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Innovative Research on TMS Tripartite Collaborative Teaching System for Higher Mathematics Based on Informational Teaching

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Abstract

With the rapid development of Information and Communication Technology (ICT), traditional college mathematics teaching is increasingly showing deficiencies in knowledge delivery, student engagement, and personalized support, making it difficult to adapt to the diverse and advanced learning needs of current college students. Based on an in-depth analysis of the current situation and main issues of mathematics teaching in colleges and universities, this paper proposes a teaching method based on an ICT platform. The platform adopts a three-tier architecture comprising foundation, data, and application layers, integrating functions such as curriculum knowledge graph construction, learning behavior data collection, student portrait generation, personalized lesson plan design, and intelligent matching of teaching resources via the Teacher-Machine-Student (TMS) integration. This system facilitates precise alignment of instructional content with student profiles, enabling personalized learning arrangements through diverse pathways and levels. Its implementation enhances teaching efficiency, refines pedagogical pathways, and drives the transformation of college mathematics education toward intelligent, digitally enhanced formats.

Keywords: Information and communication technology, Teaching and learning, Teacher-machine-student, Mathematics education in universities, Education platform.

1 | Introduction

The development and iteration of Information and Communication Technology (ICT), represented by AI, are advancing towards the fourth technological revolution. With the ongoing innovation in informatization, the education sector is undergoing self-renewal and breakthroughs [1]. In recent years, there have been many practical applications of ICT in the classroom, and many scholars have analyzed and optimized it from various

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perspectives. Hall and Lundin [2] found that the use of ICT in education accelerated during the COVID-19 pandemic. They observed that Swedish elementary school students could use ICT to simplify repetitive tasks during learning and discussed whether to use digital technology more intensively. Winter et al. [3] surveyed students and teachers in Ireland, emphasizing the dynamic interactions that influence teachers' use of ICT and the need for teachers to maximize the advantages of online learning over traditional classrooms. Providing students with greater learning flexibility and fewer learning barriers through digital materials. Graham et al. [1] investigated the use of ICT in and out of the classroom in South Africa, described the benefits of integrating ICT into mathematics teaching and learning, and provided policy guidance on resource allocation and teacher training in South African mathematics classrooms. Cirneanu et al. [4] proposed a digital teaching platform based on information technology that significantly enhanced students' understanding and decision-making abilities for abstract mathematical concepts by integrating visual simulations, interactive resources, and real-time feedback mechanisms, while supporting teachers in dynamic assessment and teaching strategy optimization.

Tashtoush et al. [5] conducted a descriptive analysis of mathematics teachers in Abu Dhabi Emirate, exploring their cognition of introducing AI systems and applications in the classroom, focusing on analyzing the role and practical challenges of AI in supporting personalized teaching, enhancing students' learning motivation and academic performance, and providing an empirical basis for the integration of AI teaching in future schools. Li [6] comprehensively adopted the technology acceptance model and the technological pedagogical and content knowledge to systematically reveal the key factors influencing Chinese primary school mathematics teachers' adoption of AI technology, and provided theoretical support and practical guidance for promoting the effective integration of AI in teaching practice. Gouia-Zarrad and Gunn [7] introduced ChatGPT as an intelligent auxiliary tool for differential equation instruction, significantly stimulating students' interest in numerical methods, effectively enhancing their programming skills and classroom participation, and demonstrating the potential of generative AI in higher mathematics education. Overall, the research results of scholars indicate that the application of ICT in education has been widely practiced in different countries and has played a positive role in enhancing teachers' teaching efficiency and improving students' academic performance.

2 | The Main Problems in Mathematics Education in Universities

There is a significant lack of learning situation assessment and insufficient dynamic adjustment in the formulation of teaching plans [8]. In the process of constructing teaching plans for university mathematics courses, scientificity and dynamic adaptability have always been the core principles of teaching. In the process of curriculum design, teachers cannot generally collect and analyze students' pre-learning behaviors, which makes it difficult to accurately match the teaching starting point with students' actual knowledge reserves and cognitive characteristics. After the course was implemented, due to the lack of a feedback loop, student learning effectiveness data were not effectively integrated into teaching decisions.

