Analysis of the Effectiveness Evaluation and Teaching Strategies in Junior High School Mathematics Instruction Under the Background of Informatization

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Abstract. Informatized teaching boasts a variety of advantages over traditional teaching methods, and in the context of mathematics education, the application of information technology not only makes instructional content visually accessible, effectively presenting abstract mathematical concepts in a clear and intuitive manner, but also creates more vivid and engaging learning environments for students. This paper, through empirical research, examines the current state of application and instructional outcomes associated with informatization in mathematics education, the Analytic Hierarchy Process (AHP) is applied to calculate weightings for indicators assessing teacher's informational teaching abilities, thus constructing a tailor-made set of indicators for evaluating teacher's capability in information-based teaching. It further proposes strategies and recommendations for middle school mathematics teaching that are built upon information technology. These suggestions can serve as a reference for future development and improvement of junior high math instruction and, concurrently, contribute to the overall enhancement and progress of broader educational endeavors within society.

Keywords: Junior high school mathematics teaching; Analytic Hierarchy Process; Information technology; Informatization in Education

1 Introduction

China's "Compulsory Education Mathematics Curriculum Standards (2022 Edition)" (hereinafter referred to as the "New Curriculum Standards") places significant emphasis on the crucial role of modern information technology in solving mathematical problems. In the context of educational informatization, it advocates that middle school mathematics instruction should leverage information technology to enrich teaching content and formats, stimulate students' learning interest, and effectively enhance students' core mathematical competencies. Furthermore, the integration of modern information technology with mathematics curriculum is advocated, where such technology is utilized to create a better learning and teaching environment for students.

The "New Curriculum Standards"[1]further emphasize that in classroom instruction, modern information technology should be fully utilized to provide teachers with high-quality teaching resources and students with a rich array of learning materials. By leveraging technology to design vibrant teaching activities, it drives reform in the methods and approaches to

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mathematics education. In the process of solving practical issues, modern information technology is employed to create well-structured and efficient digital learning environments for students, thereby enhancing their enthusiasm for learning, expanding their knowledge domains, stimulating their imagination, and elevating the information literacy of both teachers and students.

Information technology can help overcome the pedagogical challenges posed by the abstract and complex nature of middle school mathematics knowledge, thereby enhancing students' understanding and mastery of mathematical concepts. In this context, exploring the use of information technology to support middle school mathematics instruction is of paramount importance for advancing the reform process of middle school math curricula, as well as for teachers to master modern educational technologies, transform teaching philosophies, and cultivate students' divergent thinking and mathematical consciousness. Consequently, middle school mathematics teachers need to effectively and appropriately integrate modern information technology into their classroom practices, which helps sustain high levels of student engagement during the learning process, ultimately leading to improved efficiency in mathematics classroom instruction.

2 The current status and research overview of the application of informatization in mathematics education

One of the most salient features of mathematics as a discipline is its high degree of abstraction, which necessitates spatial visualization abilities and divergent thinking skills in students during the learning process. However, middle school students are typically at an early stage of developing such spatial imagination capabilities, and they often encounter difficulties when grappling with these abstract concepts. Consequently, teachers can leverage information technology to assist instruction by dynamically and visually presenting complex mathematical ideas.

2.1 The concept of informatization in education

Mathematics education informatization is a modern teaching paradigm where educators and teachers, with the aim to significantly enhance classroom instruction, integrate contemporary information technology, advanced multimedia technologies, and instructional design techniques in mathematics education under the guidance of modern educational informatization principles.

UNESCO defines Information Technology as: "Information technology refers to the scientific, technical, and engineering training methods and management skills applied in the processing and handling of information; the application of these methods and skills; computers and their interactions with humans and machines; and the corresponding range of socio-economic and cultural matters." In this definition, Information Technology generally encompasses a series of technologies related to computers and concerns the impacts and interactions that such technologies may have on human social activities.[2]

The information technology referred to in this paper encompasses hardware and software devices that can be effectively integrated with the practical demands of mathematics education, serving a positive role in classroom instruction and exerting certain favorable influences on

education. Examples include multimedia equipment, electronic whiteboards, projectors, and software tools such as Microsoft PowerPoint, Geogebra (a software tool based on the manipulation of fundamental elements), as well as Z+Z Super Sketchpad, etc.

In junior high school mathematics classrooms, four widely-applied information technology-based teaching methods are: playing instructional videos during the course of teaching, utilizing teaching slide presentations in class, employing electronic whiteboards in classroom activities, and using geometric drawing software such as a Geometric Sketchpad as an auxiliary teaching tool.

