DIGITAL TECHNOLOGY INTEGRATION MODEL FOR HIGHER VOCATIONAL MATHEMATICS INSTRUCTIONAL DESIGN IN SHANDONG PROVINCE

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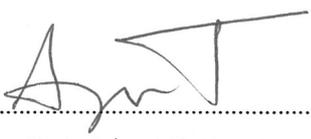
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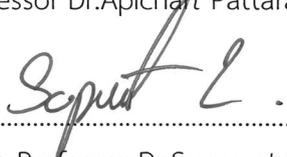
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Abstract

This study systematically developed and validated a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province (2023–2025). A literature review and the first Delphi round identified key problems and corresponding solutions, which were refined into 40 operational core elements and validated through IOC by five experts. The second and third Delphi rounds (n = 21) established consensus on a five-module model. A focus group evaluated and improved the model, and a quasi-experimental study with 80 students, analyzed using independent sample t-tests, examined its effectiveness.

The findings indicate that:

Firstly, a high level of expert consensus was achieved in the third round of the Delphi consultation, confirming the scientific validity and feasibility of the model structure.

Secondly, the KR-20 reliability analysis indicated satisfactory internal consistency of the test instrument, ensuring the credibility of the research findings.

Thirdly, the experimental group demonstrated significantly greater improvement in mathematics achievement than the control group, verifying the instructional effectiveness of the model in practice.

The model optimizes instructional organization and digital resource integration, strengthens formative assessment, and supports data-driven decision-making. Compared with traditional approaches, it enhances learning engagement, facilitates personalized learning, and promotes students' innovative and practical competencies.

Keywords: Digital technology integration model, Higher vocational mathematics, Instructional design, Delphi method, Focus group

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to persevere. You are my eternal refuge and the inexhaustible driving force that propels me forward.

Looking ahead, I regard this dissertation not as an end, but as a new beginning. I will continue to explore the integration of digital technology into higher vocational mathematics education, striving to translate academic findings into practical contributions. At the same time, I hope to collaborate with fellow scholars and practitioners to explore innovative pathways for educational reform and to contribute to the ongoing development of higher vocational education in China.

Once again, I wish to express my most sincere gratitude to all who have offered their care, support, and encouragement throughout this journey. This achievement is as much yours as it is mine.

Zhang Pengfei

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Chapter 1

Introduction

Rationale

In higher vocational mathematics instruction in Shandong Province, the integration of digital technology has become a trend. This integration not only improves the teaching efficiency and learning interest, but also enriches the teaching content, so that students can better understand and apply mathematical knowledge. With the support of digital technology, teachers can make use of multimedia resources, online platforms and interactive tools to make the instructional process more vivid and intuitive. At the same time, the introduction of digital technology also provides the possibility for personalized learning and distance education, and further promotes the innovative development of higher vocational mathematics instruction.

As an important public basic course, higher vocational mathematics plays an important role in cultivating students' logical thinking ability, improving students' comprehensive quality and promoting professional learning. However, at present, there are still some problems in higher vocational mathematics instruction, such as inadequate use of digital resources, weak student foundation, lack of learning interest, disconnection between teaching content and practice, lagging teaching methods and models, and single evaluation method. It is difficult to serve professional development and meet the requirements of lifelong learning from the level of talent training.

Therefore, mathematics teachers in higher vocational colleges should constantly innovate teaching concepts, actively introduce digital technologies, use teaching platforms to carry out online check-in, questioning, question-answering and testing, reform teaching methods and means, optimize teaching content, combine mathematical knowledge with professional cases, mathematical software and mathematical modeling, and reform assessment models. Actively explore the integration of digital technology into the instructional design model of higher

vocational mathematics in Shandong Province, and continuously enhance students' learning engagement and instructional effectiveness.

Research Question

How to develop an effective Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province?

Objective(s)

1. To identify problems and its resolutions on digital technology integration for higher vocational mathematics instructional design in Shandong Province.

2. To develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

3. To evaluate the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

4. To implement the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

Research Hypothesis/Hypotheses

Students have basic digital literacy and can flexibly use digital technology for learning.

Scope of the Research

Population and the Sample Group

Objective 1: To identify problems and its resolutions on digital technology integration for higher vocational mathematics instructional design in Shandong Province.

Population: More than 2,000 experts in 7 representative higher vocational colleges in Shandong Province are required to have a title of associate professor or above and have worked for more than 10 years.

The Sample Group

Sampling and Expert Selection Method

Because the Delphi technique emphasizes the quality, relevance, and authority of expert judgment rather than statistical representativeness, this study employed stratified purposive sampling combined with a nomination-based selection procedure to recruit experts.

Firstly, a candidate pool was established from the seven institutions according to the predefined eligibility criteria and demonstrated relevance to at least one of the following areas: higher vocational mathematics instructional design, digital technology-enhanced instruction, or education management/quality assurance.

Secondly, experts were nominated by program leaders, department heads, and senior academics within each institution. The final panel was determined using a two-dimensional stratification framework: (1) institutional stratum to ensure coverage across institutions; (2) role stratum to ensure multidisciplinary perspectives.

Finally, experts were selected to meet the predetermined quotas within each stratum, resulting in a Delphi panel of 21 experts.

Composition of the 21 Delphi Experts

Distribution by institution (n = 21)

Shandong Institute of Commerce and Technology: 3 experts

Jinan Vocational College: 4 experts

Jinan Engineering Polytechnic: 4 experts

Zibo Normal College: 3 experts

Qingdao Ocean Shipping Mariners College: 2 experts

Shandong Transport Vocational College: 3 experts

Dongying Vocational College: 2 experts

Distribution by role (n = 21)

Educational technology experts: 3 experts

Mathematics teachers: 15 experts

Education administrators: 3 experts

This composition reflects a deliberate design of mathematics instructional design as the core, supported by educational technology and administrative perspectives, which strengthens both the theoretical rigor and practical feasibility of constructing the Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province.

Objective 2: To develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

Population: Experts in 7 representative higher vocational colleges in Shandong Province are required to have a title of associate professor or above and have worked for more than 10 years.

The Sample Group: Select 21 experts from Shandong Province, who should have rich experience in higher vocational mathematics Instruction and a deep understanding of the application of digital technology, and should cover the fields of educational technology, mathematics education and vocational education. The experts include 3 higher vocational education administrators, 15 mathematics teachers, and 3 education administrators.

Objective 3: To evaluate the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

Population: Experts and students from 7 representative higher vocational schools in Shandong Province. Experts should have the title of associate professor or above, and have worked for more than 10 years; Students are required to be sophomores and juniors from different majors who frequently use digital technology in their studies.

The Sample Group: 9 focus group members selected.

2 Expert members: Scholars or education experts with in-depth research on the application of digital technologies to instructional design.

5 teacher representatives: Teachers with rich experience in higher vocational mathematics Instruction, who directly use digital technology to teach.

2 student representatives: Students involved in the integration of digital technology in higher vocational mathematics instructional design.

Objective 4: To implement the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

Population: 5 classes with a total of 200 students in the 2024 cohort of the Mechatronics program at Jinan Engineering Polytechnic.

40 students in class 1

40 students in class 2

40 students in class 3

40 students in class 4

40 students in class 5

The Sample Group: There are 40 students in the experimental group and 40 students in the control group.

Guideline

1. Teaching Analysis

2. Resource Matching

3. Teaching Implementation

4. Learning Support

5. Evaluation Improvement

To study

Digital Technology Integration model for Higher Vocational Mathematics Instructional Design in Shandong Province

Content (s)

The purpose of this study is to systematically develop and validate a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province, with the aim of enhancing instructional quality and strengthening students' learning engagement and academic performance.

This research is structured into 4 interrelated stages.

In the first stage, a comprehensive literature review and semi-structured expert interviews are conducted to identify existing challenges and potential solutions concerning digital technology integration within higher vocational mathematics instructional design in Shandong Province. This stage establishes the

theoretical foundation and practical problem framework for subsequent model construction.

In the second stage, the digital technology integration model is systematically constructed through the Delphi method. Multiple rounds of expert consultation are employed to refine the structural components, core elements, and operational mechanisms of the model, ensuring its theoretical rigor and contextual relevance.

In the third stage, the effectiveness, feasibility, and practical applicability of the model are further evaluated through a focus group method. This stage provides qualitative validation and offers insights for model optimization and broader implementation.

In the fourth stage, the constructed instructional design model is implemented in an experimental setting. A two-sample t-test is conducted to empirically examine the model's effectiveness in improving students' mathematics achievement, thereby providing quantitative evidence of its instructional impact.

Time

The research period of this study is from May 2023 to December 2025

Place

Shandong Province, China

Advantages

1. Enhancement of Students' Learning Engagement. The model promotes active learning by integrating digital visualization tools, interactive simulations, and multimedia resources into mathematics instructional design. Abstract mathematical concepts are transformed into dynamic and intuitive representations, which facilitates conceptual understanding and increases students' cognitive engagement and intrinsic motivation.

2. Improvement of Academic Achievement. By systematically incorporating mathematical modeling, digital experiments, and profession-oriented case analysis into the instructional design framework, the model strengthens the alignment between theoretical knowledge and practical application. This structured integration

enhances students' problem-solving abilities and leads to measurable improvements in mathematics achievement.

3. Optimization of Instructional Effectiveness and Efficiency. The model enables structured resource integration and digital platform-supported instructional management. Through learning management systems and online instructional tools, teaching materials, assignments, formative assessments, and feedback mechanisms can be efficiently organized and delivered. This systematic design reduces instructional, redundancy, improves time allocation, and enhances overall instructional effectiveness.

4. Development of Innovative and Practical Competencies. The model embeds digital tools and data-driven learning tasks within the instructional design process, providing students with opportunities to apply mathematical knowledge in authentic and technology-rich contexts. Through modeling, simulation, and problem-based tasks, students' innovative thinking and practical competencies are cultivated in alignment with the goals of higher vocational education.

Definition of Terms

Digital technology integration: refers to the process of combining information technology (such as computer, Internet, artificial intelligence, multimedia technology, etc.) with traditional education and teaching. In instruction, digital integration means using a variety of digital tools and platforms to enhance teaching and learning experiences.

Higher vocational mathematics: refers to mathematics courses taught in higher vocational education that aim to provide students with mathematical knowledge and skills related to their field of specialization. These courses typically focus on applied mathematics, covering topics such as algebra, geometry, statistics, calculus, etc., but place more emphasis on how to apply these mathematical concepts and methods to practical problem solving.