It is difficult for teachers to implement personalized teaching for students [9]. Due to the relatively short teaching cycle in university mathematics, the interactive relationship between teachers and students in the classroom exhibits a phased pattern. If personalized teaching plans are implemented, on the one hand, due to the limitations of traditional teaching, the limited teaching period makes it difficult to form effective accumulation of learning behavior data; On the other hand, teachers need to invest a large amount of human capital in diagnosing learning situations and designing teaching plans, which leads to low efficiency in the output of teaching resources in the unit. In addition, due to the lack of dynamic feedback mechanisms and iterative algorithms for teaching strategies, it is difficult for teaching plans to form a spiral upward pattern of "evaluation adjustment optimization", which can easily lead to deviations in the adaptability of teaching strategies to learning contexts.

Teaching behavior exhibits significant homogenization and low levels of interaction [10]. Classroom teaching activities heavily rely on textbooks and presentation materials, forming a single teaching paradigm dominated by teacher-led text transplantation and courseware display. Under this teaching model, teachers dominate classroom discourse by leveraging their structural mastery of the subject knowledge system and their absolute control over teaching materials. Due to the predetermined nature of teaching content and presentation formats, the classroom teaching process is highly formulaic, with the roles of teachers and students solidified as knowledge transmitters and passive receivers. This imbalance in the teaching power structure has led to serious alienation in the classroom interaction ecology. Students' participation in classroom activities is often limited to passive listening and mechanical recording, lacking knowledge construction, thinking collision, and practical application, thereby weakening their learning motivation and willingness to explore independently.

Classroom interaction exhibits significant one-way characteristics [11]. Traditional classroom teaching revolves around imparting knowledge, forming a linear knowledge transmission model of "teacher lectures and student reception". This argument-cramming teaching compresses students' active thinking space, leaving them in a passive receiving state for a long time, making it difficult to sustain a deep-thinking, knowledge-construction process. Mathematics, with its rigorous logic and systematic knowledge, further exacerbates cognitive contradictions between teachers and students in higher education. Due to the limitations of classroom time, when teachers fail to effectively implement pre-class preview design, and students lack prior knowledge, students are easily trapped in comprehension difficulties due to cognitive overload from short-term classroom teaching. Especially in the teaching of highly theoretical courses such as advanced mathematics and calculus, teachers often focus on the teaching of abstract knowledge, such as formula derivation and theorem proof, neglecting the construction of the connection between mathematical knowledge and practical application scenarios. The imbalance in this teaching content makes it difficult for students to establish a cognitive bridge between mathematical theory and practical problem-solving, seriously restricting their ability to apply mathematics and the development of innovative thinking in practice.

3 | Design of College Mathematics Education Platform Based on Information and Communication Technology

3.1 | Discussion on Digital Teaching

Digital teaching is a new product of the deep interaction between ICT and education. This concept is an educational method that enhances the quality of student learning and teacher teaching. It can not only ensure that students meet teachers' teaching requirements, but also improve teachers' objective controllability in the teaching and knowledge transfer processes [12]. The core features of digital teaching include teachers using ICT to organize all teaching processes, and students using ICT to enhance their understanding of abstract knowledge. Through the use of ICT in teaching preparation and process, teachers can ensure that their students not only master classroom knowledge but also learn from it and develop skills that benefit them.