Research on information technology-based teaching practices in Western countries has reached a relatively mature stage, with different nations exhibiting varying levels of development. For instance, in the United States, Mulenga et al. highlight that the U.S. has put forward specific actionable recommendations to fully realize digital learning.[3]

Meanwhile, concerning Germany, Byun and Joung point out that with the rapid advancements in information technology, Germany has increasingly focused on information and communication skills. To propel educational digitalization and to innovate educational technology under the core concept of "Education 4.0," the German government has implemented its "Digital Education Strategy."[4]

Brahier further notes that in recent years, Germany has introduced several significant strategies and policies within the field of digital education and, through a series of digital education reform measures, has facilitated the digital transformation across all levels and types of education.[5]

2.2 The advantages and significance of information-based teaching

Integrating information technology into junior high school mathematics classrooms can effectively enhance teaching quality, making abstract and complex mathematical theories more tangible and accessible, thereby creating an active and relaxed learning environment. This process stimulates students' interest in learning and is conducive to cultivating their practical skills and logical thinking abilities, as well as promoting the comprehensive development of their overall qualities and literacy.

The significance of integrating information technology with mathematics teaching in junior high schools is manifested in both theoretical and practical aspects. On a theoretical level, it provides a theoretical foundation for enriching the means of mathematical instruction, improving teaching outcomes, upgrading teaching quality, broadening students' thinking, expanding their knowledge horizons, and enhancing their information literacy. In practice, the integration allows for the intuitive presentation of mathematical concepts through information technology, effectively simplifying and visualizing mathematical problems, which aids students in understanding and mastering abstract theories. Furthermore, incorporating information technology into practical approaches to learning mathematics contributes to exploring the essence of mathematics itself, deepening students' comprehension and retention of theorems and patterns, and fostering their capacity to process and handle information effectively.

2.3 Problems in information-based teaching

Despite the widespread adoption of information-based teaching and its advantages, there are still several significant issues that cannot be overlooked within the actual teaching process. Based on analysis of existing research, problems related to information-based teaching can be categorized into four main areas: Firstly, teachers hold inadequate or outdated concepts regarding information-based teaching, lacking a pedagogical philosophy conducive to constructing highly effective classrooms. Secondly, issues arise in the utilization of information technology resources for teaching purposes. Thirdly, there are challenges associated with the application of information technology in teaching, where insufficient or ineffective communication and interaction occur between teachers and students. Fourthly, there exist problems concerning the environment in which information-based teaching is implemented.

3 Research design and empirical analysis

The effectiveness of mathematics teaching in junior high school refers to the learning experiences, academic achievements, and the mechanisms of learning influence demonstrated by students during the process of mathematics instruction. In the field of educational research, measures of learning effectiveness often include indicators such as student satisfaction, subjective evaluations, and academic performance.[6]

3.1 Experiment analysis

The following presents a concrete implementation case of an information-based teaching method, followed by an evaluation of the effectiveness of applying information technology teaching strategies through statistical analysis and interpretation of teaching outcome data:

1) The employed information technology-based teaching method consists of utilizing instructional software and online interactive classrooms, complemented by digital case studies, to teach geometry in junior high school mathematics.

2) Experimental Subjects and Period: First-year students from a certain junior high school; one month.

3) Experimental Procedure:

Firstly, during a one-month teaching period, the teacher enhances instruction by utilizing various methods such as playing educational videos, employing instructional PowerPoint presentations in class, using an electronic whiteboard, and leveraging Geogebra software to demonstrate the transformation processes of two-dimensional and three-dimensional shapes, and deepening students' understanding of the concept of net diagrams. Concurrently, the teacher also conducts interactive online classes where students engage in real-time interaction, answering questions, and participating in discussions and other activities within the classroom setting.

After a month, the teacher designed case studies related to planar and solid shapes, guiding students to solve practical problems using geometric knowledge. Students were required to complete relevant exercises and assignments on a digital platform and submit their answers.

As shown in Table 1, it presents the specific experimental results (with a full score of 120 points).

Table 1 Development Results of Information-based Teaching Case

Experimental Indicators	Initial Average Score	Average Score after One Month	Overall Average Score
Degree of Mastery of Basic Mathematics Knowledge	91	102	96.5
Ability to Solve Problems through Information-based Cases	75	97	86

A preliminary conclusion: From the experimental results, it is evident that after implementing the information-based teaching approach, students demonstrated notable improvements in both their mastery of fundamental geometry knowledge and their ability to solve problems using information-based cases. So, this form of instructional technology proves effective in enhancing student engagement and motivation, as well as fostering innovative thinking and practical skills development among students.