Instructional design: Teaching design refers to the systematic integration of digital technologies, such as online platforms, mathematical software, virtual experiments and interactive tools, to design effective teaching processes and strategies according to curriculum objectives and student characteristics in mathematics teaching in higher vocational colleges, so as to achieve optimal learning experience and learning results.

Teaching platform: Teaching platform refers to a series of hardware and software facilities used for teaching practice. These include providing places for teaching practice, such as traditional classrooms and playgrounds, and new ones such as the Internet and television.

TPACK framework: a technology-teaching method-subject content knowledge model (Technological Pedagogical Content Knowledge), used to guide teachers on how to effectively integrate subject knowledge, teaching methods and technological tools.

Delphi method: Delphi method is a method that relies on the experts to express their opinions back to back, conducts several rounds of consultation, makes the experts' opinions tend to be concentrated, and finally makes judgment and prediction.

Focus group: Also known as group interview, is commonly used qualitative research methods in social science research. Usually conducted by a research-trained investigator, a group of respondents is spoken to in a semi-structured manner.

Research Framework

The digital technology integration model for higher vocational mathematics instructional design in Shandong Province includes four research objectives, the specific research framework is shown in the figure below.

Objectives	Research Process	Research Method

1. To identify problems and its resolutions on digital technology integration for higher vocational mathematics instructional design in Shandong Province

21 experts

1. Data collection.
2. Data analysis.
3. Existing problem.
4. Solution.

1. Literature review
2. Delphi (Round 1)
3. IOC.

2. To develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province

21 experts

1. Second round survey.
2. Third round survey.
3. Design higher vocational mathematics instructional model.

Delphi (Round 2 and Round 3) (IQR. Md.Mo.)

3. To evaluate the digital technology Integration model for higher vocational mathematics instructional design in Shandong Province

9 experts

1. Discuss the design.
2. Data collection.
3. Evaluate higher vocational mathematics instructional

Focus group

4. To implement the digital technology integration model for higher vocational mathematics instructional design in Shandong Province

1. Experimental group: 40 people; control group: 40 people.

Independent sample t-test

Figure 1.1 Research Framework

Chapter 2

Literature Review

In the study of "Digital Technology Integration model for Higher Vocational Mathematics Instructional Design in Shandong Province", the researchers explored the following concepts and related theories and proposed the following themes:

1. Problems and solutions in higher vocational mathematics instructional design

2. The application of digital technology in education

3. Digital technology integration in higher vocational mathematics teaching design

4. Digital technology integration in higher vocational mathematics learning design

5. Digital technology integration in higher vocational mathematics evaluation design

6. Higher vocational mathematics teaching content reform

7. Types and applications of teaching platforms

8. The application of higher vocational mathematics teaching platforms

9. Instructional Design Theory and TPACK Framework

Problems and solutions in higher vocational mathematics instructional design

When discussing the problems and solutions in the model of mathematics Instruction in higher vocational colleges, we can analyze it from many angles. First of all, Wang Qian (2019), Gao Jie (2023), Pu Bingyuan (2019) believe that there are mainly the following problems: (1) Students generally have weak mathematical foundation and low interest in learning; (2) The professional quality of teachers is not high; (3) Teachers' teaching mode and teaching method are relatively obsolete; (4) The teaching materials do not conform to the teaching practice, and the teaching

hours are relatively insufficient; (5) Backward assessment methods. In addition, Zhang Bin and Yang Miaomiao (2020) analyzed that the current problems in mathematics teaching in higher vocational colleges mainly exist, such as students' belief that mathematics is difficult to learn, teachers' belief that mathematics is difficult to teach, and teachers' belief that mathematics is "useless", which reflects the disconnection between teaching content and practical application.

At present, the main problems of mathematics instructional design in higher vocational colleges are shown in Table 2.1.

Table 2.1 Problems of higher vocational mathematical instructional design

Scholar	1	2	3	4	5	6	7	8	9
Wang qian (2019)	√	√		√	√				
Zhang Bin (2020)						√	√	√	
Feng Tianxiang (2009)			√	√					√
Meng Ling (2017)			√	√					√
Han Jie (2023)	√		√						
Shang Xiuli (2018)	√			√					
Sun Na (2020)			√	√					√
Liu Ximing (2007)	√			√					
Lei Yuhong (2024)			√		√				
Gao Jie (2023)	√		√	√					√
Miao Yehong (2023)	√		√	√					
Wang Yuanying (2023)	√	√	√						
Cheng Zhonghui (2012)	√	√				√		√	
Qin Qianqian (2023)	√	√	√	√					
Pu Bingyuan (2019)	√	√	√	√					
Total	10	5	10	10	2	2	1	2	4

1-Students have weak foundation and low interest in learning

2-The professional quality of teachers is not high

3-The teaching mode and teaching method are outdated

4-The teaching material is not in line with the teaching practice, the teaching content is boring, and the idea of mathematical modeling is not integrated enough

5-Backward assessment method

6-Students think math is difficult

7-Math teachers think that math is difficult to teach

8-Professional teachers think mathematics is useless

9-Students' practical application ability is insufficient

In order to solve these problems, the following resolutions can be taken:

Integration of teaching content: Feng Tianxiang (2009) proposed to adjust and optimize teaching content according to the actual social needs and professional characteristics, so as to make it more in line with the application needs in practical work. This includes the introduction of MATLAB mathematical software and the strengthening of mathematical modeling teaching so that students can apply what they have learned to solve practical problems (Meng Ling, 2017).

Reform of teaching methods: Adopt diversified new training methods, such as problem-oriented teaching method (Han Jie, 2023), case teaching method, flipped classroom teaching method, and mixed teaching mode (Zhang Bin and Yang Miaomiao, 2020), in order to improve the classroom interest and students' learning efficiency. Qin Qianqian (2023) also proposed a flipped classroom teaching design based on digital blended learning with students as the main body. At the same time, teaching equipment should be updated, and teaching efficiency should be improved by combining information technology with traditional teaching (Shang Xiuli, 2018).

Stimulating interest in learning: Liu Ximing (2007) pointed out that stimulating students' interest in learning mathematics is one of the most important tasks in mathematics teaching. According to the existing knowledge base, ability level and learning willingness of students, reasonable levels should be divided, teaching

objectives and requirements at different levels should be formulated, and hierarchical teaching should be implemented to teach students according to their aptitude (Gao Jie and Wang Dalu, 2015).

Improve teachers' quality: Teachers should constantly explore and study efficient teaching methods, change teaching concepts, and pay attention to the play of students' main role and the development of their personalities (Shang Xiuli, 2018). At the same time, teachers need to pay attention to the cultivation of students' comprehensive application ability and form a new curriculum system of student-centered teaching reform (Sun Na, 2020).

Reform of assessment methods: Miao Yehong(2023) Lei Yuhong(2024) believe that the traditional end-of-course evaluation will affect the learning enthusiasm of higher vocational students, and process assessment is of great significance in mathematics teaching in higher vocational colleges. By setting reasonable assessment standards, students' learning efficiency and enthusiasm can be effectively improved. Keep up with the development of educational technology, provide teachers with an information-based teaching platform, urge teachers to integrate online and offline, internal and external teaching resources, promote the reform of teaching and assessment methods, and improve teaching quality (Wang Yuanying, 2023).

In view of the problems existing in the mathematical instructional model of higher vocational colleges, the specific countermeasures given by scholars are shown in Table 2.2.

Table 2.2 The solutions of problems existing in higher vocational mathematics
instructional design

Scholar	1	2	3	4	5	6	7	8	9	10
Wang qian (2019)	√	√	√	√	√	√				
Zhang Bin (2020)			√		√		√	√	√	
Feng Tianxiang (2009)			√		√					√
Meng Ling (2017)					√					
Han Jie (2023)	√		√		√					
Shang Xiuli (2018)	√				√					
Sun Na (2020)					√					√
Liu Ximing (2007)					√			√		
Lei Yuhong (2024)						√				
Gao Jie (2023)				√	√			√	√	
Miao Yehong (2023)		√				√				√
Wang Yuanying (2023)			√		√		√	√	√	
Cheng Zhonghui (2012)	√				√			√		
Qin Qianqian (2023)	√	√		√				√	√	
Pu Bingyuan (2019)		√	√				√	√		√
Total	5	4	6	3	11	3	3	7	4	4

1-Enhance students' interest in learning

2-Improve the comprehensive quality of teachers

3-Mixed online and offline teaching

4-Applied micro-lesson teaching

5-Reform the teaching content, the introduction of mathematical modeling, highlighting practicability

6-Reform the assessment method

7-Set up course modules

8-Strengthen professional integration

9-Implement stratified teaching

10-Strengthen practical teaching

The application of digital technology in education

In the 21st century, the rapid development of digital technology has brought profound changes to the field of education. Teachers and students are able to interact through multiple digital platforms and tools, which not only changes the way knowledge is delivered, but also redefines what learning means. This section focuses on the application of digital technologies at different levels of education, disciplines and interdisciplinary fields, analyzes in detail the benefits and challenges they bring, and looks at future trends.

Multi-dimensional application of digital technology in education

Application of digital technology in basic education

At the basic education level, digital technologies enhance students' learning experience through intelligent teaching systems, interactive learning platforms and educational applications. Roschelle et al. (2010) pointed out that the popularity of mobile learning devices such as tablet computers and smart phones makes interactive learning possible, which not only improves students' learning motivation, but also promotes collaborative learning and personalized teaching. For example, online learning platforms such as Khan Academy provide a wealth of educational resources that allow students to learn at their own pace and receive instant feedback.

Applications of digital technology in higher education

In the field of higher education, the application of digital technology is more extensive and in-depth. The rise of online courses, such as MOOCs, and hybrid courses is providing greater flexibility in higher education. Anderson (2008) mentioned that online learning in higher education can break the restrictions of region and time, so that students from all over the world can share quality education resources. In addition, the application of virtual laboratories and simulated environments also

provides practical operation opportunities for students in engineering, medicine and other disciplines, reducing the limitations of physical resources.

