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Effect of Smart Classroom Learning Modes and Strategies on Student's Academic Capability at Primary Education

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Abstract: The rapid advancement of technology promotes the development of modern education technology while catalyzing transformation and innovation in teaching. A smart classroom with effective learning modes and strategies enables students' academic growth, whereas the physical environment of a smart classroom alone can only have limited effect on students' academic growth. Conducting research on smart classroom learning modes and strategies holds both theoretical significance and practical value for promoting students' academic achievement. The objective of this study is to determine the effect of smart classrooms learning modes and strategies among primary school students. The study involved 36 students, and the data were analyzed using test. The results show a significant difference in the students' academic performance between the conventional learning modes and strategies and smart classroom learning modes and strategies. In addition, the use of smart classroom learning modes and strategies has greatly improved students' performance in several areas: personalized learning capacity, autonomous inquiry, knowledge construction, collaborative interaction, innovative utilization of information resources, and self-assessment capabilities.

Keywords: Informationization; Smart Classroom; Learning Modes; Learning Strategies

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1.Introduction

In the current era, characterized by unprecedented technological progress, a wave of innovation and transformation in education has been ignited by the emergence of next-generation technologies including artificial intelligence and AR/VR technology, among other cutting-edge information technologies, have spurred significant transformations and innovations in education (Kwet & Prinsloo, 2020). This evolution has given rise to the concept of "smart education," but it is not just about embracing technology. Smart classrooms, which are pivotal components of smart education, designed to elevate the experience for teachers and students. These smart classrooms define a new learning paradigm marked by distinct attributes: shared premium resources, real-time assessment and feedback mechanisms, diverse modes of communication and interaction, intelligent resource delivery, individualized learning experiences, tailored teaching approaches, and data-driven management strategies. As such, the exploration of learning modes and strategies tailored for smart classrooms holds profound theoretical significance and practical worth. It plays a crucial role in nurturing students' intellectual maturation, driving the personalization and holistic growth of education, accelerating the advancement of educational informatization, and ultimately, elevating the overall quality of education.

1.1 Current research regarding learning modes and strategies

Despite the widespread acceptance of the philosophy behind smart education, practical implementation methods, particularly the specific construction measures and implementation techniques for smart classrooms, still present challenges (Saini & Goel, 2019). Currently, the design of teaching modes in smart classrooms and the exploration of corresponding teaching strategies are at an early stage, lacking detailed, concrete, and proven-effective implementation plans (Lu et al., 2021). The current learning modes still have deficiencies in the design of their constituent elements, and their feasibility and effectiveness have not been comprehensively validated. Therefore, conducting in-depth research into learning modes and strategies tailored for smart classrooms not only bridges the gap between theory and practice but also provides strong support for enhancing teaching quality and achieving educational equity. Thus, further promoting the healthy development of the smart education endeavor.

This paper identifies that research on learning modes and strategies within smart classrooms largely relies on project-based practice, typically focusing on aspects such as instructional design and implementation. It tends to delve into these areas while also addressing current research hotspots, paying considerable attention to the establishment of a technological environment and the development of learning resources.

2.Literature review

2.1 Smart Classroom

Smart classroom refers to the use of technologies and services such as cameras, interactive boards, smart attendance systems, and a student response system in the learning process, which not only can provide students with better access to what they need, but also allow educators to evaluate their students' response in real time (Mircea et al., 2021).In the current context of building smart classrooms, significant challenges lie predominantly in the realization of personalized learning, adaptive learning, and learning analytics.

Firstly, personalized learning caters to students' diverse learning needs. Educators are tasked with providing a broader array of choices and distinct learning approaches for students to accomplish personalized learning. In the era of big data, it is the responsibility of educational departments and institutions to explore how information technology can be leveraged to help students tackle complex problems and cultivate systemic thinking based on the cognitive level, preferences, and learning style of the students, among other factors (Zhang, 2022). Secondly, adaptive learning enables tools to automatically align with students' learning requirements. Adaptive learning technologies refer to software and online platforms that proactively respond to students' learning needs (Alam, 2022). This advanced, data-driven form of learning tracks students' academic progress, reflecting their engagement levels and performance metrics. Thirdly, learning analytics plays a crucial role in the design process of smart classrooms by collecting and analyzing data accumulated in a smart classroom (Aguilar et al., 2018). Beyond merely measuring student progression, learning analytics also adapt and respond to the teaching and learning requirements of students. Within curriculum instruction, learning analytics technologies combine data analysis and visualization techniques, in order to improve the learning process (Aguilar et al., 2018). However, early studies mainly focused on the effectiveness of smart classroom facilities and information gadgets rather than the specific learning modes and strategies that can contribute to the effective us of such classroom.

2.2 Smart Classroom Learning Mode

Research related to smart classroom learning modes includes those involving mobile technology-supported smart classroom learning, activity-centered smart classroom learning, as well as personalized, autonomous, and collaborative inquiry-based learning modes.

