increases by 0.354 units. The t - value of 5.515 and a significance level less than 0.001 indicate that it is a significant predictor. Similarly, the "Degree of Student Subjectivity" has a B value of 0.368, a t - t-value of 5.512, and a significance level less than 0.001, also making it a significant predictor. The "Ability to Create a Gamified Environment" has a B value of 0.200, a t - t-value of 3.453, and a significance level less than 0.001, and is also significant. The constant term of 0.365 represents the predicted value of the implementation effect when all independent variables are zero

Table 4.3: Model Summary for Implementation Effect (teachers)

Model	R	Coefficient of Determination (R - square)	Adjusted R - square	Standard Error of the Estimate
1	0.964	0.930	0.929	0.383

Table 4.4- ANOVA Results for Implementation Effect(teachers)

Model	Sum of Squares	Degrees of Freedom (df)	Mean Square	F - value	Significance(Sig.)
1 - Regression	383.355	3	127.785	871.248	<0.001
1 - Residual	28.894	197	0.147		
1 - Total	412.249	200			

Table 4.5: Coefficients for Implementation Effect (teachers)

Model	Sum of Squares	Degrees of Freedom (df)	Mean Square	F - value	Significance(Sig.)
1 - Regression	383.355	3	127.785	871.248	<0.001
1 - Residual	28.894	197	0.147		
1 - Total	412.249	200			

Table 4.6: Model Summary for Implementation Effect (Students)

Model	R	Coefficient of Determination (R - square)	Adjusted R - square	Standard Error of the Estimate
1	0.964	0.929	0.928	0.418

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The R-value is also 0.964, showing a very strong correlation between the independent variables at the student-level (level of interest, participation level, degree of knowledge understanding) and the dependent variable (implementation effect). The coefficient of determination (R-square) value of 0.929 means that approximately 92.9% of the variation in the implementation effect can be explained by these independent variables. The adjusted R-square of 0.928 further reflects the goodness-of-fit of the model.

The F - F-value is 854.972, and the significance level (Sig.) is less than 0.001, again indicating that the regression model is statistically significant, suggesting that at least one independent variable has a significant association with the dependent variable.

The unstandardized coefficient (B) for "Level of Interest" is 0.516, which means that, with other variables held constant, for every one-unit increase in the level of interest, the implementation effect increases by 0.516 units. The t-value of 8.864 and a significance level less than 0.001 indicate that it is a significant predictor. Similarly, the "Participation Level" has a B value of 0.155, a t-value of 2.859, and a significance level less than 0.001, also making it a significant predictor. The "Degree of Knowledge Understanding" has a B value of 0.367, a t-value of 7.123, and a significance level less than 0.001, and is also significant. The constant term of 0.199 represents the predicted value of the implementation effect when all independent variables are zero.

Table 4.7: ANOVA Results for Implementation Effect (Students)

Model	Sum of Squares	Degrees of Freedom (df)	Mean Square	F - value	Significance(Sig.)
1 - Regression	448.794	3	149.598	854.972	<0.001
1 - Residual	34.470	197	0.175		
1 - Total	483.264	200			

Table 4.8: Coefficients for Implementation Effect (Students)

Model	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (Beta)	t - value	Significance (Sig.)	Lower Bound of 95.0% Confidence Interval for B	Upper Bound of 95.0% Confidence Interval for B
1 - (Constant)	0.199	0.078		2.542	<0.001	0.353	0.045
1 - Degree of Understanding of the Gamification Method	0.516	0.058	0.498	8.864	<0.001	0.401	0.631
1 - Degree of Student Subjectivity	0.155	0.054	0.145	2.859	<0.001	0.048	0.261
1 - Ability to Create a Gamified Environment	0.367	0.052	0.349	7.123	<0.001	0.266	0.469

4.4 Inferential Analysis

The multivariate research, inferential analysisserves as the core approach to uncover the associative mechanisms among variables. Beyond descriptive statistics, researchers must employ inferential analysis to explore the nature, direction, and significance of variable relationships. This study utilizes regression analysis to test the predictive effects of independent variables on dependent variables, thereby revealing the intrinsic associations between constructs [24].

4.4.1 Research Hypotheses and Analytical Framework

This section addresses two research hypotheses:

: The ability to create a gamified environment, degree of understanding, and degree of student subjectivity significantly predict the effect of implementation.

: Degree of understanding, participation, and level of

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interest significantly predict the implementation effect [25].