3.2 Teacher's information technology-integrated teaching ability ahp evaluation system

By leveraging the Teacher Informatization Index System, the Analytic Hierarchy Process is applied to calculate weightings for indicators assessing teacher's informational teaching abilities, thus constructing a tailor-made set of indicators for evaluating teacher’s capability in information-based teaching.

Establishing AHP Model and Indicator Selection: According to the three stages of the teaching process (pre-class teaching preparation, in-class teaching implementation, and post-class professional development), the assessment of teachers' informationalized teaching abilities is set as the objective, denoted as A. Three first-level indicators are established: Informational Awareness and Acquisition Abilities, Informational Teaching Design and Implementation Skills, Informational Teaching Assessment and Research Capabilities , each denoted as B1 to B3 respectively. Fourteen second-level indicators under these categories include recognition of the importance of informatization, awareness of informational applications, ability for information positioning and expression, skills in information retrieval and acquisition, design of informational teaching methods, design of informational teaching content, design of course instructional models, operational proficiency with information technology, offline multimedia production abilities, design of evaluation criteria for informational teaching, refinement of assessment contents for informational teaching, optimization of informational teaching evaluation approaches, capability for information-based academic communication, and capacity for professional development in an informational context, each denoted as C1 to C14 respectively. The AHP model is constructed as shown in the figure 1.

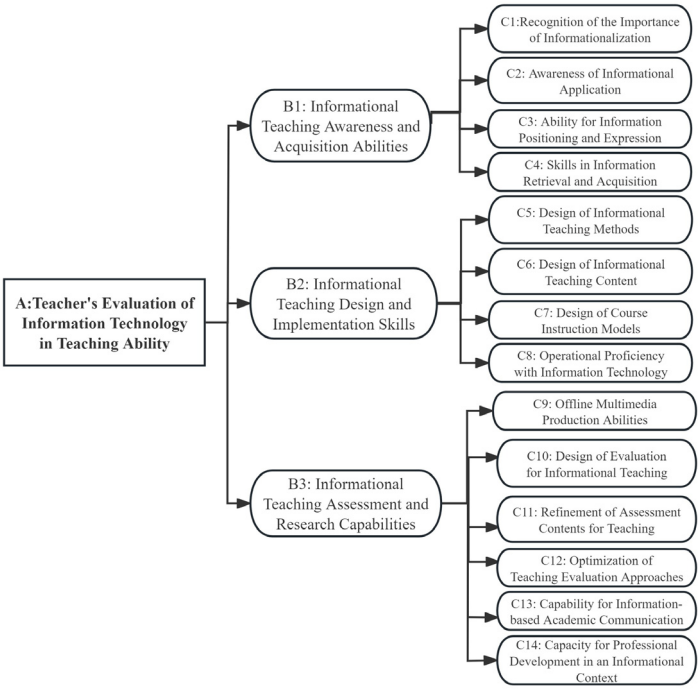

Figure 1 Teacher's Information Technology-Integrated Teaching Ability Assessment Indicator System

3.2.1 Determination of indicator weights and construction of judgment matrix

Firstly, based on the comprehensive analysis of educational experts regarding the evaluation indicators, pairwise comparisons are conducted among all indicators. The relative superiority sequence of each evaluation indicator is then arranged according to a nine-point scale ratio. Subsequently, a judgment matrix for the evaluation indicators is constructed, where the internal elements represent the degree of importance between each pair of indicators. To ensure the rationality of the judgment matrix, consistency tests are introduced based on the proportional standards of importance. This provides both theoretical and data support for the subsequent steps.

Secondly, the judgment matrix and its weight calculation are established. For determining the weights within the judgment matrix, we adopt the geometric mean method, which involves multiplying the rows of the matrix first, taking the nth root (where n represents the order or dimension of the matrix), and finally normalizing the resulting vector. The normalized vector thus obtained constitutes the sought-after weight vector. The maximum eigenvalue of the matrix is calculated and subjected to a second consistency test to verify the reasonableness of the indicator weights. A pairwise comparison approach is employed to validate the rationality of each indicator's weight.

Lastly, using the fuzzy comprehensive evaluation method, the domain of discourse for the evaluation object is determined. A fuzzy relation matrix is established, and a quantitative

analysis is carried out for each evaluated element. This process enables the determination of the overall evaluation results(Wi represents the weight value of Ci, i=1,2,…,14).