3.2 | Analysis of the Function of Information and Communication Technology in Teaching

Human-computer interaction views intelligent technology and machines as participating entities in the educational and teaching process, thereby forming a two-way learning and constructive relationship with teachers and students [13]. We propose establishing a Teacher-Machine-Student (TMS) tripartite interactive university mathematics education platform based on information-based teaching to address the problems in university mathematics education that need to be solved. As shown in *Fig. 1*, the education platform uses the entire teaching process as the vertical axis, with three core stages: teaching preparation, teaching implementation, and teaching feedback. Using ICT as the horizontal axis, covering three key layers: the foundation layer, data layer, and application layer. Interweaving vertically and horizontally, forming a three-dimensional architecture with stages as veins and technologies as networks. The progressive logic of vertically anchoring teaching stages and the deep penetration of technology empowerment at the horizontal level support the interaction and integration of the two, which not only provides precise technical support for each teaching stage but also enables the value of different technical levels to be concretely implemented in the teaching process.

Table 1. Analysis of the function of ICT in teaching.

ICT in Teaching	Base Layer	Data Layer	Application Layer
Instructional preparation	Split content with mind maps; design layered preview tasks; collect preview questions via "Rain Classroom."	Record test accuracy and response time; calculate knowledge mastery; generate learning profiles and trend predictions	Automatically generate multi-difficulty lesson plans; support teachers in adjusting teaching arrangements.
Teaching implementation	Visualize content with dynamic tools; interact via "Rain Classroom"; insert quizzes and discussions.	Collect and analyze attention data; generate real-time feedback based on answers and questions.	Remind teachers to adjust the rhythm; recommend micro-courses and challenges; assist with grouping and track progress.
Teaching feedback	Generate reports with interaction data, knowledge heatmaps, and ability growth curves.	Statistic homework/quiz results; compare with previous data; identify students needing tutoring	Push personalized supplementary resources; provide periodic analysis; generate next-stage learning plans.

3.3 | Preparation Stage for Teaching

Basic level: divide the content of this section into four levels, which include concept, formula, example, and application. Use a mind map to present the teaching context clearly. Three sets of preview tasks were designed for students with varying backgrounds, covering basic concepts, advanced proofs, and programming examples. These tasks were accompanied by text lectures, diagrams, and animations to help students organize their knowledge frameworks in advance; at the same time, through the "Rain Classroom" platform, questioning, voting, and answering modules are set up to enable teachers to understand students' previous progress and questions before class, providing a basis for subsequent hierarchical teaching.

Data level: the online prerequisite test is stratified based on students' level, and the platform automatically records the number of students as s, the correct answer rate for each knowledge point as $CR_{s,c}$, the answer time as $T_{s,c}$, and common types of mistakes. To comprehensively measure the mastery of n knowledge points by s students, based on the concept of "mastery score" proposed by Sapountzi et al. [14] in the Bayesian Adaptive Mastery Assessment (BAMA) model, this platform proposes the following model to calculate their knowledge mastery as $M_{s,c}$:

$$M_{s,c} = \frac{1}{n}\sum_{c=1}^{n} CR_{s,c}(1 - \frac{T_{s,c}}{T_{maxs,c}}). \tag{1}$$

Among them, $CR_{s,c}$ represents the accuracy of students on knowledge point c, $T_{s,c}$ is the time for students to answer on knowledge point c, and $T_{max,c}$ is the reasonable upper limit time for the question on that knowledge point. This model accounts for both accuracy and fluency in answering questions, with an output range of [0, 1]. The higher the value, the more firmly the student grasps the knowledge point. At the same time, the system also collects multimodal student behavior data during the preview stage, including video-viewing duration and playback speed, practice submission records, question keywords, and time distribution. Based on test results and behavioral data, the system automatically generates learning profiles for each student, covering core information such as mastery of various knowledge points, programming interests, typical weak links, and more, and presents them as radar charts or progress bars for visualization. Based on historical class data, the system further predicts students' future learning trends. It provides teachers with risk warnings and personalized supplementary teaching suggestions, such as pushing basic reinforcement resources and arranging hierarchical teaching activities.