4.4.2 Model Construction and Result Analysis

Influencing Factors of Implementation Effect(teachers)

The "ability to create a gamified environment", "degree of understanding", and "degree of student subjectivity" were entered as predictors, with "implementation effect" as the dependent variable. The model exhibited an R^2 of 0.930 and adjusted R^2 of 0.929, indicating that the three independent variables explained 92.9% of the variance in the implementation effect, reflecting an extremely high goodness of fit.The F-value was 871.248 ($p < 0.001$), confirming the overall significance of the model and that at least one independent variable possessed predictive power for the dependent variable (Table 4.4).The degree of understanding ($\beta = 0.375$, $p < 0.001$), degree of student subjectivity ($\beta = 0.394$, $p < 0.001$), and ability to create a gamified environment ($\beta = 0.213$, $p < 0.001$) all demonstrated significant positive predictions of the implementation effect. The degree of student subjectivity had the highest standardized coefficient, indicating that enhancing students' subjective participation most potently promoted the implementation effect. The constant term was 0.365 ($p < 0.001$), suggesting a baseline implementation effect in the absence of independent variables. (Table 4.5)

Influencing Factors of Implementation Effect (Students)

"Degree of understanding", "participation", and "level of interest" were entered as predictors, with "implementation effect" as the dependent variable. The model showed an R^2 of 0.929 and adjusted R^2 of 0.928, indicating that independent variables explained 92.8% of the variance in the implementation effect, demonstrating a good fit(Table 4.6). The F-value was 854.972 ($p < 0.001$), confirming the overall significance of the model. The level of interest ($\beta = 0.498$, $p < 0.001$), degree of understanding ($\beta = 0.349$, $p < 0.001$), and participation ($\beta = 0.145$, $p = 0.005$) all exhibited significant positive predictions of the implementation effect. The level of interest had the highest standardized coefficient, highlighting that stimulating students' intrinsic interest is crucial for enhancing the implementation effect. The constant term was 0.199 ($p = 0.012$), indicating the existence of a baseline implementation effect (Table 4.8).

4.4.3 Hypothesis Testing and Theoretical Implications

Validation: All three independent variables significantly and positively predicted the implementation effect, supporting . This suggests that strengthening gamified environment design, deepening students' understanding, and enhancing subjective participation can effectively improve implementation outcomes.

Validation: All three independent variables significantly and positively predicted the implementation effect, supporting . The strong predictive power of interest levels indicates that fostering students' intrinsic interest is a core pathway to optimizing implementation effects [26,27,28].

5. Discussion

5.1 Influence of Teachers on the Implementation Effect of Gamification Method

5.1.1 Teachers' Understanding of Gamification Method

This study reveals that teachers' understanding of the gamification method plays a crucial role in its implementation effect. Several teachers do not know about this approach well, because they rely on methods they have been using for years and lack full knowledge of its principles and procedures. In turn, reliance on the classical method of lectures makes it harder to use the potential of gamification in mathematics classrooms. It is clear from the investigation that just about 30% of teachers are skilled in explaining the conceptual background of gamification, and this has resulted in several difficulties related to gamified teaching design and implementation. Often, because of a lack of full knowledge, teachers tend to use a few simple games, which do not allow them to fit the activity to their class. It is very important for teachers to learn about the gamification method before implementing it effectively[29].

5.1.2 Teachers' Attention to Students' Subjectivity

When teachers notice students’ opinions and beliefs, it also strongly affects the success of using games in teaching. Students do not hold the main role in today’s mathematics gamification activities. Because teachers sometimes do not consider students’ preferences when setting up games, the students might not help or work as a team.

For example, to choose students for games, teachers may go for top-achieving students instead of giving a chance to those who are very active. Because of this practice, other students’ personal experiences are low-prioritised, which creates marginalisation and reduces the overall impact of gamification in education. Also, letting teachers make many decisions spoils students’ opportunity to make their own choices and prevents effective learning motivation. So, teachers ought to view students as important, create fair communication with them, and ensure that all students are able to improve[30].

5.1.3 Teachers' Ability to Create Learning Environments

Teachers need to establish learning spaces, as this helps in using gamification effectively. In the process of using games in current primary school mathematics, problems with the classroom setting mostly involve order in the room and how often games are played. Some instructors choose some severe tactics for controlling students' unruly behaviour: either not paying attention to them to preserve the learning process, or setting aside time to deal with their conduct. They both do not find a suitable balance between maintaining order and keeping lessons going[31].