Firstly, concerning the smart classroom learning mode focused on mobile information technology, Liu (2021) proposed it is necessary to construct English smart classroom and innovate teaching mode under the background of Internet of Things (IoT) multimedia communication. Hu (2023) argued that in the field of wisdom, applying IoT technology to classrooms can effectively improve the deficiencies of traditional teaching models, Albalawi's (2013) research suggested that tangible interaction interfaces based on mobile intelligent terminals could facilitate student's development of learning abilities and social interaction skills through interactive learning experiences. Finally, focusing on personalized, autonomous, and collaborative inquiry-based learning modes, Slotta et al. (2008) introduced the Knowledge Community and Inquiry (KCI) instructional model that integrates a dimension of scaffolded inquiry within a knowledge community approach. This model promotes collaborative exploration among students. Benkiran et al. (2015) posited that in a smart classroom setting, students can follow their own pace to learn or selectively access knowledge relevant to them to participate in courses effectively.

2.3 Smart Classroom Learning Strategy

Research related to smart classroom learning strategies includes the study of strategies that examine how and to what extent smart classrooms transform the dynamic of teaching and learning of students thereby improve learning experiences. In addition, project-based research focuses on smart classroom learning strategies for the purpose of understanding and optimizing the learning process and the teaching environments.

Firstly, concerning studies on how learning strategies in smart classrooms improve student learning capabilities, Christensen (2008) posits that a smart classroom constitutes a student-centric and intelligent environment that integrates multiple technological means such as smart devices, interactive whiteboards, and wireless network technologies in a way that humanizes education and promotes personalized and diversified pathways to improve students' academic outcomes. Secondly, attention is given to project-based research underpinning the development of information-focused smart classroom learning strategies. For more than two decades, the Maine Learning Technology Initiative (MLTI) investigated the effectiveness of various kinds of learning strategies in smart classrooms, for instance, the use of portable computers for every 7th and 8th grade students and middle-level educators (Maine Government, 2023). Moreover, Canadian universities have also conducted research by analyzing typical behaviors of 1,129 students using intelligent devices in their classes to examine whether these devices genuinely enhance students' learning abilities.

3.Design of Learning Models and Strategies for Smart Classrooms

3.1 Design of the Learning Model for Smart Classrooms

By integrating domestic and international research findings on the design aspects of learning scenarios, learning resource design, learning activity design, learning process design, and learning environment design in the context of smart classrooms, a learning mode for a smart classroom is formulated, guided by theories such as Smart Learning Theory, Learning Activity Theory, and Situated Cognition Theory.

3.1.1 Inspirations from Smart Learning Theory for Personalized Learning Design

Smart learning necessitates the recognition and understanding of fundamental facts and objective laws governing phenomena, as well as the application of knowledge and skills to create artifacts that meet personal, societal, and communal needs. It fosters mutual influence, reciprocal shaping, and bidirectional adaptation between students and their environment. In a smart learning environment, students should proactively engage in their studies, collaborate and support one another, and have the opportunity to learn anytime, anywhere, and according to their individual needs (Zhu & He, 2012).

Smart learning integrates intelligent information technology with learning activities, enabling students to access resource information and facilitating effective interaction among students themselves or between students and teachers. Moreover, it designs self-directed learning environments for students (Lee et al., 2012). Thus, in constructing the learning model for a smart classroom, it is essential to fully leverage its characteristics of personalized and collaborative environments, intelligent tracking, and a rich array of tools. This involves making appropriate choices in pedagogical approaches, subject content, and supportive technologies to facilitate the occurrence of wisdom-based learning among students.

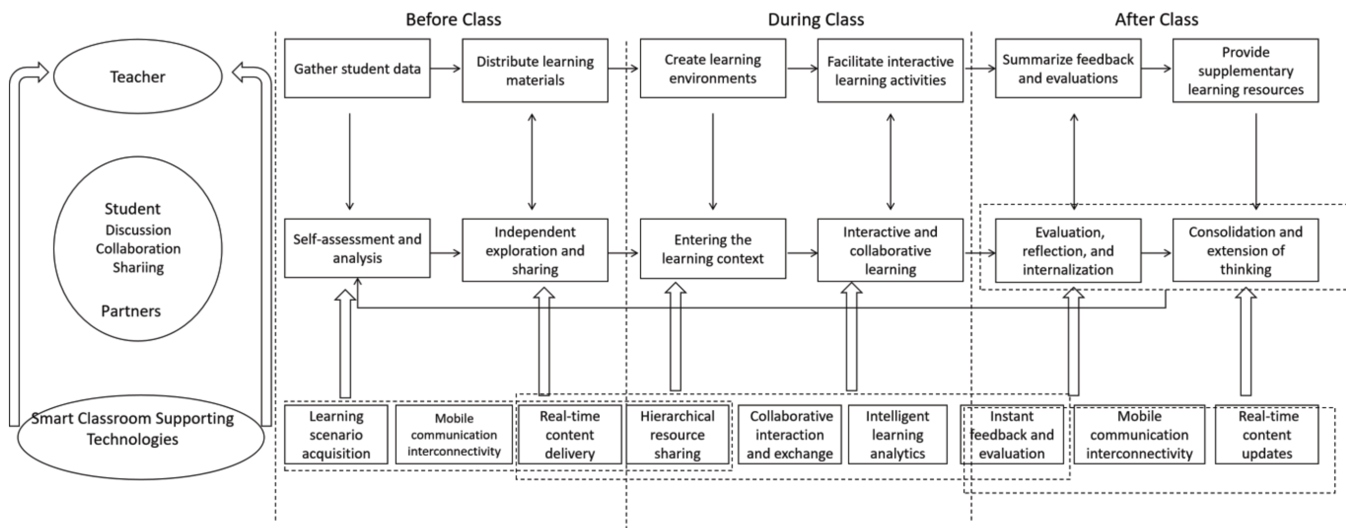
3.1.2 Insights from Learning Activity Theory for the Design of Learning Activities