Application level: based on the knowledge graph and student profile description, automatically generate three difficulty levels of lesson plans: basic version, advanced version, and challenge version, including blackboard outline, demonstration examples, interactive design, and expansion task suggestions. At the same time, select materials from the question bank, video library, and code example library that align with this section's objectives, and prioritize pushing them based on students' needs. Teachers can adjust the module order and resources in real time on the visualization platform, and the platform will automatically synchronize updates and generate teaching arrangements, including time nodes and links, ensuring that the teaching design is highly compatible with students' needs.

3.4 | Teaching Implementation Stage

Basic level: in the classroom, abstract content is visualized through dynamic animations, pausing GIFs, and interactive charts, supporting students to interact in real-time on large screens or mini programs; with the help of the "Rain Classroom" answering function, the real-time answering accuracy is calculated, and the bullet screen questioning module helps teachers respond to students' questions promptly. The classroom also includes timed quizzes, group discussion tasks, and Python modeling exercises, allowing students to consolidate their foundational knowledge while experiencing interdisciplinary applications.

Data level: during the classroom process, the platform continuously samples the attention status of students through a camera and judges whether each student is "focused" (marked as 1) or "distracted" (marked as 0) once per second, for a total of N samples. Based on the attention quantification method proposed by Zheng et al. [15] for classroom behavior recognition, the platform proposes dynamically updating students' learning state labels, such as "focused" or "distracted," based on sampled data. The calculation formula is as follows:

$$A_s^{(t)} = \frac{1}{N}\sum_{i=1}^{n} I\{\text{fucosed}_{s,i}\} = 1, A_s^{(t)} \in [0,1].$$

When $A_s^{(t)}$ reaches the preset threshold τ_A, it is judged that the period is "concentrated"; otherwise, it is "distracted", that is:

$$A_s^{(t)} = \begin{cases} 1, A_s^{(t)} \geq \tau A, \\ 0, A_s^{(t)} \leq \tau A. \end{cases}$$

The platform combines $Z_s^{(t)}$ with other classroom behaviors such as quick-response performance and barrage questioning to draw students' knowledge mastery curves, and to analyze the quality of group discussions and the depth of questioning, providing teachers with immediate feedback and supporting flexible adjustments to classroom strategies.

Application level: when the platform detects a decrease in the attention of most students, it will automatically remind teachers to adjust the pace of explanation; The intelligent learning assistant recommends corresponding micro lesson videos in real-time based on bullet comments and questions; For students who are actively learning, higher difficulty challenge questions or interdisciplinary projects will be pushed, and automatic grouping of competition questions will be assisted to track the progress of each group and issue mid-term reminders promptly, so that the classroom can maintain high interactivity while also considering in-depth exploration.

3.5 | Teaching Feedback Stage

Basic level: the report generated after class includes the correct answer rate, number of questions, discussion activity, and completion status of quizzes and programming tasks; Visualize the mastery of each knowledge point through a knowledge graph heatmap; at the same time, the ability growth curve of the achievement rate of hierarchical goals over time provides teachers with a learning overview of the class and individuals, helping to evaluate the overall teaching effectiveness.

Data level: the platform calculates the completion rate and types of errors in assignments and tests, generates a class learning heatmap and individual blind spot reports for students, and compares the current and previous learning reports to visually present areas of progress and improvement; By combining teacher evaluation with platform automatic scoring and community discussion participation, a comprehensive assessment of students' comprehensive abilities is conducted to timely identify high-risk students and provide data support for subsequent tutoring.

Application level: based on student learning reports, push personalized micro lessons, exercises, and simulation questions, and build an adaptive remedial system; Regularly release periodic reports to provide teachers and students with overall class analysis and personalized learning suggestions, and adjust interactive activities and homework difficulty based on feedback suggestions, recording the effectiveness of educational reform for iterative optimization; Finally, based on the full cycle data and project evaluation, the platform generates the next stage of learning plan and expansion route, helping students clarify their future learning and development direction.

3.6 | Architecture Design

To utilize ICT and build a digital teaching platform for higher mathematics courses in universities, the architecture can be divided into four layers, as shown in *Fig. 2*.