Application of digital technology in vocational education

Vocational education emphasizes the cultivation of practical skills, in which the application of digital technology is particularly important. Simpson & Payne (2004) mentioned that virtual reality (VR) and augmented reality (AR) technologies can provide students with a realistic operating environment that simulates real work scenarios, which is particularly effective in training skilled workers. For example, vocational skills such as welding and mechanical operation can be trained with VR devices, thereby reducing risks and costs.

Application of digital technology in special education

For students in special education, digital technology provides personalized and accessible learning tools. Burgstahler (2003) emphasizes that the development of adaptive and assistive technologies, such as screen readers, speech recognition software, and personalized learning plans, can help students with special needs better integrate into the learning environment and improve their learning outcomes. The spread of digital technology makes special education no longer limited to specific places, but can be achieved in the general education environment.

Challenges in the application of digital technologies in education

Teachers' ability to integrate technology

While digital technologies offer new possibilities for teaching, the ability of teachers to integrate technology remains a key challenge. Teachers not only need to master new digital tools, but also redesign curricula to take full advantage of these technologies. The TPACK model proposed by Mishra & Koehler (2006) points out that effective technology integration requires teachers to possess both technical knowledge, subject knowledge and pedagogical knowledge. However, many teachers have inadequate training and support in this area, which has led to limitations in the application of digital technology in practical teaching.

Digital divide and resource imbalance

The promotion of digital technology in education also faces the problem of digital divide, that is, the ability of students from different regions and different social and economic backgrounds to access digital resources is significantly different. Van Dijk (2006) points out that this resource imbalance can lead to increased inequality in education, especially in resource-poor rural or developing country areas. To address this, governments and non-profit organizations need to strengthen infrastructure and promote equitable distribution of digital education resources.

Data privacy and security issues

With the spread of digital technology in education, data privacy and security issues have become more prominent. Students' learning data, personal information, and behavioral data can all be at risk of disclosure or misuse. Livingstone (2019) mentioned that educational technology providers and schools need to establish strict data protection mechanisms to ensure that students' information is secure. Educators also need to raise students' awareness of data security and help them protect their privacy in the digital environment.

Future directions of digital technology in education

The application of artificial intelligence and big data

Artificial intelligence (AI) and big data technologies are changing the future of education. AI can not only be used in adaptive learning systems, but also provide students with intelligent learning assistants through natural language processing and machine learning. Luckin et al. (2016) proposed that the application of AI technology can provide personalized learning suggestions, identify students' learning patterns, and predict their learning needs. In addition, big data analysis can help education decision-makers optimize teaching strategies and improve the quality of education.

The deepening application of augmented and virtual reality technology

The application of augmented reality (AR) and virtual reality (VR) technology in future education has a broad prospect. These technologies can provide students with an immersive learning experience that dramatically increases the engagement and effectiveness of learning. Pantelidis (2010) pointed out that VR technology is

especially suitable for high-risk and high-cost experiments and operations, such as medical surgery simulation and chemical laboratory simulation. Future research could explore how to integrate these technologies more closely with curriculum content, and how to reduce the cost of the technology and make it more accessible.

Fostering digital literacy

With the continuous development of digital technology, digital literacy has become a basic ability that students must possess in modern society. Jenkins (2009) mentioned that digital literacy includes not only technical operation ability, but also critical thinking, information management and ethical awareness. Future education needs to focus more on digital literacy to ensure that students are not only able to use technological tools, but also to learn effectively and safely in a complex digital environment.

The rapid development of digital technology has brought many opportunities and challenges to education. In the fields of basic education, higher education, vocational education and special education, the application of digital technology has significantly improved the teaching effect and the learning experience of students. However, the effective integration of technologies, the fair distribution of resources, and data privacy issues remain key challenges to be addressed. Future research and practice should continue to explore how to overcome these challenges and make full use of the potential of digital technologies to drive innovation and development in education.

Digital technology integration in higher vocational mathematics teaching design

With the rapid development of information technology, digital technology has become a critical component in the field of education, particularly in vocational education. Vocational education places a strong emphasis on cultivating students' practical abilities, and mathematics, as a fundamental discipline, plays a key role in developing students' logical thinking and problem-solving skills. However, traditional vocational mathematics teaching models face challenges such as abstract teaching

content and low student engagement. To address these issues, the integration of digital technology offers new opportunities and challenges.

Application of digital technology in vocational mathematics teaching

Blended Learning: Blended learning combines the advantages of traditional face-to-face teaching with online learning, providing students with a more flexible and personalized learning experience. According to Boelens et al. (2017), blended learning can enhance student engagement and learning outcomes through the effective combination of online resources and offline classroom activities. In mathematics teaching, students can use online learning platforms for pre-study and review, while classroom sessions focus on discussions, practice, and problem-solving. This model not only increases students' learning autonomy but also deepens their understanding of mathematical concepts.

Flipped Classroom: The flipped classroom is an innovative teaching model that shifts the traditional knowledge transmission from the classroom to pre-class activities, allowing students to engage in self-directed learning through videos and other digital resources. Class time is then dedicated to interaction, discussion, and practical exercises. Bergmann & Sams (2012) emphasize that the flipped classroom can enhance students' self-directed learning abilities and deepen their understanding of knowledge through interactive classroom activities. In vocational mathematics teaching, teachers can record micro-lessons for students to study independently before class, and use class time for problem-solving discussions and case analysis. This model effectively addresses the issue of low student engagement in traditional classroom teaching and improves teaching outcomes.

Virtual Reality (VR) and Augmented Reality (AR): VR and AR technologies are increasingly being applied in education, providing students with immersive and interactive learning experiences. Research by Merchant et al. (2014) shows that VR can help students better understand and apply complex concepts by simulating real-world scenarios and operations. In vocational mathematics teaching, AR can be used for 3D visualization of geometric shapes, while VR can allow students to engage in mathematical modeling and simulation experiments in a virtual environment,

enhancing the fun and practicality of learning. These technologies not only make abstract mathematical concepts more concrete but also improve students' hands-on skills and spatial imagination.

Mathematics-Specific Software: Software such as GeoGebra, MATLAB, and Wolfram Alpha is increasingly being used in vocational mathematics teaching. Liu & Wang (2020) point out that dynamic mathematics software like GeoGebra can help students intuitively understand abstract concepts in geometry, algebra, and calculus through graphics and animations. Computational tools like MATLAB can be used for constructing and analyzing complex mathematical models, cultivating students' abilities to solve real-world problems. These tools not only enrich the means of mathematics teaching but also enhance students' computational and data processing skills.

Challenges in integrating digital technology in vocational mathematics teaching

Insufficient Teacher Skills: Despite the broad prospects for applying digital technology in teaching, teachers face challenges in mastering and applying these technologies. Clark & Mayer (2016) note that many teachers lack a thorough understanding and operational skills related to digital technology, which may lead to suboptimal teaching outcomes. To effectively integrate digital technology, teachers need specialized training to develop the ability to use digital tools and design digitalized courses. Additionally, teachers must shift traditional teaching concepts and actively embrace the changes brought by technology, becoming guides in learning and supporters of technology.

Equipment and Resource Limitations: Equipment and resource limitations are also significant challenges in the integration of digital technology. Means et al. (2013) emphasize that insufficient hardware and digital resources can make it difficult to implement digital teaching in vocational education. This issue is particularly pronounced in remote areas, where schools may lack sufficient funding and technical support to equip modern digital devices. To address this, schools can collaborate with governments and enterprises to obtain more resource support. Additionally, the

use of Open Educational Resources (OER) is an effective solution, providing schools with more quality teaching resources.

Differences in Students' Digital Literacy: Differences in students' digital literacy can also impact the effectiveness of digital technology in teaching. Pape et al. (2012) suggest that some students may experience significant difficulties when using digital tools, leading to uneven learning outcomes. Teachers need to design personalized learning paths and provide differentiated support and guidance for students with varying levels of digital literacy. Schools can also offer digital literacy courses to improve students' technical application abilities, helping them better adapt to the digital learning environment.

Future directions for digital Technology integration

Adaptive Learning and Artificial Intelligence: The application of Artificial Intelligence (AI) technology in education offers new possibilities for designing personalized learning paths. Tsai & Lee (2014) suggest that adaptive learning systems can dynamically adjust teaching content and pace based on students' learning data, better meeting individual student needs. In the future, vocational mathematics teaching can further utilize AI technology to provide more precise learning support through learning analytics and real-time feedback systems, enhancing learning outcomes.

Utilization of Open Educational Resources (OER): The promotion and application of OER provide more quality resources for education. Means et al. (2013) mention that OER can help schools save costs while providing more learning resources for students. However, the quality control and proper utilization of OER remain issues that need to be addressed. Future research can focus on how to improve the quality and efficiency of OER and how to better integrate it into vocational mathematics teaching.

Interdisciplinary Integration and Cross-Disciplinary Learning: The role of digital technology in interdisciplinary integration is becoming increasingly significant, especially in the application of mathematics in cross-disciplinary fields. Garrison & Kanuka (2004) mention that blended learning can not only enhance the effectiveness

of mathematics teaching but also promote the integration of mathematics with other disciplines such as physics and computer science, fostering students' interdisciplinary thinking abilities. In the future, vocational mathematics teaching can explore more cross-disciplinary project-based learning models, enhancing students' comprehensive abilities through the design of practical application projects.

In conclusion, the integration of digital technology in vocational mathematics teaching can not only improve students' interest and effectiveness in learning but also provide them with a richer and more diverse learning experience. However, the effective application of digital technology still faces challenges such as insufficient teacher skills, limited equipment and resources, and differences in students' digital literacy. Therefore, future research and practice should continue to explore how to overcome these challenges and fully utilize the potential of digital technology to promote innovation and development in vocational mathematics teaching.

Digital technology integration in higher vocational mathematics learning design

Through the review of relevant literature, many scholars have done beneficial research and exploration in the direction of digital technology integration in higher vocational mathematics learning model, mainly through the following aspects to achieve the integration of learning model and digital technology:

Concepts related to the integration of digital technology into learning models: Through the integration of digital technology in the aspects of perceived usefulness, perceived ease of use and external environment support, etc., to enhance the digital learning initiative and digital teaching effect of college students (Han Yang et al., 2024).

Application of teaching platform and multimedia software technology: Through the use of network teaching platform to provide resources, conduct tests and record learning data, as well as the introduction of Matlab mathematical software and provide opportunities for independent practice, digital technology has been effectively integrated into the learning model, which is conducive to improving

students' learning effect and career ability (Yang Hui et al., 2019). Through the use of multimedia software technology, the construction of teaching situations, the integration of mathematical knowledge, the construction of information evaluation system, the application of multimedia to construct problem situations and the implementation of dynamic demonstrations, digital technology is integrated into the learning model to improve students' learning interest, understanding ability and learning effect (Chen Lina et al., 2022).