Drawing from the relevant findings in Activity Theory, learning can be viewed as a holistic learning activity system. In this system, the subjects correspond to different roles, with the objects referring to the teaching content designed according to curriculum objectives. The division of labor, in the context of learning, pertains to the allocation of learning tasks among students (Yang, 2010). In the context of a smart classroom learning activity that is geared towards informatization, learning rules encompass teaching regulations, interaction norms among students, and evaluation criteria for learning outcomes. Here, the subject refers to the broad concept of students, which includes all participants in the learning process. The object denotes the subject matter being studied. The community constitutes the collective of learning partners and teachers who collaborate with students in accomplishing the learning process. Tools represent the intelligent supportive technologies employed during the learning process. Rules are the agreements that facilitate the coordination between subjects and objects within the smart classroom's learning activities. Learning division of labor pertains to the allocation of different learning tasks among various participants involved in the learning activities within such a smart classroom setting.

3.1.3 Insights from Situated Cognition Theory for Learning Context Design

In a smart classroom, it is essential to provide students with concrete learning contexts that facilitate the construction of their knowledge. These learning contexts support the development and application of conceptual understanding and methods in domain-specific knowledge. Students can leverage these contexts to build their cognitive frameworks, thereby aiding in the internalization of knowledge.

Fig. 1. Diagram of the Learning Model for Smart Classrooms



3.2 Design of Learning Strategies for Smart Classrooms

In this paper, drawing upon research on learning strategies by scholars (Weinstein, 1990; Pokay, 1990; Mckeachie et al., 1990), an analysis is conducted on the effective learning procedures, methods, techniques, and regulatory approaches that need to be considered in the learning process within smart classrooms. Combining empirical experiences gathered from case studies in smart classroom environments, this section discusses the learning strategies for such classrooms from three dimensions: cognitive strategies, resource management strategies, and multifaceted assessment strategies.

3.2.1 Cognitive Strategies

Preparation: Prior to lessons in a smart classroom, teachers can use intelligent terminals to engage students with questions and discussions, identifying their learning styles, weaknesses, and attitudes toward upcoming content. By pinpointing entry points, they can effectively organize teaching materials, setting clear objectives, content, challenges, and even sharing lesson designs. Students utilize terminals to familiarize themselves with resources and apps beforehand. For instance, in a primary school English class, pupils might learn animal vocabulary via tablets and upload collected images and audio recordings for group sharing.

Interactive Engagement: The smart classroom facilitates dynamic learning through diverse interactive spaces. Teachers create virtual scenarios where students interact and manage their time effectively. Leveraging software tools, instructors can prompt inquiry-based or task-driven activities that stimulate critical thinking and deepen understanding, e.g., composing music on a tablet app then playing it on a recorder.

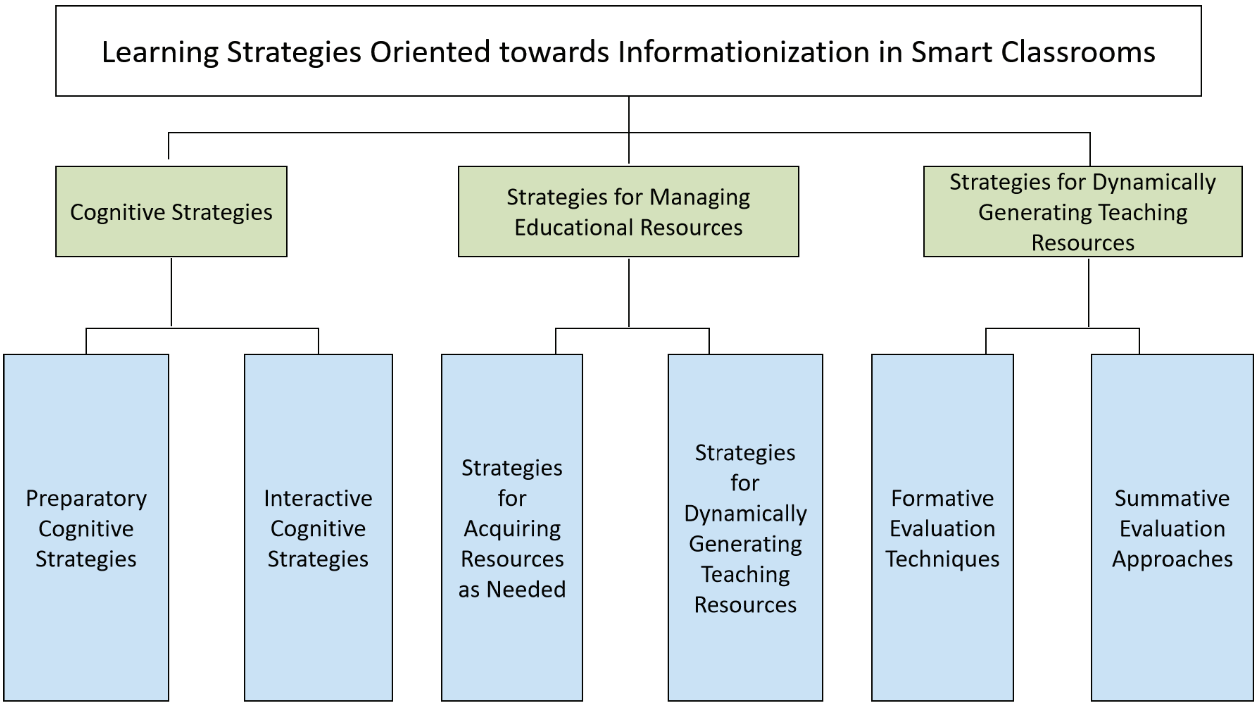
3.2.2 Resource Management Strategies

Acquisition of Resources: Smart classrooms involve a variety of hardware (e.g., tablets, interactive whiteboards, servers, network devices) and software resources (cloud libraries, teacher-shared materials, real-time pushes, and student-contributed content). Students access resources adaptively based on collaborative filtering, content sequencing, and related knowledge, enhancing problem-solving skills.