Meanwhile, excessively high frequency of game application also causes problems. Overusing gamification teaching keeps students in a state of constant excitement, making it difficult to maintain classroom order, distracting students, weakening the learning atmosphere, and reducing the practical effect of gamification teaching. Therefore, teachers need to scientifically regulate the frequency of game use, reasonably arrange game links, and implement refined management to optimise the classroom environment for gamification teaching and improve teaching effects.

5.1.2 Influence of Students on the Implementation Effect of Gamification Method

5.1.2.1 Students' Interest Level

Students' interest level is closely related to the implementation effect of gamification teaching. The original intention of gamification teaching is to stimulate students' learning interest through the fun of games, and the gamification method can effectively enhance students' learning interest and activate the classroom atmosphere. However, current gamification teaching faces problems such as insufficient innovation in game resources and a lack of targeted game design, leading to difficulties in maintaining students' interest.

Surveys indicate that when game forms are single and lack innovation, students' interest gradually declines over time. For example, repeated use of the same game types causes students to develop aesthetic fatigue and continuously decrease their participation enthusiasm. Therefore, to improve the effect of gamification teaching, teachers need to continuously innovate game resources and design more attractive games based on students' interests and teaching content to maintain and enhance students' interest levels[32].

5.1.2.2 Students' Participation in Classroom Games

Students' participation in classroom games directly reflects the implementation effect of gamification in teaching. Students who actively participate in games can more deeply understand and master knowledge and enhance their comprehensive abilities. However, survey results show that most students have limited participation opportunities in gamification teaching, which is related to factors such as teachers' teaching focus and game design.

Failing to be aware of how students differ in games can result in some students not joining fully, and there is less participation on average. In addition, teachers not guiding or organizing the students well during the game reduce students' desire to participate. In order to help students take part more in games, teachers should adjust the games, pay attention to all students, and arrange chances for students to participate[33].

5.1.2.3 Students' Comprehension of Knowledge

It is important to look at students' understanding of knowledge to judge how gamification teaching works. With gamification teaching, educational games help students learn and grasp mathematical knowledge. Still, many games now have problems since they may not match students' mental capabilities or teaching goals. Some games are either too hard or too easy: tough games confuse students, and easy games do not properly challenge them. Also, the same old topics and rules in some games do not inspire students and make it harder for them to understand concepts in great detail. As a result, when teachers design games, they should focus on the main things to be taught, match the game to students' abilities, and choose meaningful game materials and guidelines to guide learning and complete the goals of gamification teaching[34].

5.2 Implication

Although students' participation and interest in the gamification method have been somewhat enhanced, the comprehensive and effective implementation of the gamification method in primary school mathematics classrooms still faces challenges. Thus, teachers play a crucial and decisive role in improving the effectiveness of the gamification method. Therefore, teachers' teaching concepts, methods, and strategies need corresponding adjustments and optimisations to better meet the requirements of the gamification method.

Teachers should continuously update their teaching concepts and deepen their understanding of the gamifica-

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tion method. They should not only systematically master their theoretical basis but also constantly explore and innovate in practice, closely integrating theory with actual teaching. Through diverse learning channels, such as participating in professional training and studying academic literature, they can enhance their professional competence. Meanwhile, schools should build platforms for teacher communication to promote the sharing and exchange of teaching experiences, jointly driving the development of the gamification method. In terms of game design, teachers need to reasonably grasp the depth of the game, fully considering students' age, cognitive level, physical and mental development characteristics, as well as the difficulty and objective requirements of the teaching content. Design games that are challenging yet not overly complex to stimulate students' interest and desire for exploration. Moreover, it is essential to constantly innovate game forms, incorporate novel game elements, and enhance the fun and interactivity of the games to continuously attract students' attention.

Strengthening students' subject status and improving the quality of teacher-student interaction are also of great significance. Teachers should transform their roles, shifting from being knowledge disseminators to learning guides, and make students the main body of teaching activities. By carrying out project-based learning activities, such as mathematics-themed adventure games, students' learning interests and abilities can be stimulated. At the same time, with the help of modern technological means, such as virtual reality, augmented reality, and interactive teaching software, immersive learning environments can be created to enhance students' sense of participation and substitution. The construction of game contexts is crucial for enlivening the classroom atmosphere and increasing students' participation. Teachers should customize game contexts based on students' characteristics, combining mathematical knowledge with students' familiar life scenarios and hobbies to make abstract knowledge concrete. Strengthen students' interaction and collaboration in the game. Through cooperative models such as group discussions and project-based learning, guide students to jointly design contexts and complete tasks, cultivating their sense of cooperation and mathematical application ability. Meanwhile, clarify game rules and reward-punishment mechanisms to ensure the orderly progress of the gamification method.