Building a smart classroom in colleges and universities: relying on the Internet to establish a classroom learning community, using the power of digital technology to create a learning space-time environment containing wisdom (such as perception, reasoning, auxiliary decision-making), and organically integrating intelligent teaching systems into the classroom space through virtual reality, augmented reality and other intelligent technologies (Li Hongxiu et al., 2023).

Advancing digital technology empowerment in education: According to professional learning needs, adjust and optimize the development of higher vocational mathematics course textbooks, build high-quality shared digital resources, innovate and practice online and offline hybrid teaching design with the help of flipped classroom concept, and complete teaching design, implementation, diagnosis and evaluation with virtual simulation math software based on digital campus, smart classroom and other learning Spaces (Chai Yanhong, 2023).

Carry out adaptive learning: Higher vocational colleges should deeply integrate "cloud, network and terminal", and in the cloud side, the application is not limited by the traditional equipment resources; On the network side, more low-delay edge computing applications are promoted by connecting distributed computing power. On the end side, with the help of digital technology to build a resource library, centralized storage, management and sharing of various types of course resources, in-depth application of virtual simulation technology in the field of vocational education, simulation of work scenarios in different industries around the core knowledge points and application scenarios, so that students can experience the work content, cultivate students' practical ability, so as to achieve appropriate

learning. Improve the learning effect and vocational ability of students in higher vocational colleges (Xiao Haiwen et al., 2024).

Goal of integrating digital technology into learning model: Students can construct and set up models, design programs to carry out research, and use virtual platforms to conduct financial simulation experiments; Verification of pathological knowledge through digital human body model; Through a variety of exploration methods, including structural exploration, collection exploration, virtual exploration and verification exploration, experiments are carried out with the help of digital technology, and relevant factors are excluded to find the answer to the question. Through the establishment of interactive platform: to provide strong support for students' personalized learning, inquiry learning and teaching interaction, so as to achieve the goal of going beyond the classroom.

To sum up, the integration of learning design into digital technology can start from the aspects of perceived usefulness, perceived ease of use and external environment support, and apply teaching platform and multimedia software technology to build college smart classroom, promote educational digital technology empowerment, carry out adaptive learning, and achieve the goal of surpassing the classroom, so as to improve the quality of mathematics teaching in higher vocational colleges and students' learning effect. Promote the all-round development of students.

Digital technology integration in higher vocational mathematical learning design in Shandong

In recent years, with the rapid development of information technology, the application of digital technology in the field of education has gradually deepened, and higher vocational education is also exploring how to effectively integrate these technologies into the teaching and learning process. Especially in mathematics teaching, the introduction of digital technology not only helps to improve teaching efficiency, but also stimulates students' learning interest and improves learning effect. Shandong Province, as one of the key development areas of vocational

education in China, actively promotes the integration of digital technology in the mathematical learning model of higher vocational education.

Application of online learning platform: Online learning platform is one of the most widely used forms of digital technology in higher vocational education. Many higher vocational colleges in Shandong Province actively adopt online learning platforms, such as MOOCs, SPOCs, Chaoxing, Wisdom vocational education, etc., to assist the teaching of mathematics courses. These platforms provide a wealth of teaching resources, including video courses, exercise question banks and discussion forums, to help students conduct self-study and review (Li Wei, 2020). Research shows that the use of online learning platforms effectively improves students' learning engagement and learning effect (Wang Na, 2021).

Exploration of mixed learning mode: Mixed learning mode has been widely promoted in the mathematics teaching of higher vocational colleges in Shandong Province. This model combines traditional classroom teaching with digital learning tools, and provides students with more flexible learning methods through the organic combination of online and offline (Zhao Ming, 2021). Shandong Vocational College has introduced a blended learning model in mathematics teaching, where students can receive guidance from teachers in class and use an online platform to study independently after class. This not only improves the teaching quality, but also enhances students' autonomous learning ability (Chen Hua, 2020).

Application of mobile learning platform: With the popularity of smart phones, the application of mobile learning platform in higher vocational mathematics teaching in Shandong Province has gradually increased. Such platforms provide students with the opportunity to learn anytime and anywhere, access teaching resources, complete assignments and participate in discussions through mobile devices (Zhao Fang, 2020). Research shows that the use of mobile learning platforms improves students' learning flexibility and engagement, especially in vocational education, which can better meet the needs of in-service students and other adult learners (Liu Li, 2020).

Introduction of Intelligent learning Platform: Intelligent learning platform utilizes big data and artificial intelligence technology to provide personalized learning advice and paths for students. These platforms can conduct data analysis based on students' learning behaviors, so as to recommend suitable learning content and review strategies for students (Zhang Wei, 2021). Some higher vocational colleges in Shandong Province have introduced intelligent learning platforms in mathematics teaching, which has effectively improved students' learning results, especially in personalized teaching (Zhao Mei, 2021).

The advantages of digital technology application

Improving teaching efficiency: The application of digital technology in mathematics teaching has significantly improved teaching efficiency. Online learning platforms and blended learning models enable teachers to manage the teaching process more efficiently and reduce the repetitive work of classroom teaching (Chen Qiang, 2019). At the same time, these platforms also provide automated assessment tools to help teachers quickly assess students' learning outcomes (Li Fang, 2020).

Facilitate personalized learning: By analyzing student learning data, the intelligent learning platform is able to provide personalized learning recommendations for each student. This personalized learning model can not only meet the needs of students with different learning levels, but also effectively improve the learning effect (Wang Qiang, 2021). Personalized learning programs can help students overcome difficulties in learning and enhance their learning confidence (Zhao Li, 2020).

Enhance students' interest in learning: The application of digital technology has greatly stimulated students' interest in learning mathematics. Through the mobile learning platform and virtual simulation technology, students can participate in learning in a more interactive and immersive way (Gang Chen, 2020). This interactive and interesting way of learning makes students more engaged in the learning process, thus improving the learning effect (Li Na, 2021).

Challenges in the application of digital technology

Technology and resource constraints: Despite the significant impact of digital technology in mathematics teaching, technology and resource constraints remain an important challenge. Due to the lack of technical equipment or limited funds, it is difficult for some higher vocational colleges to fully introduce and promote advanced digital teaching platforms (Zhao Qiang, 2020). In addition, teachers and students may face technology adaptability problems when using these platforms, especially for some older teachers, learning and mastering new technologies requires time and training (Chen Fang, 2021).

Data privacy and security: The wide application of intelligent learning platforms involves the collection and analysis of a large amount of student data, so data privacy and security issues become a challenge that cannot be ignored (Wang Wei, 2020). How to make full use of big data and artificial intelligence technology on the premise of ensuring data security is still a hot issue in current research (Li Na, 2021).

Lack of teachers' digital teaching ability: With the introduction of digital technology, the role of teachers has changed from traditional knowledge imparts to learning guides and supporters. This transformation requires teachers to have high digital teaching ability (Liu Ming, 2019). However, some teachers face great adaptability challenges in this process and need to improve their digital teaching ability through systematic training (Zhao Liang, 2020).

Future direction of development

Intelligent and personalized development: In the future, the intelligent learning platform will be further developed and more advanced artificial intelligence technology will be used to provide students with more accurate personalized learning programs and learning paths (Wang Qiang, 2021). This development direction can not only improve the learning effect of students, but also help educational institutions better manage teaching resources and teaching processes (Zhang Wei, 2021).

The interconnection of teaching platforms: With the increase of digital teaching resources, the interconnection between different platforms will become an important trend in the future. Through standardized interfaces and protocols, data from different platforms can be seamlessly connected to provide students with an integrated learning experience (Zhao Ming, 2021). This trend will promote the sharing and optimal allocation of educational resources and improve teaching efficiency (Li Fang, 2020).

Improve teachers' digital teaching ability: Teachers' digital teaching ability directly affects the application effect of digital technology in teaching. Therefore, the training of teachers should be strengthened in the future to help them master and apply the latest digital technologies (Wang Li, 2021). This initiative will provide strong support for the in-depth application of digital technology in mathematics teaching in higher vocational colleges (Chen Gang, 2020).

In Shandong Province, the integration of digital technology in higher vocational mathematics learning design has achieved remarkable results in improving teaching efficiency, promoting personalized learning and enhancing students' learning interest. However, technology and resource limitations, data privacy and security concerns, and insufficient digital teaching capabilities of teachers remain major challenges to be overcome in the application of digital technologies. In the future, digital technology will play a more important role in higher vocational mathematics teaching through the development of intelligence and personalization, the interconnection between platforms and the improvement of teachers' digital teaching ability.

Digital technology integration in higher vocational mathematics evaluation design

As for evaluation models, most scholars have proposed diversified evaluation models, but there are few relevant literatures on the integration of digital technology to build evaluation models. By combing relevant literatures, we can integrate digital

technology to build mathematical evaluation models for higher vocational colleges from the following aspects.

A diverse range of evaluation subjects are integrated into digital technologies: With the focus on improving students' practical ability in technical positions, the evaluation index system of diversified evaluation subjects including student self-evaluation, enterprise evaluation and school teacher evaluation is constructed. Relying on big data and artificial intelligence technology, the Delphi method is adopted for preliminary screening of various indicators. The importance scoring method and expert meeting method are adopted according to the feedback of experts. The indicators were further screened and revised. Relying on a new generation of information technology, digital empowerment builds a post competency evaluation platform, establishes an intelligent post competency evaluation "management brain", collects students' post competency in the whole process, covering before, during and after the internship, and makes real-time sharing and intelligent analysis of the collected data. Form an evaluation management system that integrates intelligent decision-making of evaluation, innovation of evaluation management mechanism, and multiple collaboration between school and enterprise students. Make statistics based on students' learning, task completion, practical ability, etc., assign scores to students in the form of a points system, and make intelligent analysis based on students' score acquisition in different evaluation stages to generate a graph. Realize the intelligence of the whole evaluation process (Zhang Fang, 2024).