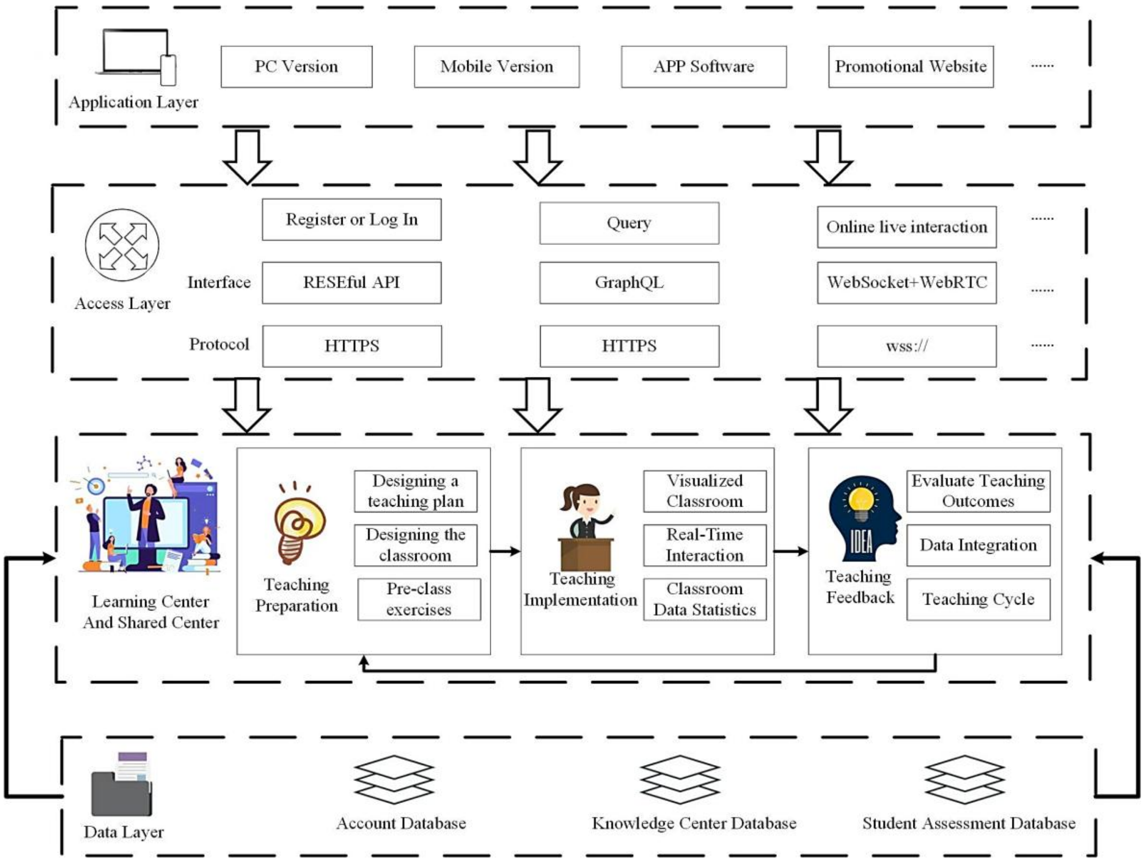

Fig. 2. Design of ICT teaching platform.