3.2.3 Multifaceted Assessment Strategies

Interactive technologies transform resource creation and presentation. Teachers develop tailored, interactive resources while the system records and analyzes students' learning behaviors, creating valuable data for future reference. Students are encouraged to actively generate and share self-created resources, contributing to the educational database. This not only expands native resource generation but also organizes them hierarchically, making them easily accessible and memorable. In practical examples, students may collaborate to produce instructional videos which they upload and share within the smart classroom ecosystem, broadening their knowledge horizons and fostering creativity.

Fig. 2. Diagram of Learning Strategies for Smart Classrooms



4.Method

4.1 Participants

The test subjects consisted of 36 primary school students from Grade 4 Class (4) at Guangzhou Yunshan Primary School who were studying the subject of Mathematics. The experiment employed the smart classroom learning model and strategies as independent variables, with the learning outcomes serving as the dependent variable.

4.2 Procedures

The experiment utilized a pre-test and post-test within a single group, as well as questionnaire surveys, to validate the effectiveness of applying the smart classroom learning model and strategies.

In the pre-test phase, the teacher presented the 'Vertical and Parallel Lines' lesson content in the smart classroom environment without employing the targeted learning model and strategies. The process included the following steps:

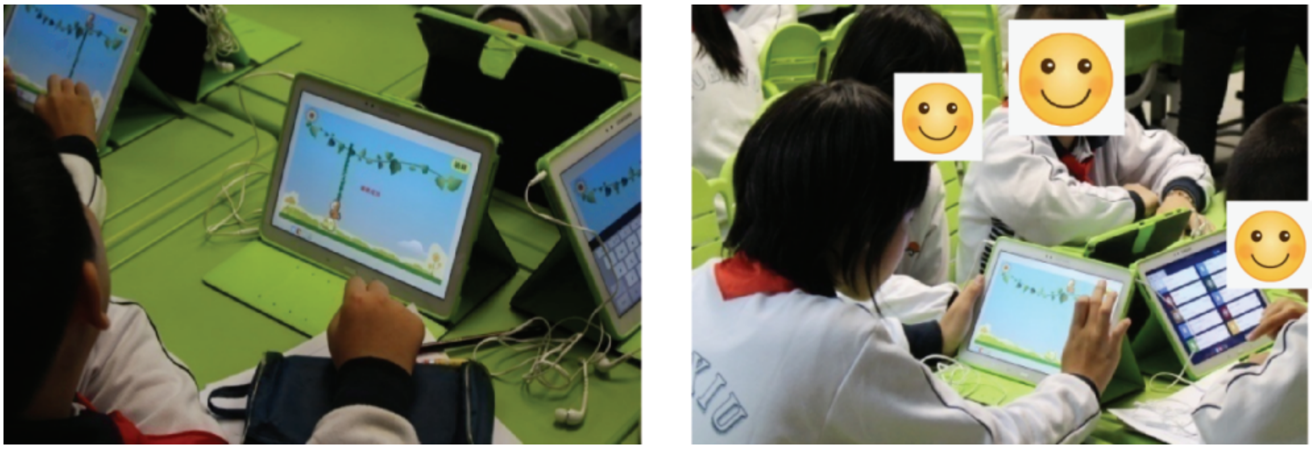
Learning session on the topic "Vertical and Parallel Lines;"

Quality assessment of learning, where the researchers collaborated with the class teacher to design an in-class test consisting of 2 major questions encompassing a total of 15 sub-questions;

A survey on students' attitudes toward their personalized learning process.

After this initial teaching period, the targeted learning model and strategies were implemented for the subsequent lessons, followed by a post-test to compare the results before and after the application of these strategies.

Fig. 3. Students Engaging in Math Games



The post-assessment content is facilitated by the same mathematics teacher within a smart classroom learning system environment that embraces information teaching models and strategies, giving a lecture to students about "drawing perpendicular lines." The process unfolds as follows:

Learning Community Design: Prior to the class, teachers, students, and peers collaboratively establish learning objectives, aiming to master the skill of accurately drawing perpendicular lines.

Learning Activity Design integrated with information-enabled smart classroom learning approaches:

(1) Preview: Students engage in analysis of drawing perpendicular lines, sharing videos for discussion.

(2) Game-based Introduction: A game is used to create a contextualized learning scenario.

(3) Review and Presentation of Pre-class Preparation: Homework assignments are critiqued, and learning roadmaps are presented.

(4) Mastery of Drawing Perpendicular Lines through Given Points: Two tasks are completed. Task one involves teachers sharing resources; students view these while completing outlines and uploading photos of their work. Task two requires group discussions where teams draw corresponding perpendicular lines according to the outline, record videos of the process, and submit them.