Integrating digital technology into the evaluation index system: The complete and complex learning process is decomposed into a single influencing factor, the evaluation factor is determined, the evaluation factor set of students' learning effect is established and the corresponding weight is assigned. With the help of fuzzy transformation principle and maximum subordination principle, the fuzzy comprehensive evaluation method and the implementation technology of improving teaching evaluation system are constructed considering the influence of various factors related to the things being evaluated. Membership function or membership

relationship was determined by fuzzy statistics and expert experience method, and secondary factors were evaluated, scores were counted and normalized. The evaluation matrix was obtained by using Stratheen method to improve matrix multiplication algorithm, and multi-dimensional and comprehensive evaluation of students' learning effect was carried out by digital technology (Li Yajie, 2012).

Evaluation using the teaching platform: The online education platform uses the functions of each student's learning progress and learning time statistics to detect students' learning status, and evaluates students' learning effect through online Q&A, demonstration, group discussion, homework, tests, etc. Teachers give accurate policies, students find out the weak links in time and carry out intensive training to promote students' independent learning (Wang Yanling, 2021). By relying on digital platforms and resources, comprehensively using a variety of data, using five-point Likert scale method from three dimensions, designing a scientific questionnaire, conducting two-paired sample T-test on the collected data, and conducting data analysis, teaching evaluation using digital technology can be realized and students' learning effects can be evaluated more objectively (Li Jun, 2021).

Future trend of evaluation model: Through the use of digital technologies such as artificial intelligence, big data, virtual simulation technology and blockchain technology, to achieve a comprehensive evaluation of students' mathematics learning and pay attention to students' "soft literacy" to evaluate students' learning outcomes and ability development in a more comprehensive and scientific way (Qin Juan et al., 2024).

To sum up, these literatures discuss the integration of mathematical evaluation model and digital technology in higher vocational colleges from different angles, apply fuzzy mathematics theory, use digital technology to collect and analyze data through teaching platform and network teaching data resource center, and conduct diversified evaluation and feedback for students, providing a useful reference for further research and practice.

Digital technology integration in the higher vocational mathematical evaluation design in Shandong Province

With the rapid development of digital technology, the field of education is undergoing profound changes. Especially in higher vocational education, the application of digital technology provides new possibilities for the innovation of teaching and evaluation mode. In higher vocational mathematics education, the traditional evaluation method has been difficult to meet the current teaching needs. Through the integration of digital technology, the higher vocational mathematics evaluation model in Shandong Province can reflect the learning effect of students more comprehensively and objectively, and promote the improvement of teaching quality. This paper studies the relevant literature on digital technology integration in the mathematical evaluation model of higher vocational colleges in Shandong Province since 2019, and discusses its application status, advantages, challenges and future development direction.

Application of digital technology in mathematical evaluation design of higher vocational colleges in Shandong Province

Application of online assessment tools: With the development of online education, online assessment tools have become an important part of mathematics evaluation in higher vocational colleges. These tools help teachers monitor students' learning progress and mastery in real time through online testing, assignment submission and automated grading (Li Ming, 2020). For example, Shandong Vocational College has introduced a web-based test platform in its mathematics curriculum, which improves the efficiency and accuracy of evaluation through real-time feedback and data analysis (Zhao Na, 2021).

Introduction of Learning Analytics: Learning Analytics provides a powerful support for the evaluation of mathematics courses by collecting and analyzing student learning data. This technology can track students' behavior patterns in the learning process, thus helping teachers to understand students' learning status more comprehensively (Wang Wei, 2021). Some higher vocational colleges in Shandong

Province use learning analysis technology to build data-driven evaluation models to enhance the ability to evaluate students' learning effects (Zhang Li, 2020).

Application of adaptive assessment system: Adaptive assessment system uses artificial intelligence technology to dynamically adjust the assessment content and difficulty according to students' learning performance. This assessment method can more accurately measure students' learning ability and knowledge mastery (Zhao Qiang, 2020). For example, Shandong Technician College introduced an adaptive assessment system in mathematics teaching to realize the assessment and guidance of students' personalized learning path (Chen Gang, 2021).

The use of digital portfolios: As a comprehensive evaluation tool, e-Portfolios have been paid more and more attention in mathematics teaching in higher vocational colleges. It can record students' multi-dimensional performance in the learning process, including test scores, assignments, project results and reflective logs (Liu Fang, 2020). Some higher vocational colleges in Shandong Province have adopted the digital portfolio system to help teachers understand students' learning process more comprehensively through long-term tracking and comprehensive evaluation (Wang Qiang, 2020).

The advantages of digital technology convergence

Improved accuracy and objectivity of evaluation: The introduction of digital technology has made the evaluation process more standardized and objectified. Online assessment tools and adaptive assessment systems can automatically score according to preset algorithms, reducing the interference of human subjective factors (Zhang Hua, 2020). In addition, learning analysis technology can reflect students' learning situation more comprehensively through big data analysis, and help teachers make more accurate judgments (Zhao Li, 2021).

Promote personalized learning: Through an adaptive assessment system, students can receive personalized assessments based on their learning progress and ability level. This will not only help students find their weaknesses, but also provide teachers with targeted teaching suggestions (Li Wei, 2021). Personalized assessment

can better meet the learning needs of different students and improve their learning results (Liu Na, 2020).

Enhancing student motivation: The convergence of digital technologies makes the assessment process more flexible and diverse. Students can take the initiative to participate in the evaluation process and record and display their learning results through tools such as digital portfolios (Wang Ming, 2020). This kind of active participation not only improves students' learning enthusiasm, but also enhances their learning motivation (Chen Qiang, 2020).

Challenges in the convergence of digital technologies

Technical adaptability and resource allocation: The introduction of digital technology puts forward higher requirements for technical facilities and resource allocation in higher vocational colleges. Some colleges and universities still have deficiencies in technical equipment, network environment and teachers' technical ability, which limits the wide application of digital technology in evaluation (Zhao Fang, 2020). In addition, some teachers may face certain difficulties in adapting to the new evaluation methods and need systematic technical training (Li Gang, 2021).

Data privacy and security concerns: When using learning analytics technologies and adaptive assessment systems, students' personal data and learning behavior data will be collected and analyzed in bulk. This brings concerns about data privacy and security (Wang Qiang, 2020). How to give full play to the advantages of digital technology while ensuring data security has become an important topic of current research (Liu Wei, 2021).

Uniformity of evaluation criteria: Although digital technologies can improve the accuracy of evaluation, there are still differences in evaluation criteria across institutions and programs. Such differences may lead to inconsistencies in evaluation results and affect the overall evaluation of education quality (Zhao Liang, 2020). Therefore, it is necessary to formulate unified evaluation standards in the application process of digital technology to ensure the fairness and reliability of evaluation results (Zhang Ming, 2021).

Future direction of development

Data-driven intelligent evaluation system: With the development of big data and artificial intelligence technology, the future mathematical evaluation model of higher vocational education will be more intelligent and data-driven. By integrating multiple data sources, intelligent evaluation systems can provide students with more accurate learning assessment and guidance (Wang Hua, 2021). Such a system can not only improve the accuracy of evaluation, but also provide strong support for personalized learning (Liu Li, 2021).

The deep integration of evaluation and teaching: Digital technology will further promote the deep integration of evaluation and teaching. Through real-time learning data feedback, teachers can adjust teaching strategies in time to help students constantly improve in the learning process (Zhao Qiang, 2021). This trend will break the monogeneity of traditional evaluation and make evaluation an organic part of the teaching process (Chen Gang, 2021).

Improve teachers' digital ability: In order to better use digital technology, it is particularly important to improve teachers' digital ability. In the future, technical training for teachers should be strengthened to help them master and use the latest digital evaluation tools (Wang Wei, 2021). By improving teachers' digital teaching and evaluation ability, the deep integration of digital technology in higher vocational mathematics evaluation model can be better promoted (Zhao Ming, 2021).

The integration of digital technology in the mathematical evaluation model of higher vocational colleges in Shandong Province provides a new idea for the innovation of teaching evaluation. The introduction of online assessment tools, learning analysis techniques, adaptive assessment systems and digital portfolios has effectively improved the accuracy and objectivity of assessment, promoted personalized learning, and enhanced students' learning motivation. However, technical adaptability, data privacy and security concerns, and uniformity of evaluation criteria remain major challenges to be addressed. In the future, with the development of data-driven intelligent evaluation system and the deep integration

of evaluation and teaching, digital technology will play a more important role in the mathematical evaluation model of higher vocational colleges.

Higher vocational mathematics teaching content reform

With the deepening development of vocational education, mathematics teaching in higher vocational colleges is faced with the problem of how to combine closely with modern vocational needs. The traditional mathematics teaching content often focuses on the impartation of theoretical knowledge, but neglects the application of mathematics in practical occupation. Therefore, the reform of mathematics teaching content has become an important way to improve teaching effect and enhance students' vocational ability. This paper combs and analyzes the relevant literature after 2019, and discusses the status quo, challenges and development trend of the reform of mathematics teaching content in higher vocational colleges.

Background and necessity of teaching content reform

The contradiction between the development of vocational education and mathematics teaching: In recent years, with the continuous development of vocational education, the traditional mathematics teaching content has gradually failed to meet the needs of vocational education. Research shows that traditional mathematics curriculum content is too theoretical and out of touch with students' future career needs (Zhang Qiang, 2020).

The contradiction between students' weak foundation and vocational demand: the mathematics foundation of vocational college students is relatively weak, and the traditional teaching content is difficult to stimulate students' learning interest and motivation. The reform of mathematics teaching content in higher vocational colleges must consider students' basic ability to ensure that the course content is both basic and can be applied to practical work (Li Hua, 2021).

The influence of the development of information technology on mathematics teaching: The rapid development of information technology provides new ideas and methods for the reform of mathematics teaching content in higher vocational

colleges. The research points out that the use of information technology can effectively promote the modernization and professionalization of mathematics teaching content (Wang Lili, 2022).

The main direction of teaching content reform

Increased vocational relevance: In recent years, more and more research has emphasized the close integration of mathematics teaching content and vocational skills. For example, in engineering majors, mathematics teaching should focus on the application of engineering mathematics, such as the practical application of probability theory and mathematical statistics in engineering (Liu Wei, 2021).

Modular curriculum design: Modular curriculum design is one of the important directions of the reform of mathematics teaching content in recent years. The modular design can divide the content of mathematics courses into multiple modules according to the characteristics and needs of different majors, and students can choose corresponding modules for learning according to their career needs (Chen Fang, 2020).