The application layer is the entry point for teachers and student users to access the digital teaching platform. This level includes PC, mobile, and computer terminal devices, as well as promotional websites accessed via browsers, etc. Teachers analyze, judge, guide, and provide feedback on students' learning processes at the application layer. Students can complete various learning tasks assigned by teachers through the application layer, increasing their interaction with teachers during learning. The access layer mainly provides program interfaces for users. The access layer of the education platform needs to support multiple interfaces and protocols, tailored to business scenarios. The access layer registers and logs in to the terminal devices and teaching platform applications for teacher and student users, and sends registration requests to the platform's Application Programming Interface (API) gateway via HTTPS. After receiving the client's registration request, the API gateway performs preliminary verification and forwards it to the user service responsible for user management. In the query scenario of the teaching platform, the HTTPS protocol serves as the transport layer protocol, providing encrypted communication between the client and server to ensure the security of query requests and data responses. The GraphQL interface, as an application-layer query language, allows clients to specify the structure of the required data, avoiding the data redundancy or multiple-request problems of traditional APIs. The GraphQL server parses it and returns accurate results. In the online live interaction scenario of teaching platforms, WebSocket provides low-latency signaling interaction through wss://, such as students executing actions to connect to the microphone, teachers executing actions to control the digital teaching classroom, and WebRTC is responsible for point-to-point or multi-terminal real-time audio and video streaming, such as teacher-student microphone connection, screen sharing, and other actions. The learning and sharing centers are among the core layers of the digital teaching platform.

The functions of this layer can be included in three parts: 1) teaching preparation, 2) teaching implementation, and 3) teaching feedback. Each function is designed to meet the needs communicated by users through the access layer and to accurately perform actions such as retrieval, push, browsing, and on-demand playback. For example, in teacher preparation, teachers rely on the teaching platform to design lesson plans, conceptualize classrooms, and assign pre-class exercises to better align students with the teacher's teaching pace during implementation.

During the teaching process, teachers control the teaching platform and present visual teaching content that traditional teaching lacks. For example, using Python to simulate the monotonicity, additivity, and boundedness of the function $f(x) = [(1 + 1/x)]x$, and modifying the input code to obtain a new image of the value of x, provides students with a visual mathematical teaching process that is not limited to textbooks and presentations. The platform supports real-time interaction and real-time testing between teachers and students. The system synchronously collects classroom data, including interaction frequency and answer accuracy, helping teachers dynamically adjust the teaching pace and strategies. In the feedback stage of teaching, teachers use the teaching platform to dynamically track students' mastery of knowledge and classroom participation, and combine multidimensional data, such as homework completion quality and project performance, to form personalized student ability profiles. Students can assess their own learning through the platform's teaching assessment. If students participate in teaching evaluation, two-way communication can quickly expose teaching problems.

Teachers adjust course content and optimize teaching strategies based on the teaching improvement suggestions generated by the platform, then apply them in subsequent classrooms. The iterative optimization mechanism based on data feedback makes teachers' teaching decisions more scientific, students' learning processes more autonomous, and ultimately achieves continuous improvement in teaching and learning. The data layer is primarily used to store, read, compute, and manage important data. This layer includes an account database, which is the core of user identity management and permission control, storing user account data to ensure account security, functional adaptation, and personalized services. At the same time, encrypted storage and operation logs are used to ensure account security and data traceability.

The knowledge center database is the core of supporting teacher-led content management, personalized learning for students, and the optimization of teaching resources. It can construct a structured knowledge graph by discipline and stage, including knowledge point names, definitions, chapters, related knowledge points, etc., forming a clear knowledge network. Capable of storing metadata of various teaching materials, such as courseware, videos, audios, exercises, cases, etc. The core storage module for recording and analyzing students' learning processes and outcomes in the student assessment database. Form process-based learning data on students' completion of previews, classroom interaction performance, and completion of classroom exercises. The interim achievement data includes submission times and assignment quality, as well as the teacher's grading and correction records. The learning effectiveness report, generated by a multidimensional analysis of the above data using deep learning algorithms, provides a basis for personalized tutoring and teaching optimization.

3.7 | Operating Mechanism

The tripartite collaborative paradigm of TMS clearly defines the division of labor: teachers focus on cultivating higher-order thinking, machines undertake cognitive computing tasks and construct learning archives, and students explore learning in the space of ICT. The three parties work closely together in typical scenarios such as flipped classrooms and math lab classes in advanced mathematics. As shown in *Fig. 3*.