(5) Group Presentations and Real-time Peer Reviews: Teams present their findings, engaging in peer evaluation activities .

(6) Completion of Advanced Exercises and Surveys: Students tackle progressive practice exercises and surveys, with real-time display of answer progress, immediate feedback on scores, and dissemination of survey results, culminating in summary evaluations.

(7) Student Self-reflection Using PMIQ (Gains, Improvements Needed, Questions, and Puzzles): Students reflect on their learning experience.

(8) Completion of Post-class Assignments: students wrap up with after-class homework tasks.

Fig. 4. Creation of a Mathematical Game Practice Scenario for Jungle Exploration

The design process for a smart classroom learning environment relies on a smart classroom learning system oriented towards information technology, which delivers real-time learning resources, collects student data, facilitates instant peer evaluation, pushes adaptive game-based exercises, and dynamically displays progress of answering questions. It also conducts visual analysis of quiz scores and survey results, captures and shares videos in real time.

The learning process design encompasses pre-class, in-class, and post-class stages. In the pre-class phase, students preview the material, draw perpendicular lines to given straight lines, take photos, and upload them. They share videos demonstrating their drawing process, identify uncertainties in their methods, and proceed to the next stage of learning with these questions in mind.

During class, students engage in learning through game scenarios created to establish a learning context. They interactively learn by completing tasks and practicing within these scenarios. Post-class, students enter a personalized student space where they promptly conduct self-assessment and reflection. The learning system then pushes out supplementary exercises to reinforce what they have learned, enabling them to consolidate their knowledge through extended practice.

5.Results

5.1 Pretest-Posttest Design with a Paired T-test

According to tracking data from the "Teaching Analysis Center" module within the smart classroom learning system, the overall class average for correct rates on two quizzes improved from 91.7% to 94.5%, indicating a significant enhancement in students' mastery of knowledge.

This study utilized IBM SPSS Statistics to conduct a paired-sample t-test on the students' scores from the pre- and post-assessments in order to examine the differences in their academic performance. The results are presented the table 1.

Table 1: Paired-sample t-test results for Case 2's pretest and posttest scores.

	Paired Differences					t	df	Sig.
	Mean	SD	SE	95% CI				
				Lower	Upper			
Pre-post test	-2.85714	8.34784	1.28810	-5.45851	-.25577	-2.218	41	.032

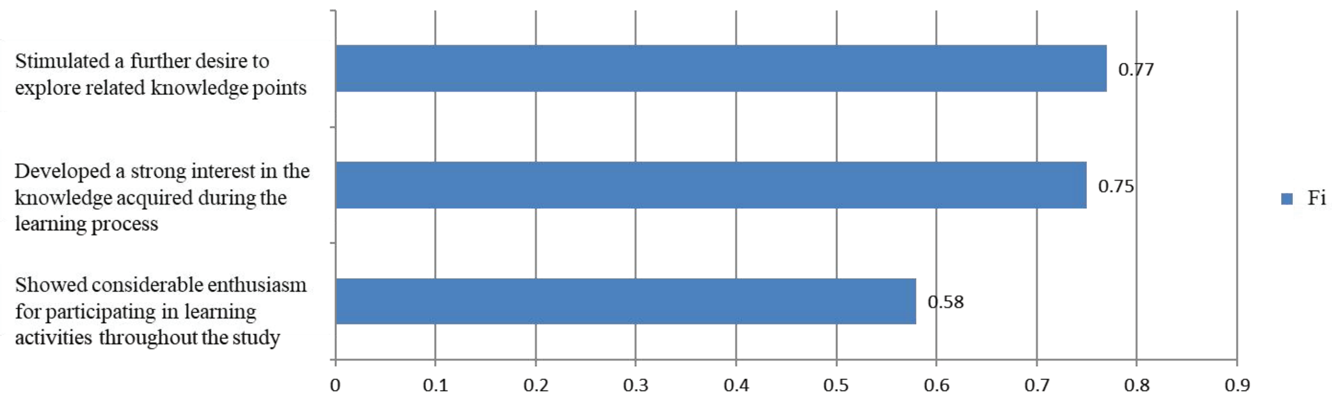
From the results of the paired-sample t-test comparing the pretest and posttest scores, it can be observed that the probability of a significant difference (Sig. [two-tailed]) = 0.032 is less than 0.05. Consequently, there is a statistically significant difference between the pretest and posttest scores. The mean score difference is -2.857, indicating that the average posttest score was higher than the average pretest score. This demonstrates that implementing a smart classroom learning model and strategies in teaching has significantly improved students' learning quality.

5.2. Survey on Enhancing Personalized Learning Engagement

The data from the survey on "enhancing personalized learning interest" among students in the mathematics lesson "drawing perpendicular lines" have been visually rendered by the smart classroom learning system.

The system's statistical results show that for the dimension of "enhancing personalized learning interest," the response rates (Fi) for all items are greater than 0. This indicates that the application of intelligent classroom learning models and strategies oriented towards information technology significantly boosts students' interest in personalized learning. Based on observations, students have reported being effectively engaged by learning activities during the pre-class, in-class, and post-class stages. They perceive the knowledge they acquire to be personally meaningful and express overall satisfaction with their learning process. Moreover, they demonstrate an aptitude for adapting to this mode of study.