Interdisciplinary integration: Interdisciplinary integration has become an important trend in the reform of mathematics teaching content in higher vocational colleges. By organically combining mathematics with professional courses, students can not only learn mathematical knowledge, but also understand the practical application of mathematics in professional fields (Zhang Ming, 2021).

Introduction of information technology: The introduction of information technology provides new tools and methods for the reform of mathematics teaching content. Using online platforms, math software and big data analysis tools, teachers can provide students with a more intuitive and practical learning experience (Li Na, 2022).

Practice and case of teaching content reform

The reform of mathematics curriculum for architectural engineering major: The reform of mathematics curriculum for architectural engineering major mainly focuses on the practical application of engineering mathematics. Through the introduction of construction cost calculation, structural analysis and other contents,

the course content is closely integrated with the future career needs of students (Wang Qiang, 2020).

Modular design of mathematics course for information technology major: The reform of mathematics course for information technology major adopts modular design, and the course content is divided into several modules such as algorithm design, data analysis, probability statistics, etc. Students can choose modules independently for learning according to career needs (Liu Fang, 2019).

Combination of blended teaching and online learning platform: The introduction of blended teaching mode in mathematics courses, combined with online learning platform, students can independently arrange learning progress, through the platform to complete preview, review and practical operation, so as to improve learning efficiency (Chen Wei, 2021).

The challenge and countermeasure of teaching content reform

Improvement of teachers' ability: The reform of mathematics teaching content puts forward higher requirements for teachers' comprehensive ability. Teachers should not only master modern teaching tools and methods, but also possess interdisciplinary knowledge and application ability (Zhang Li, 2021).

The cultivation of students' learning adaptability: The reformed mathematics curriculum may put forward higher requirements on students' learning habits and adaptability. Therefore, teachers should attach importance to the guidance and support of students' learning methods to help students adapt to the new learning mode (Wang Fang, 2022).

Integration and optimization of teaching resources: Mathematics teaching content reform needs to invest a lot of teaching resources, including textbooks, courseware, online platform and so on. How to integrate and optimize these resources effectively and improve the teaching effect is an urgent problem to be solved (Li Qiang, 2020).

Future development trend

Digitalization and intelligence: Digitalization and intelligence will become the core direction of the future reform of mathematics teaching content in higher

vocational colleges. With the popularization of artificial intelligence, big data and other technologies, mathematics teaching will rely more on intelligent tools and platforms to provide students with personalized learning experiences (Liu Ming, 2022).

Combination of internationalization and localization: The reform of mathematics teaching content should not only draw on international advanced experience, but also combine with the actual situation of China's vocational education, so as to achieve an organic combination of internationalization and localization (Zhang Qiang, 2021).

Continuous and dynamic adjustment: The reform of mathematics teaching content should be continuous and dynamically adjusted according to social needs and scientific and technological developments to ensure that the curriculum content is always consistent with professional needs (Li Hua, 2022).

The reform of mathematics teaching content in higher vocational colleges is an important way to improve teaching quality and enhance students' vocational ability. Through enhancing vocational relevance, modular design, interdisciplinary integration and the introduction of information technology, the content of mathematics teaching has been effectively updated and optimized. However, there are still challenges in the process of reform, such as improving teachers' ability, cultivating students' adaptability and integrating resources. In the future, with the development of digitalization and intelligence, the reform of mathematics teaching content will be more diversified and dynamic, providing students with a more comprehensive and personalized learning experience.

Shandong Province higher vocational mathematics teaching content reform

In recent years, with the continuous deepening of vocational education in China, especially in Shandong Province, the development of higher vocational education is closely related to the transformation and upgrading of regional economy. As a basic subject, mathematics plays a vital role in higher vocational education. However, the traditional mathematics teaching contents and methods

gradually show their limitations in training vocational ability of higher vocational students. In order to meet the needs of modern industry and intelligent manufacturing industry, higher vocational colleges in Shandong Province have carried out the reform of mathematics teaching content, aiming at improving students' practical application ability and professional quality.

The present situation of higher vocational mathematics teaching in Shandong Province

The teaching content is strong in theory and weak in practice: the traditional mathematics courses in higher vocational colleges are mainly taught in theory, and the course content tends to the basic theories such as calculus and linear algebra. Although these contents are important, they are not strongly related to students' future career needs and lack practicality and application (Li Ming, 2020).

Disconnection between curriculum and professional needs: the mathematics curriculum of higher vocational colleges often lacks connection with professional courses, which makes it difficult to apply mathematics knowledge effectively in professional courses. This disconnect is particularly evident in some emerging technology majors (Zhang Li, 2021).

Students' low interest in learning: Mathematics learning is boring for most higher vocational students, because the teaching content is not closely related to the actual work, students' interest and initiative in learning are low, and the learning effect is not good (Wang Fang, 2022).

The necessity of the reform of higher vocational mathematics teaching content in Shandong Province

To meet the needs of regional economic development: Shandong Province, as an important economic province in China, has put forward higher requirements for highly skilled talents in the rapid development of intelligent manufacturing, information technology and other fields. The reform of mathematics teaching content in higher vocational colleges can better serve the development of regional economy and train high-quality talents with strong practical application ability (Li Na, 2019).

Enhance the vocational ability of students: the goal of higher vocational education is to train technical talents who meet the needs of the industry. Therefore, the content of mathematics teaching should be closely combined with vocational skills, enhance the applicability and practicability of the curriculum, and help students better apply mathematical knowledge to professional learning and future work (Chen Qiang, 2021).

Responding to the national education reform policy: The national education reform policy emphasizes the connotation development and teaching reform of vocational education, and the reform of higher vocational mathematics curriculum is an important measure to respond to the national policy and improve the teaching quality (Zhao Lei, 2020).

The direction of the reform of higher vocational mathematics teaching content in Shandong Province

Add applied mathematics module: on the basis of traditional mathematics courses, add applied mathematics module, covering such as geometric operation in numerical control technology, differential equation application in automatic control, etc. These modules can be directly linked to professional courses to help students apply mathematical knowledge to practical operations (Wang Li, 2020).

Implementation of project-driven teaching method: Through project-driven teaching method, mathematics knowledge is integrated into specific projects, so that students can master mathematics knowledge in the process of completing projects. For example, in the mechatronics technology major, robot programming projects can be designed, and students need to apply mathematical knowledge to solve practical problems (Li Qiang, 2022).

Interdisciplinary integration and curriculum integration: Integrate mathematics courses with professional courses organically, break the discipline barrier, and design interdisciplinary courses. For example, when learning linear algebra, it can be combined with computer programming courses to deepen the understanding of mathematical knowledge through programming practice (Zhang Ming, 2021).

Introduction of information technology and intelligent teaching tools: With the help of modern information technology, such as online teaching platform, virtual laboratory, etc., abundant learning resources and diversified learning methods are provided to help students better grasp mathematical knowledge (Zhao Wei, 2021).

A case study of the reform of mathematics teaching content in higher vocational colleges in Shandong Province

Modular curriculum design of Weifang Vocational College: In the reform of mathematics curriculum, Weifang Vocational College has implemented modular curriculum design, which is divided into basic mathematics, applied mathematics and practical modules according to professional needs. Students can choose modules according to their own learning progress and professional needs, and the learning effect will be significantly improved (Li Fang, 2020).

Project-driven teaching method in Qingdao Vocational and Technical College: In the Mechatronics major, Qingdao Vocational and Technical College integrates mathematical knowledge into specific project practice through a project-driven approach. For example, by designing and programming robots and using calculus and matrix operations to solve practical problems, students have greatly improved their interest in mathematics learning and application ability (Zhang Qiang, 2022).

Information teaching platform of Jinan engineering polytechnic: Jinan Engineering polytechnic has developed a mathematics teaching platform based on big data, which provides personalized learning paths and resources through intelligent analysis of student learning conditions to help students learn mathematics more efficiently (Wang Na, 2021).

Challenges and countermeasures of the reform of mathematics teaching content in higher vocational colleges in Shandong Province

Lack of teachers: A major challenge in the reform process is the lack of teachers, especially those with both the ability and expertise to teach mathematics. In this regard, schools need to strengthen teacher training and encourage teachers to conduct interdisciplinary learning and teaching research (Chen Fang, 2020).

Students' basic difference: The mathematics foundation of vocational college students is uneven, and how to take into account the needs of students at different levels in the process of reform is a difficult problem. One solution is to provide personalized teaching support through information technology to help students with weak foundation to keep up with their learning progress (Zhao Hua, 2021).

Development and integration of teaching resources: In the process of reform, it is necessary to develop and integrate new teaching resources, including textbooks, case libraries, online courses, etc. Schools should cooperate with enterprises and research institutions to jointly develop teaching resources that meet actual needs (Li Wei, 2019).

Future outlook

Deepening interdisciplinary integration: The future reform of mathematics curriculum will further deepen the interdisciplinary integration with professional courses, make mathematics learning closer to the actual career needs, and help students better cope with future career challenges (Zhang Li, 2021).

The development of intelligent and personalized learning: With the development of information technology, intelligent and personalized learning will become an important direction of mathematics teaching reform. This will enable students to receive more personalized support in math learning, thus improving learning efficiency (Wang Na, 2021).

Strengthening school-enterprise cooperation: In the reform of mathematics teaching content, school-enterprise cooperation will become more important. Through cooperation with enterprises, schools can timely understand the needs of the industry, adjust and optimize the content of mathematics curriculum, and make it more close to the actual vocational needs (Zhao Lei, 2020).

The reform of higher vocational mathematics teaching content in Shandong Province is an important measure to improve students' vocational ability and adapt to the needs of regional economic development. Through the addition of applied mathematics modules, the implementation of project-driven pedagogy, the strengthening of interdisciplinary integration, and the introduction of information

technology, the mathematics curriculum content has been significantly improved. However, the reform process still faces challenges such as the shortage of teachers, the difference of student foundation and the development of teaching resources. In the future, with the development of intelligence and information technology, the reform of mathematics teaching content will be more in-depth, providing strong support for training high-quality skilled talents to meet the needs of modern economy.

Types and applications of teaching platforms

With the rapid development of information technology, digital teaching platform has become an important part of modern education. The teaching platform can not only support the digital transformation of the traditional teaching mode, but also promote the practice of new teaching modes such as personalized learning, online education and blended learning. Especially in the field of higher vocational education, the application of teaching platform has effectively improved the teaching efficiency and students' learning effect. This literature review aims to systematically review the research on teaching platforms in recent years (after 2019), analyze their types, application scenarios, advantages and challenges, and look forward to their future development direction.