The TMS tripartite collaborative teaching system demonstrates overall synergy within the teaching subject and establishes a circular mechanism around the core teaching subject. Teachers, as leaders, break through the traditional role of lecturers, and students progress from passive learners to subjectivity. ICT serves as

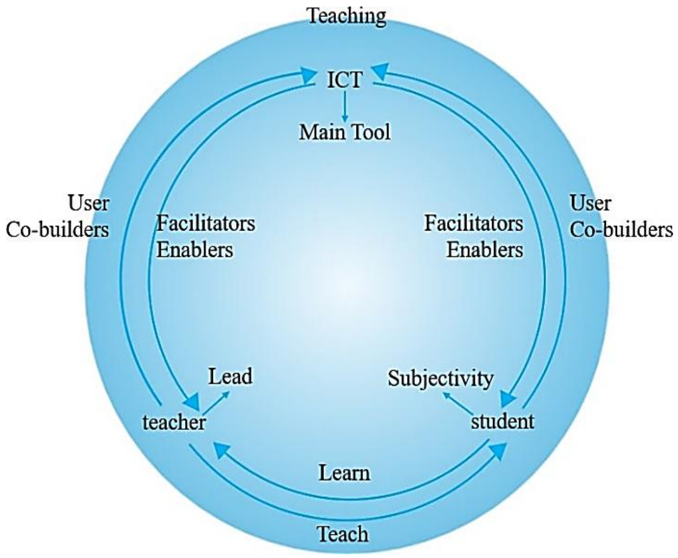

Fig. 3. Operating mechanism of the TMS tripartite collaborative teaching system.

The main tool linking teaching and learning. Although both serve as facilitators and enablers of ICT, they carry different connotations. For teachers, it serves as a teaching assistant to assist in lesson preparation, position learning situations, and an innovative engine to expand their abilities in virtual experiments, AI analysis, and more. For students, it is a learning carrier that supports micro-lesson previews and interactive feedback, as well as a growth fuel that activates personalized paths and data reflection. Similarly, although teachers and students describe ICT as a facilitator and an enabler, their connotations differ. For teachers, technology helps with precise lesson preparation and analysis of learning situations, and empowers the expansion of teaching methods and the improvement of skills. For students, technology facilitates the promotion of self-directed learning behavior, empowers active exploration and reflection on growth potential, stimulates traditional one-way Teach-Learn relationships, and enables two-way collaboration. Teachers extend from teaching guidance to learning support, and students upgrade from learning response to teaching participation. The two, as users and co-builders of ICT, continuously iterate the system, forming a cyclic enhancement effect of "teaching technology learning" mutual promotion.

4 | Conclusion

This article proposes a TMS tripartite collaborative teaching platform based on ICT to address the common problems of insufficient personalization, weak interactivity, and lagging teaching adjustments in mathematics teaching in universities. This system adopts a three-layer architecture of "foundation data application", integrating teacher experience, intelligent algorithms, and student learning behavior data, running through all aspects of teaching preparation, classroom implementation, and feedback optimization, achieving precise matching between teaching resources and student characteristics. This model not only enhances the responsiveness and adaptability of teaching but also provides an effective path to building a data-driven, dynamic teaching mechanism. Teachers can quickly diagnose learning situations and develop tiered teaching plans based on this; Students can also receive continuous support and personalized resource recommendations, enhancing their self-directed learning abilities and learning outcomes. Future research can further introduce artificial intelligence generation technology and multimodal data analysis methods to expand the intelligent interaction and resource-optimization capabilities of teaching systems and to promote the continuous evolution of mathematics teaching in universities towards smarter, more accurate, and more efficient directions.

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Authors' Contributions

The author solely conducted the research and prepared the manuscript and has approved its final version.

Data Availability

The data are available from the corresponding author upon reasonable request.

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Conflict of Interest

The authors declare no conflict of interest.

Consent for Publication

The author confirms consent for the publication of this work

Ethics Approval and Consent to Participate

This article does not include experiments involving humans or animals.