Fig. 5. Visualization of the Score Rate for Enhancing Personalized Learning Interest

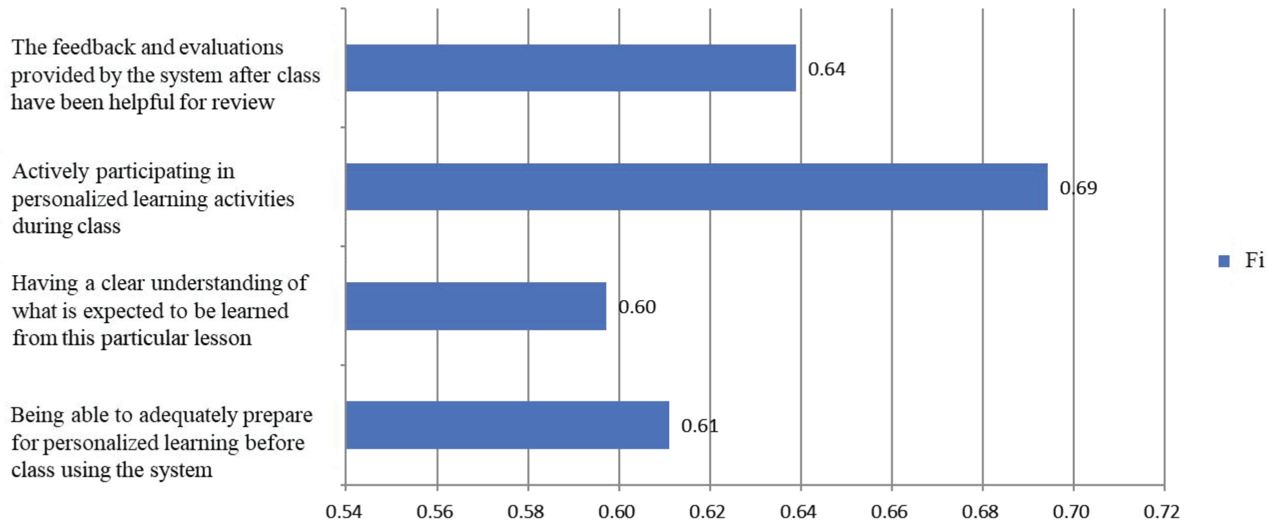


5.3 Optimizing Personalized Learning Process Survey on Drawing Perpendicular Lines

Student survey data on "Optimizing Personalized Learning Processes" in the math lesson "Drawing Perpendicular Lines" has been visually presented through an intelligent classroom learning system as shown in the figure below.

The statistical results from the system data indicate that for the dimension of optimizing personalized learning processes, the scores (Fi) for each item are all greater than 0. This suggests that the application of smart classroom learning models and strategies effectively optimizes students' learning processes, significantly enhancing their learning initiative and fostering an increase in academic self-confidence.

Fig. 6. Visualization of the Score Rate for Optimizing Personalized Learning Process



5.4 Analysis of Student Learning Ability Survey Data

In a smart classroom learning environment designed for information education, teachers and students employed a specific learning mode and strategy in a math lesson titled "Drawing Perpendicular Lines." This learning mode and strategy integrated the capabilities of the smart classroom system not only during the instructional phase but also for post-lesson evaluation. Following the lesson, the teacher utilized the intelligent classroom learning system to investigate the improvement in learning abilities among all 36 students.

All 36 students participated, indicating high levels of engagement and willingness to provide feedback. The 100% response rate and validity rate suggest that the data collected were reliable and representative of the class's experience. Upon analyzing the data, it was found that across all six critical aspects of learning—personalized learning ability (the capacity to learn at an individual pace and style), autonomous inquiry ability (ability to ask questions and seek answers independently), knowledge construction ability (constructing meaning from new information), collaborative interaction ability (working together with peers to solve problems), information resource innovation ability (creatively utilizing and contributing to digital resources), and learning evaluation ability (assessing one's own progress and understanding)—the average score rates exceeded 0.5.

This threshold value indicates a significant improvement in these skills among students when compared against some hypothetical midpoint or baseline. It signifies that the smart classroom model and its associated strategies were successful in cultivating advanced cognitive, social, and technical competencies necessary for effective learning in the digital age. The findings underscore the potential of technology-integrated classrooms to enhance the overall quality and depth of education by empowering students to be active students who can navigate complex information environments and work collaboratively in solving real-world problems.

Table 2: Questionnaire Survey Data

Dimensions	Indicator	5	4	3	2	1	Fi
Personalized Learning Abilities	Actively search for learning resources during the learning process	16	10	10	0	0	0.83
	Proactively share personal learning resources with classmates during the learning process	16	12	8	0	0	0.84
	Obtain needed learning resources through system notifications during the learning process	28	4	4	0	0	0.93
	Analyze the learning resources obtained during the learning process	26	6	4	0	0	0.92
	Master the knowledge to be learned during the learning process	24	8	4	0	0	0.91
	Learn and grasp knowledge at a relatively fast pace during the learning process	20	4	12	0	0	0.84
	Apply the mastered knowledge to solve problems within the learning process	15	13	8	0	0	0.84
Autonomous Inquiry Abilities	Actively identify learning objectives during the learning process	24	8	4	0	0	0.91
	Express personal learning needs proactively in the learning process	22	9	5	0	0	0.89
	Adjust the learning pace based on system feedback at appropriate times during the learning process	26	7	3	0	0	0.93
	Improve study methods independently within the learning process	21	9	5	1	0	0.88
Knowledge Construction Abilities	Rapidly acquire required knowledge during the learning process	26	7	3	0	0	0.93
	Analyze and synthesize knowledge effectively during the learning process	21	9	5	1	0	0.88
	Approach problems from multiple perspectives while learning	21	9	6	0	0	0.88
	Identify problems proactively and apply learned knowledge to solve them during the learning process	21	9	5	1	0	0.88
Collaborative Interaction Abilities	Actively communicate with peers and teachers during the learning process	24	8	4	0	0	0.91
	Proactively propose personal viewpoints in the learning process	22	8	6	0	0	0.89
	Humbly listen to and accommodate differing opinions from peers during the learning process	23	8	5	0	0	0.90