The main types of teaching platforms

Online learning Platform: Online learning platform is a web-based education platform that supports students to conduct self-directed learning through the Internet. Common online learning platforms include Coursera, edX, Moodle, etc. (Wang Wei, 2020). These platforms often offer video courses, online quizzes, forums and other features that allow students to arrange their own learning progress. Online learning platforms are widely used in higher education and vocational education, especially during the pandemic, and their application has been significantly expanded (Li Na, 2021). Students can use these platforms for distance learning and achieve a learning experience without time and space constraints.

Blended Learning Platform: Blended Learning platform combines the advantages of online learning and traditional classroom teaching, and supports the blended learning mode through digital tools (Chen Hua, 2020). Such platforms often integrate learning management systems (LMS), content management systems (CMS), and social learning tools to support a combination of online and offline teaching. Blended learning platforms have been widely used in vocational education and corporate training to help educational institutions and enterprises achieve flexible teaching and training arrangements (Zhao Ming, 2021).

Intelligent learning platform: Based on artificial intelligence and big data technology, intelligent learning platform can provide personalized learning suggestions and paths according to students' learning behaviors and data analysis results (Li Qiang, 2019). This kind of platform usually has intelligent recommendation, learning path optimization, learning effect analysis and other functions. Intelligent learning platforms are mostly used in K12 education and higher education to enhance students' learning effectiveness and engagement through personalized learning programs (Zhang Wei, 2021).

Mobile Learning Platform: Mobile learning platform is an education platform based on mobile devices, which supports students to learn through mobile devices such as mobile phones and tablets (Zhao Fang, 2019). Such platforms are often flexible and convenient, making them suitable for fragmented learning. The mobile learning platform is widely used in adult education, enterprise training and higher vocational education, and is especially suitable for learners who have both work and study (Liu Li, 2020).

Virtual Simulation Platform: Virtual simulation platform utilizes virtual reality (VR) and augmented reality (AR) technologies to provide students with an immersive learning experience. This kind of platform is suitable for simulating complex experimental environment or practical operation to enhance students' practical ability (Chen Wei, 2021). Virtual simulation platform is widely used in engineering education, medical education and higher vocational education to improve students'

practical skills and application ability through virtual laboratory and simulation (Wang Na, 2021).

The application effect of teaching platform

Improving teaching efficiency: Teaching platforms can greatly improve teaching efficiency, especially online learning and blended learning platforms, which break the time and space restrictions of traditional teaching and enable teachers to manage the teaching process more efficiently (Li Wei, 2020). Studies have shown that the learning effect of courses using online learning platforms is comparable to traditional classroom teaching, and even exceeds it in some aspects (Zhang Qiang, 2021).

Promote personalized learning: By analyzing students' learning behaviors and data, intelligent learning platforms can provide students with personalized learning paths and resources, which greatly improves the learning effect (Wang Fang, 2021). Personalized learning not only improves students' learning interest, but also effectively solves the difficulties encountered by students in the learning process (Liu Hua, 2019).

Enhancing learner engagement: Mobile learning platforms and virtual simulation platforms enhance student engagement through interactive and immersive learning experiences (Mei Chen, 2021). Especially in vocational education and engineering education, virtual simulation platforms help students better understand and master complex knowledge and skills by simulating real scenarios (Zhao Li, 2020).

The challenge of teaching platform

Technology and resource limitations: Although the teaching platform has been outstanding in improving teaching results, technology and resource limitations are still the main obstacles to their popularization and application. Especially in educational institutions with limited resources, the development, maintenance and updating costs of the platform are high (Zhao Qiang, 2020). In addition, some teachers and students may face technical adaptability problems when using these platforms (Chen Fang, 2021).

Data Privacy and security: The massive data processing and storage of the teaching platform involves privacy and data security issues for students. How to make full use of big data and artificial intelligence technology on the premise of ensuring data security is a major challenge facing current teaching platforms (Wang Wei, 2020).

The transformation of the role of teachers: With the application of the teaching platform, the role of teachers has changed from knowledge imparts to learning guides and supporters. This transformation requires teachers to have higher digital teaching ability and data analysis ability (Li Na, 2021). However, some teachers face great adaptability challenges in this process and need to improve their abilities through systematic training and learning (Liu Ming, 2019).

Future direction of development

Enhance the intelligence and personalization of the platform: The future teaching platform will pay more attention to the development of intelligence and personalization, and provide more accurate personalized learning programs and recommendations through artificial intelligence and big data technology (Wang Qiang, 2021). At the same time, the interaction and user experience of the platform will continue to improve, further enhancing students' learning engagement (Chen Hua, 2020).

Interconnectivity between platforms: One of the future trends of teaching platforms is the interconnectivity between different platforms. Through open interfaces and standardized protocols, data between different platforms can be seamlessly connected, providing students with a more integrated learning experience (Zhao Ming, 2020).

Deep integration of platform and educational resources: With the digitalization and opening of high-quality educational resources, the future teaching platform will further integrate all kinds of educational resources to realize the sharing and efficient use of teaching resources (Li Wei, 2021). This trend will greatly promote the improvement of education equity and education quality (Liu Li, 2020).

To sum up, the application of teaching platform in modern education has achieved remarkable results, especially in improving teaching efficiency, promoting personalized learning and enhancing learner participation. However, technology and resource constraints, data privacy and security concerns, and the changing role of teachers remain challenges to be faced in the development of teaching platforms. In the future, with the development of intelligence, platform interconnection and deep integration of resources, teaching platforms will play a more important role in the field of education.

The application of higher vocational mathematics teaching platforms

With the rapid development of information technology, digital, networked and intelligent education platform has gradually become an important part of higher vocational education. Especially in higher vocational mathematics teaching, the traditional classroom teaching method can not meet the requirements of modern vocational education for students' practical ability and innovative ability. Based on this background, the development and application of effective mathematics teaching platform has become one of the important directions of higher vocational education reform. This paper analyzes the research results after 2019, and systematically discusses the development status, main application modes, existing problems and future development direction of higher vocational mathematics teaching platform.

The development background of mathematics teaching platform in higher vocational colleges

The integration of information technology and vocational education: the progress of information technology has promoted the reform of education mode, especially the development of network technology and mobile technology, which makes the development of higher vocational mathematics teaching platform possible. Through these platforms, students can break the restrictions of time and space and learn mathematics anytime and anywhere, which provides a new way to improve teaching efficiency (Li Wenbin, 2020).

Demand for intelligent education: With the rise of artificial intelligence, big data and other technologies, intelligent education platforms are gradually popularized. These platforms can not only enable online learning, but also provide personalized learning paths through big data analysis to help students improve their learning efficiency (Wang Fang, 2021).

The promotion role of the epidemic: The outbreak of the novel coronavirus has accelerated the development of online education, and many higher vocational colleges have quickly built math teaching platforms to meet the challenge of offline teaching interruption. This emergency makes the application and development of online teaching platform necessary, and promotes the development of related research (Liu Wei, 2020).

The main application mode of mathematics teaching platform in higher vocational colleges

Web-based online learning platform: Online learning platform is the most common type of vocational mathematics teaching platform. Through these platforms, students can access teaching videos, e-textbooks, online quizzes and other resources. For example, platforms such as Moodle and Blackboard have been widely used in mathematics teaching in higher vocational colleges (Zhang Li, 2019).

Mobile learning applications: Mobile learning applications (such as apps) provide students with a more convenient way to learn. Through mobile phones or tablets, students can use fragmented time to study. These applications often provide interactive learning content, instant feedback, and online discussion capabilities that greatly enhance students' learning experience (Chen Hua, 2021).

Virtual experiment and simulation platform: Virtual experiment and simulation platform provides simulation experiment environment for students through virtual reality technology, so that students can carry out mathematical modeling, problem solving and experimental operation in virtual space. This type of platform is particularly suitable for complex computation and application problems involved in higher vocational mathematics (Zhao Ming, 2020).

Intelligent learning platform: Intelligent learning platform utilizes big data and artificial intelligence technology to provide personalized learning suggestions and learning paths. By analyzing students' learning behavior and performance data, the platform can automatically adjust the difficulty and progress of learning content to help students master math knowledge more effectively (Wang Wei, 2021).

The effect and challenge of mathematics teaching platform in higher vocational college

Improve the teaching effect and learning interest: The research shows that the mathematics teaching platform in higher vocational colleges has a remarkable performance in improving students' learning interest and teaching effect. Through the diversified learning resources and interactive functions provided by the platform, students' participation and enthusiasm have been significantly improved (Li Na, 2021).

Implementation of personalized learning: The intelligent learning platform provides customized learning resources and exercises according to students' learning progress and weaknesses through a personalized recommendation system. This model effectively helps students improve their learning efficiency, especially for students with weak foundation (Zhang Qiang, 2021).

Enhanced interaction between teachers and students: Another advantage of digital platforms is enhanced interaction between teachers and students. Online discussion boards, instant messaging tools and online tutoring functions enable teachers to keep abreast of students' learning progress and provide targeted guidance and help (Chen Wei, 2020).

Existing challenges: Although the teaching platform has significant advantages in improving teaching results, there are also some challenges. First of all, the development and maintenance cost of the platform is high, and many higher vocational colleges are insufficient in terms of capital and technical support (Zhao Fang, 2021). Secondly, some teachers and students may face technical obstacles or maladaptive problems when using digital platforms, which need to be solved through training and adaptation period (Wang Qiang, 2019).

Research and practice of mathematics teaching platform in Shandong Province

The practice of Weifang Vocational College: Weifang Vocational College has introduced an intelligent learning platform in the mathematics teaching of higher vocational colleges, which provides personalized learning paths and suggestions for students through the analysis of students' learning data. Studies have shown that the application of the platform has significantly improved students' math scores, especially those with weak foundations (Li Fang, 2020).

Exploration of Qingdao Vocational and Technical College: Qingdao Vocational and Technical College has developed a mathematics learning APP based on mobile terminal, through which students can study and test anytime and anywhere. This application has improved students' learning flexibility and initiative, especially during the epidemic (Zhang Wei, 2021).