References

[1] Graham, M. A., Kruger, G. M., & van Ryneveld, L. (2024). Developing a novel model for ICT integration in South African education: Insights from TIMSS. *Education sciences*, *14*(8), 865. https://doi.org/10.3390/educsci14080865

[2] Hall, C., & Lundin, M. (2024). Technology in the classroom: Personal computers and learning outcomes in primary school. *Economics of education review*, *100*, 102536. https://doi.org/10.1016/j.econedurev.2024.102536

[3] Winter, E., Costello, A., O'Brien, M., & Hickey, G. (2021). Teachers' use of technology and the impact of Covid-19. *Irish educational studies*, *40*(2), 235–246. https://doi.org/10.1080/03323315.2021.1916559

[4] Cirneanu, A. L., & Moldoveanu, C. E. (2024). Use of digital technology in integrated mathematics education. *Applied system innovation*, *7*(4), 66. https://doi.org/10.3390/asi7040066

[5] Tashtoush, M. A., Wardat, Y., Ali, R. Al, & Saleh, S. (2024). Artificial intelligence in education: Mathematics teachers' perspectives, practices and challenges. *Iraqi journal for computer science and mathematics*, *5*(1), 20. https://doi.org/10.52866/ijcsm.2024.05.01.004

[6] Li, M. (2025). Integrating artificial intelligence in primary mathematics education: Investigating internal and external influences on teacher adoption. *International journal of science and mathematics education*, *23*(5), 1283–1308. https://doi.org/10.1007/s10763-024-10515-w

[7] Gouia-Zarrad, R., & Gunn, C. (2024). Enhancing students' learning experience in mathematics class through ChatGPT. *International electronic journal of mathematics education*, *19*(3), 1–9. https://doi.org/10.29333/iejme/14614

[8] Großmann, L., & Krüger, D. (2024). Assessing the quality of science teachers' lesson plans: Evaluation and application of a novel instrument. *Science education*, *108*(1), 153–189. https://doi.org/10.1002/sce.21832

[9] Gibbs, K. (2023). Voices in practice: Challenges to implementing differentiated instruction by teachers and school leaders in an Australian mainstream secondary school. *The Australian educational researcher*, *50*(4), 1217–1232. https://doi.org/10.1007/s13384-022-00551-2

[10] Gunawardena, M., Bishop, P., & Aviruppola, K. (2024). Personalized learning: The simple, the complicated, the complex and the chaotic. *Teaching and teacher education*, *139*, 104429. https://doi.org/10.1016/j.tate.2023.104429

[11] Yu, H., Shi, G., Li, J., & Yang, J. (2022). Analyzing the differences of interaction and engagement in a smart classroom and a traditional classroom. *Sustainability*, *14*(13), 8184. https://doi.org/10.3390/su14138184

[12] Hase, A., & Kuhl, P. (2024). Teachers' use of data from digital learning platforms for instructional design: A systematic review. *Educational technology research and development*, *72*(4), 1925–1945. https://doi.org/10.1007/s11423-024-10356-y

[13] He, H. (2025). From human-computer interaction to entangled symbiosis: Research on the theoretical model and real-world applications of" teacher-student-machine" triadic interaction in new engineering under the digital intelligence era. *Journal of educational theory and practice*, *2*(2). https://doi.org/10.62177/jetp.v2i2.408

[14] Sapountzi, A., Bhulai, S., Cornelisz, I., & van Klaveren, C. (2021). Analysis of stopping criteria for bayesian adaptive mastery assessment. *Proceedings of the 14th international conference on educational data mining* (EDM 2021) (pp. 745–750). International Educational Data Mining Society. https://educationaldatamining.org/EDM2021/virtual/static/pdf/EDM21_paper_134.pdf

[15] Zheng, Z., Liang, G., Luo, H., & Yin, H. (2025). Attention assessment based on multi-view classroom behaviour recognition. *IET computer vision*, *19*(1), e12146. https://doi.org/10.1049/cvi2.12146