Table 2 B1-C Judgment Matrix and Consistency Test Results

B1	C1	C2	C3	C4	Weight Wi
C1	1	0.50	4	0.20	0.1381
C2	2	1	3	0.33	0.2161
C3	0.25	0.33	1	0.14	0.0624
C4	5	3	7	1	0.5834

(Max Eigenvalue=4.04362, CI=0.01454, CR=0.016157<0.1)

Table 3 B2-C Judgment Matrix and Consistency Test Results

B2	C5	C6	C7	C8	Weight Wi
C5	1	0.33	2	0.50	0.1539
C6	3	1	5	2	0.4773
C7	0.50	0.20	1	0.25	0.0809
C8	2	0.50	7	1	0.2880

(Max Eigenvalue=4.02113, CI=0.0070, CR=0.00783<0.1)

Table 4 B3-C Judgment Matrix and Consistency Test Results

B3	C9	C10	C11	C12	C13	C14	Weight Wi
C9	1	8	3	2	7	6	0.4200
C10	0.125	1	0.167	0.250	0.333	0.250	0.0323
C11	0.333	6	1	0.500	3	2	0.1572
C12	0.500	5	2	1	4	3	0.2324
C13	0.143	3	0.333	0.250	1	0.333	0.0574
C14	0.167	4	0.500	0.333	3	1	0.1007

(Max Eigenvalue=6.24125, CI=0.04825, CR=0.038911<0.1)

3.2.2 Consistency test:

First, calculate the maximum eigenvalue of the judgment matrix. Next, compute Consistency Index. Finally, determine Consistency Ratio by dividing CI by RI (Random Consistency Index), where RI is the average random consistency index. The values for RI for judgment matrices of order 1 to 7 can be found in the table 5.

Table 5 Table of Average Random Consistency Indices for Judgment Matrices of Orders 1 through 7

Order	1	2	3	4	5	6	7
RI	0	0	0.58	0.90	1.12	1.24	1.32

3.2.3 Secondary indicator normalization:

Extract the weight vectors from Tables 2, 3, and 4, and normalize them as shown in the table 6.

Table 6 Normalized Table of Secondary Indicator Weights

	Non-normalized	Normalized
W1	0.1381	0.0460
W2	0.2161	0.0720
W3	0.0624	0.0208
W4	0.5834	0.1945
W5	0.1539	0.0513
W6	0.4773	0.1591
W7	0.0809	0.0270
W8	0.2880	0.0960
W9	0.4200	0.1400
W10	0.0323	0.0108
W11	0.1572	0.0524
W12	0.2324	0.0775
W13	0.0574	0.0191
W14	0.1007	0.0336

3.2.4 Teacher's informationalized teaching ability assessment:

The development of an evaluation index system for teacher informatization is pivotal to enhancing teachers' professional abilities and advancing the construction of educational informatization within schools.

As evidenced by Tables 2, 3, and 4, a teacher's capability in informationalized teaching is comprehensively evaluated through multiple assessment indicators. The evaluation method involves multiplying the scores that a teacher attains on each individual indicator by its respective weight. Summing up these products ultimately yields the final rating for the teacher's overall information-based teaching ability.

3.2.5 Data processing and summary:

The application of the Analytic Hierarchy Process (AHP) in a comprehensive evaluation of teachers' informationalized teaching abilities ensures that all constituent elements and their interactions are thoroughly considered, enhancing the scientific, objective, and fair nature of the assessment. This approach enables prompt suggestions and countermeasures to be put forth.The calculation of the Consistency Ratio (CR) is intended to evaluate the consistency level in constructing the judgment matrix: The closer the CR value is to zero, the better the consistency of the judgment matrix. If the CR value approximates zero, it indicates that the weight calculations for the judgment matrix are relatively reliable. In the three judgment matrices discussed earlier, all have a CR less than 0.1; thus, we can consider the consistency of these three judgment matrices to be relatively good.

The research findings indicate that the weight coefficients for the second-level indicators (irecognition of the importance of informatization, awareness of informational applications, ability for information positioning and expression, skills in information retrieval and acquisition, design of informational teaching methods, design of informational teaching content, design of

course instructional models, operational proficiency with information technology, offline multimedia production abilities, design of evaluation criteria for informational teaching, refinement of assessment contents for informational teaching, optimization of informational teaching evaluation approaches, capability for information-based academic communication, and capacity for professional development in an informational context) are respectively 0.0460, 0.0720, 0.0208, 0.1945, 0.0513, 0.1591, 0.0270, 0.0960, 0.1400, 0.0108 , 0.0524, 0.0775, 0.0191, and 0.0336.

4 Teaching strategy optimization

The new curriculum standards place specific requirements on the application of information technology in teaching: Teachers are expected to integrate modern information technology with concrete instructional content, prudently utilize it to provide students with a wealth of learning resources, design engaging teaching activities, thereby enhancing students' learning efficiency and facilitating transformative changes in the methods and approaches used for mathematics instruction.