Dimensions	Indicator	5	4	3	2	1	Fi
Collaborative Interaction Abilities	Share learning experiences actively throughout the learning process	23	9	4	0	0	0.91
	Utilize system tools and technologies to complete collaborative tasks during the learning process	22	10	4	0	0	0.90
Information Resource and Innovation Ability	Design information resources within the learning process	22	8	6	0	0	0.89
	Create and finish the production of information resources during the learning process	21	8	7	0	0	0.88
	Share information resources during the learning process	23	10	3	0	0	0.91
Learning Assessment Skills	Analyze their own learning level based on system evaluations during the learning process	16	11	6	3	0	0.82
	Objectively assess others' performances through the system during the learning process	18	8	6	5	0	0.83
	Proactively participate in learning evaluation activities within the system during the learning process	14	12	8	2	0	0.81

5.5 Feedback on Smart Classroom Learning Experience

Upon completion of the learning activities, the teacher leveraged the real-time feedback and evaluation functions of the smart classroom by posting a discussion task on the "Teacher's Space," which said "Please share your learning experience from this class using the PMIQ diagram." Students were required to complete this reflection task in their respective "Student Spaces" on the same day. The teacher then reviewed the entire class's feedback on their learning experience in the discussion area. According to the feedback received, the majority of students had a positive learning experience, acquired new knowledge, and reported an increased interest in learning.

Student gz17 commented: "I have learned knowledge and would also like to learn how to draw parallel lines."

Student gz05 commented: "I have learned how to locate points on a line and draw perpendicular lines from points outside the line."

Student gz17 commented: "In the learning activity, I have mastered the method of drawing perpendicular lines and even shared a video on how to draw them with my classmates."

Student gz04 commented: "Through game practice, I have learned how to draw perpendicular lines, and now I want to learn how to draw parallel lines."

Student sgz01said: "I have learned how to draw perpendicular lines."

In summary, students reported their progress in geometry skills where they each acquired the technique for drawing perpendicular lines. Based on the above information, it can be deduced that students have successfully acquired the skill of drawing perpendicular lines through various interactive learning approaches and have demonstrated a strong interest in new concepts such as the method of drawing parallel lines, along with an active commitment to continued learning. This feedback provides valuable insights for educators, enabling them to design subsequent teaching content and activities tailored to students' actual needs and points of interest, thereby fulfilling their desire for a more comprehensive and in-depth study of geometry.

6.Discussion

6.1 Improving Students' Learning Quality

This paper conducts a single-group experiment on the case, employing pre-tests and post-tests, with the differences in mean scores between the two tests being -4.924, -2.857, and -2.28571, respectively. The data show statistically significant differences ($p < 0.05$), indicating that after implementing smart classroom learning modes and strategies, students' learning quality has been enhanced during their learning process within an information-based smart classroom. This research outcome aligns with previous studies. For instance, Ngendahayo et al. (2023) found that promoting technology self-efficacy, perceived usability, and learning satisfaction in a smart teacher environment can contribute to improved academic performance (Ngendahayo et al., 2023). Similarly, Shen et al. (2022) also discovered that in a smart classroom setting, students who utilized VR-assisted teaching applications for learning outperformed those using traditional teaching methods in terms of academic achievement (Shen et al., 2022).

6.2 Enhancing Students' Personalized Learning Abilities

In this paper, the improvement of students' personalized learning abilities is individually examined through a unidimensional scale survey in the case study. The response rate (Fi) for each aspect exceeds 0.5, indicating a significant enhancement in students' ability to acquire and utilize personalized learning resources. This improvement is manifested specifically in the following aspects. Students can proactively search for learning resources during the learning process, actively share their own learning resources with classmates, access needed learning resources via system recommendations, and analyze the learning resources they obtain. There is an increase in the rate of mastering personalized knowledge, where students can effectively grasp the required knowledge at a faster pace and apply this knowledge to solve problems. Yu et al. (2022) also supports this conclusion in their research, which reveals that student engagement significantly increases within smart classrooms. Meanwhile, Li et al. (2023) implemented real-time feedback mechanisms in the teaching process, providing teachers with immediate information support and enabling them to offer personalized support to students. By doing so, these studies affirm that smart classroom environments can indeed foster and enhance students' personalized learning abilities.