Attaching importance to post-game reflection and classroom summarization is of great significance for evaluating teaching effectiveness and improving teaching quality. Teachers can introduce an external feedback mechanism, inviting other educators, parents, or experts to evaluate and provide feedback on the teaching process. Use technical tools to record the game process, conduct in-depth analysis of the existing problems in the teaching process, and formulate targeted improvement strategies. Carry out collective sharing and communication activities to promote teachers' professional growth, more comprehensively and accurately identify the problems existing in the gamification method, and drive the improvement of teaching standards.

In addition, schools should provide more support for the gamification method, such as offering sufficient teaching resources, organizing relevant training and teaching and research activities. At the same time, establish a scientific and reasonable evaluation system, comprehensively considering students' performance in the game in terms of knowledge mastery, participation, cooperation ability, etc., to provide a basis for teaching improvement. Parents should also actively participate in their children's mathematics learning, maintain close communication with teachers, understand their children's performance in the gamification method, and give encouragement and support at home to jointly create a favourable mathematics learning atmosphere.From a broader perspective, education policymakers should pay attention to the application of the gamification method in primary school mathematics education, formulate relevant policies and standards, and provide guarantees for the promotion and development of the gamification method. Meanwhile, encourage educational research institutions to conduct relevant research to provide theoretical support and technical guidance for the practice of the gamification method.

Based on the results of this study, it can be seen that there is still room for improvement in the application of the gamification method in primary school mathematics classrooms. In the future, the joint efforts of teachers, schools, parents, and education policymakers are needed to continuously improve the implementation strategies of the gamification method, so as to give full play to its advantages in primary school mathematics education and promote the comprehensive improvement of students' mathematical literacy and comprehensive abilities.

5.3 Limitations

Due to time and financial constraints, the scope of schools and regions selected in this study is extremely limited, which may fail to comprehensively reflect the differences in students' interests and perceptions of the gamification method across different regions. In addition, the study only focuses on the gamification method in primary school mathematics classrooms, without covering other subjects and different learning stages, thus restricting the universality and application scope of the research findings[35].

6. Recommendations for Future Researchers

Future research could focus on identifying other potential factors that affect the effectiveness of the gamification method, such as social-cultural backgrounds and home learning atmospheres. It is recommended to adopt a quasi - experimental research design, setting up experimental and control groups, and accurately measuring the impacts and effects of specific elements (such as game reward mechanisms and competitive elements) in the gamification method on students' learning motivation, knowledge acquisition, and classroom participation through pre-tests and post-tests. Subsequent research should preferably adopt a comprehensive research design combining qualitative and quantitative methods. By means of questionnaires, in-depth interviews, classroom observations, and other methods, it should comprehensively analyse the factors influencing students' participation in the gamification method, and explore innovative ways to stimulate students' interest in gamified learning of mathematics and related subjects based on the existing factors. Considering that this study only targets lower-grade primary school students, future research could expand the sample scope to cover all primary school grades and secondary school stages, so as to improve the gamification teaching strategies for different educational stages[36].

7. Conclusion

As conclusion of this chapter, it shows that the gamification method has achieved some initial results in the application of primary school mathematics classrooms, but it has also revealed many problems. These problems, such as the imbalance in classroom order management, the cognitive biases of teachers and students towards the gamification method, and the low achievement rate of teaching objectives, involve multiple aspects including the classroom environment, teachers' and students' cognition, and teaching implementation effects.

The study systematically analyzes the root causes of the problems from the two dimensions of teachers and students, and proposes a series of improvement strategies covering aspects such as updating teaching concepts, innovating game forms, strengthening students' subject status, optimizing the classroom environment, deepening teaching reflection, and improving the evaluation mechanism. These strategies have been demonstrated to have theoretical feasibility and practical operability.

Overall, the gamification method has great potential in the field of primary school mathematics education. However, its efficient implementation depends on the collaborative efforts of multiple stakeholders, including teachers, students, and schools. In the future, continuous in - depth exploration and practice are needed to continuously optimize the paths and methods of the gamification method, so as to fully unleash its educational value, improve the quality of primary school mathematics teaching, and promote the comprehensive improvement of students' mathematical literacy and comprehensive abilities.

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