4.1 Teachers need to enhance their information technology literacy.

Mathematics teaching is a mutual growth and shared progress journey between teachers and students, where educators should contemplate and learn: How to leverage information technology in education to maximize its effectiveness within mathematics classrooms. Therefore, teachers need to acquire more efficient methods of applying information technology, enhancing their own IT literacy. This not only involves strengthening their abilities to use mathematical software but also enriching their theoretical knowledge base. They should integrate outstanding online teaching resources to address any shortcomings in their instruction, thereby diversifying their teaching content and achieving an extension of classroom teaching.[7]

Overall, teachers need to select appropriate mathematical information technology teaching tools in accordance with the type of math class being conducted. Additionally, during the course of information-based teaching, teachers should also utilize blackboard writing to summarize key and difficult points and standardize the process of solving problems. This serves the dual purpose of enhancing junior high school students' classroom attentiveness while also regulating their learning habits.

4.2 Rational use of information technology to optimize classroom teaching structure.

Teachers need to pay attention to students' emotional experiences and, based on different teaching contents, appropriately leverage information technology. This can include: using information technology to publish online learning tasks to guide students in independent previewing; employing technology to create problem-solving scenarios that stimulate students' curiosity and cultivate their problem-solving abilities; utilizing technology for dynamic demonstrations of abstract mathematical concepts, helping students visualize these ideas and form systematic understandings; conducting simulated experiments where technology optimizes the experimental outcomes and enhances practical operation experiences; implementing blended online and offline teaching approaches to broaden learning channels and cater to diverse student learning needs; and relying on information technology to facilitate

precise evaluation, establishing a comprehensive teaching assessment system that accurately reflects students' authentic learning situations.

The basic strategies for integrating information technology with junior high school mathematics education involve: presenting mathematical knowledge dynamically, using multimedia tools such as videos to enable students to grasp mathematical concepts more vividly and intuitively; adjusting teaching methodologies to encourage self-directed learning and group collaboration among students, combining information technology in inquiry-based learning activities; transforming the instructional structure by incorporating IT, which provides diverse learning resources and ample room for creative thinking, thereby stimulating students' enthusiasm for actively participating in math studies and enhancing the efficiency of math learning.

4.3 Designing and implementing information technology-based teaching pathways for junior high school mathematics

Teachers can employ micro-lessons, smart classrooms, and other means to integrate information technology into every aspect of the teaching process, including pre-class preparation, in-class instruction, and post-class reinforcement, ensuring effective engagement and application of IT. This genuine and profound integration of information technology with mathematics curricula aims at propelling the modernization of junior high school mathematics education.

Moreover, teachers are required to adjust their teaching methods and structures, making full use of IT tools like dynamic geometry software, which graphically demonstrates mathematical processes. By doing so, they guide students to actively engage in exploration and practice, discover and summarize mathematical patterns, and thus uphold the students' central role. This approach strengthens students' abilities to solve real-world problems effectively.

5 Conclusions

In summary, when employing information technology to create instructional contexts, the principles of enhancing classroom engagement, aligning with real-life scenarios, and catering to all students should be followed:

Firstly, through the use of IT, traditional temporal and spatial limitations can be transcended, thus realizing diversified mathematics teaching in junior high schools. Teachers can produce micro-videos, PowerPoint presentations, and other types of courseware, which they can pre-deliver to students via social platforms or online teaching applications for flexible out-of-class learning and contemplation of mathematical concepts, thereby boosting the efficiency of classroom learning.

Secondly, teachers can optimize the application strategies of information technology in practical teaching based on their instructional objectives and textbook content: it is crucial to pay attention to students' emotional experiences, introduce high-quality online educational resources according to varying teaching contents, thereby broadening students' perspectives and enriching the content of junior high school mathematics instruction. Concurrently, this process also presents an opportunity for teachers to enhance their own teaching abilities.

Furthermore, the use of IT can broaden students' mathematical horizons and clarify the logical structure of mathematical thinking. For instance, when teaching quadratic functions, teachers can combine IT to showcase real-world applications in advanced fields like aerospace technology, guiding students to comprehend and apply mathematical knowledge through practical problems, thereby stimulating their spirit of inquiry and cultivating their ability to solve real-life problems.

Lastly, mathematics teachers should elevate their information literacy and proficiency in information technology. They should strengthen their skills in using mathematical software, deepen their theoretical knowledge base, and leverage the advantages of IT to innovate teaching methods. By doing so, they can make math classes more contemporary and comprehensive, thus enhancing students' autonomy and effectiveness in learning mathematics, ultimately leading to a holistic improvement in teaching quality.

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