6.3 Enhancing Students' Autonomous Inquiry Abilities

This paper evaluates the improvement of students' autonomous inquiry abilities in the case study using a unidimensional scale survey, with all response rates (Fi) exceeding 0.5. This demonstrates that applying smart classroom learning models and strategies significantly boosts students' capacity for autonomous inquiry. Specifically, these improvements are reflected in the following aspects. Students can proactively identify their learning objectives during the learning process. They can express their individual learning needs actively. They can adjust their learning pace according to system feedback at appropriate times. They can improve their learning methods independently. Lei et al. (2022), on the other hand, constructed an evaluation index system based on the Pressure-State-Response (PSR) model. By incorporating classroom assessment, after-class assessment, and feedback into this system, they effectively promoted students' initiative and enthusiasm in learning, further supporting the idea that smart classrooms can indeed foster the development of students' autonomous inquiry skills.

6.4 Enhancing Students' Knowledge Construction Abilities

In this paper, the improvement of students' knowledge construction abilities in the case study is investigated using a unidimensional scale survey. The response rate (Fi) for each item exceeded 0.5, which indicates that employing smart classroom learning models and strategies has significantly enhanced students' ability to construct knowledge. This enhancement is manifested concretely in the following aspects. Students can swiftly access required knowledge. They can analyze and synthesize the acquired information effectively. They demonstrate multi-perspective thinking when facing problems and proactively identify issues, applying their learned knowledge to solve them. Previous study also supports this conclusion in quasi-experimental research, finding that using smart classrooms for instruction leads to a notably significant improvement in students' problem-solving abilities, showcasing the most prominent advancement effects among various learning outcomes (Cheng et al., 2023).

6.5 Enhancing Students' Collaborative Interaction Abilities

In this paper, the enhancement of students' collaborative interaction abilities in the case study is assessed through a unidimensional scale survey, where all response rates (Fi) exceed 0.5. This suggests that the application of smart classroom learning models and strategies significantly improves students' ability to collaborate and interact effectively. Specifically, these improvements are evidenced by four aspects. Students actively communicate with their peers and teachers. They proactively express their own opinions. They humbly listen to and accommodate different perspectives from their peers. They willingly share experiences and use system technologies to complete collaborative inquiry tasks. These findings align with those of Yang et al. (2017), whose research showed that students in technology-rich classrooms (TRCs) tend to engage more deeply in both individual and collaborative learning compared to those in multimedia classroom environments. This study thus confirms that using smart classrooms can indeed foster enhanced collaborative interaction skills among students.

6.6 Enhancing Students' Information Resource and Innovation Abilities

In this paper, the enhancement of students' collaborative interaction abilities is examined through a unidimensional rating scale in each case study, where all scores (Fi) exceed 0.5. This signifies that employing an information -based smart classroom learning model and strategies has significantly boosted students' ability to collaborate and interact effectively. Specifically, this improvement manifests itself in students demonstrating. The initiative to communicate with their peers and teachers. A willingness to proactively express their own ideas. An open-mindedness to listen respectfully and accommodate differing opinions from classmates. An eagerness to share experiences and utilize system technologies to complete collaborative investigative tasks. These findings are consistent with existing studies, which revealed that in technology-rich classrooms (TRCs), students tend to engage more deeply in both individual and collaborative learning compared to those in multimedia classroom environments (Yang et al., 2017). Therefore, this research confirms that implementing smart classroom approaches can indeed lead to significant advancements in students' collaborative interaction skills.

6.7 Enhancing Students' Information Resource and Innovation Abilities

In this paper, the improvement of students' information resource and innovation capabilities in each case study is assessed using a unidimensional scale survey with all response rates (Fi) surpassing 0.5. Implementing information-based smart classroom learning models and strategies significantly boosts students' abilities to innovate with information resources, specifically evidenced by their capacity to design, create, and share information resources. This finding parallels the results of Nguyen et al. (2022), who discovered that projects incorporating intelligent learning concepts and innovative methods can foster a positive learning environment that enhances students' thinking abilities, knowledge, skills, and ultimately, their creativity.

6.8 Improving Students' Learning Assessment Skills

In this study, the development of students' learning assessment skills within each case was also measured using a single-directional rating scale, where the rate of success (Fi) exceeded 0.5 for all items. Applying information -oriented smart classroom learning models and strategies has led to significant advancements in students' ability to evaluate their own learning, objectively assess others' performances, and proactively engage in learning evaluations. These outcomes align with existing research findings. Previous researchers designed a method for creating an AI-driven English Language and Literature smart classroom along with its application assessment (Zhang et al., 2023). This approach facilitated students' familiarity with English contexts and cultural backgrounds, thereby leading to comprehensive improvements in their language proficiency and fostering their ability to conduct self and peer assessments effectively.

7.Conclusion

Through the examination of empirical data derived from an experiment within primary school mathematics lessons in a technologically advanced smart classroom context, the research findings underscore the substantial positive impact that these environments can exert on students' learning outcomes. The statistical measure represented by the score rate Fi serves as compelling evidence, highlighting an upward trend in students' multifaceted learning competencies across various dimensions. Synthesizing student feedback on their learning experiences and observations of teachers' practices, it is evident that the application of information-directed smart classroom learning models and strategies can effectively improve the overall learning quality for students. It also boosts students' personalized learning interests, optimizes their individualized learning processes, and elevates their abilities in personalized learning, autonomous inquiry, knowledge construction, collaborative interaction, information resource innovation, and learning evaluation.

Looking ahead, future research endeavors should delve deeper into the realm of intelligent teaching modes and instructional strategies underpinned by advanced algorithms such as machine learning and deep learning. These studies aim to validate and optimize the practical effectiveness of these emerging models and strategies, further revolutionizing education within smart classrooms and beyond.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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