Innovation of Jinan Engineering polytechnic: Jinan Engineering polytechnic adopts a virtual experiment and simulation platform, through which students carry out virtual experiments to simulate real mathematical application scenarios, enhancing students' practical ability and understanding ability. This platform has a significant effect in improving students' hands-on ability and practical application ability (Zhao Liang, 2020).

Future development direction

Further integration of intelligence and big data: In the future, higher vocational mathematics teaching platform will integrate more big data and artificial intelligence technology to further improve the precision and efficiency of personalized learning. This will help students achieve better learning results in a shorter time (Wang Li, 2022).

Popularization and promotion of the platform: Although the mathematics teaching platform in higher vocational colleges has achieved certain results, the popularity is still low in some colleges and regions. In the future, more efforts should be made to promote these platforms, and more higher vocational colleges should

be helped to adopt advanced teaching platforms through policy support and financial investment (Chen Gang, 2019).

Teacher's role transformation and ability improvement: With the application of teaching platform, the role of teachers will change from the traditional knowledge imparts to the guide and supporter of learning. Therefore, teachers need to further improve their digital teaching ability, including proficiency in operating platforms, designing online courses and using big data analysis (Zhao Mei, 2021).

To sum up, with the development of information technology, higher vocational mathematics teaching platform plays an important role in improving teaching effect, enhancing students' learning interest and improving learning efficiency. Despite challenges such as technology costs and teacher adaptability, some higher vocational colleges in Shandong Province have achieved remarkable results through intelligent learning platforms, mobile learning applications and virtual experiment platforms. In the future, with the further integration of intelligence and big data technology, the teaching platform will play a more critical role in higher vocational mathematics teaching.

Instructional Design Theory and TPACK Framework

Instructional Design Theory and TPACK Framework

Over the past two decades, the widespread use of digital technology in education has driven instructional design from linear, media-centered improvements to systematic, learner-centered integration. Mathematics instruction in higher vocational colleges faces challenges, including the visual representation and contextualized transfer of abstract knowledge, as well as the constraints of diverse learner foundations, practical assessment, and job competency orientation. Consequently, a single list of techniques or single-point strategies is unlikely to be consistently effective. Instructional Design (ID) theory provides evidence-based, reusable processes and principles, while TPACK (Technological Pedagogical Content Knowledge) provides a knowledge framework for the dynamic balance of technology, pedagogy, and subject content. The combination of these two approaches supports

the closed-loop improvement of "problem-goal-strategy-evaluation-optimization," providing a theoretical anchor for the "Digital Technology Integration Model in Mathematics Instructional Design for Higher Vocational Colleges in Shandong Province," constructed in this study.

The Evolution and Core Model of Instructional Design Theory

Instructional design theory has evolved from behaviorism to cognitivism and constructivism, and has formed a variety of models and principles in the context of informatization:

The ADDIE model consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. It emphasizes the closed loop of needs analysis and continuous evaluation and is suitable for institutionalized curriculum development and quality assurance.

Dick & Carey system design: From teaching objectives and homework analysis to evaluation tools and teaching strategies, it emphasizes the alignment of objectives, measurement, and teaching activities, which is particularly critical for the standardization and assessment of higher vocational courses.

Gagné's nine teaching events: nine "events" from attracting attention to promoting transfer, are suitable for breaking down abstract mathematical concepts into actionable teaching links and matching them with digital prompts and feedback mechanisms.

Merrill's first principles: problem-based, activating prior knowledge, demonstration, application, and integration, provide a feasible sequence for the digital implementation of project-based learning (PBL) and contextualized cases.

Cognitive load theory: emphasizes reducing external load, optimizing representation and guiding internal load, and improving mathematics learning efficiency through visualization, multimodal presentation and segmented micro-courses.

Backward Design: The design is based on the reverse process of "expected results - acceptable evidence - learning experience", which is suitable for higher vocational courses guided by job capabilities and curriculum standards.

Agile/prototype model (SAM, rapid iteration): emphasizes rapid prototyping and continuous user feedback, which is in line with the curriculum update and technology selection of higher vocational colleges under resource and time constraints.

These models converge in concept: they are centered around learning objectives and evidence, are learner-centered, and employ a closed-loop approach of evaluation and improvement. They also advocate the use of technology to enhance visual expression, interactive feedback, and personalized support. For this study, these theories provided a mappable process framework for the structured "Five Steps (Analysis - Design - Implementation - Evaluation - Optimization)" 40 Elements.

TPACK Framework: Knowledge Dimensions and Dynamic Integration

TPACK was proposed by Mishra and Koehler based on Shulman's PCK (disciplinary pedagogical knowledge). It emphasizes the complex knowledge domain formed by the three-dimensional interaction of technology (TK), pedagogy (PK) and subject content (CK): TCK (technology and content), TPK (technology and pedagogy), PCK (pedagogy and content) and TPACK, which is the intersection of the three.

TK: Understanding and ability to use digital tools and platforms (such as visual drawing, symbolic computing, and learning analytics).

PK: Teaching organization, strategies and evaluation (such as inquiry-based, flipped classroom, formative assessment).

CK: Mathematical concepts, principles and knowledge systems (such as functions and limits, probability statistics, and the application of linear algebra in professional scenarios).

TCK/TPK/PCK: answer the questions of "how does technology affect knowledge representation", "how does technology enhance teaching strategies" and "how to teach content" respectively.

TPACK (Integration Domain): Dynamic balancing and creative integration of technology, teaching, and content in specific contexts.

For higher vocational mathematics, the value of TPACK is reflected in three aspects: first, using technology to improve the representation of abstract concepts (graphical, dynamic, and visual); second, using technology to support evidence-based teaching decisions (learning analysis, instant feedback, and personalized recommendations); and third, using technology to expand the "mathematics-career" context (simulation and cases, cross-platform collaboration).

TPACK: Measurement, Evidence, and Criticism

Researchers often measure TPACK levels through self-report questionnaires, performance tasks, classroom observations, and portfolio analysis. Empirical evidence suggests that high levels of TPACK correlate with better classroom management, task design, and learning outcomes. However, TPACK has also faced three types of criticism:

Boundary and overlap issues: The intersection of TCK/TPK/PCK makes measurement dimensions easily confused.

Context-dependence: The definition and evidence of TPACK are not completely consistent across different disciplines and stages of education.

The causal chain between tools and outcomes: Technical proficiency does not necessarily lead to learning outcomes; the key lies in the alignment of "technology-task-evaluation".

Therefore, TPACK should be regarded as contextualized practical knowledge, which needs to be coupled with the teaching design process and supplemented by evidence-based evaluation and continuous improvement.

Instructional Design Theory × TPACK: From Framework to Process

Integrating ID with TPACK means clarifying the triple alignment of "knowledge-strategy-tools" in every design phase:

Analysis: Based on learner profiles and job standards, clarify "what to learn (CK) - how to learn (PK) - what to use (TK)".

Design: Use reverse design or first principles to transform mathematical objectives into evidence-based performance tasks, and match them with visualization, simulation, practice, and feedback tools (TPK/TCK).

Implementation: Organize presentation methods and interaction rhythms based on the principle of minimizing cognitive load, and use learning analytics to make real-time adjustments.

Evaluation: Use both formative and performance evaluations to drive classroom fine-tuning through a closed loop.

Optimization: Agile iteration, continuous improvement of "elements-paths-resources" based on learning data and classroom observations.

This "process-knowledge-data" collaboration is the methodological basis for the subsequent use of the Delphi method (to identify factors), T test (to verify effectiveness), and focus group (to evaluate improvements) in this study.

Adaptation Path in Higher Vocational Mathematics Context

The implementation of TPACK for higher vocational mathematics must take into account three needs: "visualization of abstract knowledge," "skill-oriented evaluation," and "differentiated support."

Concept-representation coupling: Reduce external load with dynamic geometry, function visualization, and data dashboards.

Context-task integration: embedding job contexts (such as quality inspection, finance, and logistics optimization) into problem design, and using simulation software and data sets to achieve "learning by doing".

Integrated assessment and feedback: Use online quizzes and learning analytics to provide immediate feedback, combined with peer assessment and performance-based assignments.

Support - Path Stratification: Relying on adaptive exercises and resource recommendations to build a "basic-advanced" dual channel to improve accessibility for students with different foundations.

Teacher professional development: Replace "tool list training" with "task-driven micro-skills" training to improve TCK/TPK/TPACK around typical teaching situations.

Instructional design theory provides a "reliable process + reusable strategies", while TPACK offers a perspective on knowledge integration across "teaching-learning-

skill-discipline". For higher vocational mathematics, combining these two approaches not only enhances the teachability and learnability of abstract content but also fosters continuous improvement through a data-driven approach. This directly inspired the subsequent design of this study: using the Delphi method to refine key elements, validating effectiveness through learning outcomes, and optimizing usability through focus groups. Ultimately, this resulted in a five-step, forty-element integrated model, providing replicable and scalable theoretical and methodological support for the digital transformation of higher vocational mathematics instruction in Shandong Province.

Chapter 3
Research Methodology

The purpose of this study is to explore and evaluate the effective integration of digital technology in higher vocational mathematics instructional design in Shandong Province, in order to improve the quality of mathematics instruction and the learning effect of students.

This study identified four research objectives. First, it analyzes the problems and corresponding solutions in higher vocational mathematics instructional design in Shandong Province in order to understand the current challenges and bottlenecks in teaching practice. Second, it aims to develop a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province to enhance instructional quality and improve students' learning experiences. Third, a focus group was conducted to evaluate and refine the proposed instructional design model, further verifying the effectiveness of digital technology integration in higher vocational mathematics instructional design and improving the model accordingly. Finally, an independent sample t-test was employed to implement the instructional design model and examine its effectiveness in significantly improving students' mathematics achievement.

Research methods and processes will be developed around the above four objectives, and the research objectives will be achieved through a series of scientifically rigorous research steps. This study is divided into four stages.

Stage 1 To identify problems and its solutions on digital technology integration for higher vocational mathematics instructional design in Shandong Province

Using literature review and the first round of Delphi to identify problems and its resolution on digital technology integration for higher vocational mathematics instructional design. The specific research process is shown in Figure 3.1.

Stage 1: To identify problems and its resolutions on digital technology integration for higher vocational mathematics instructional design in

21 experts:

3 educational Technologist;

15 mathematics teachers;

3 educational administrator.

Sample group

1.Literature review
2.Delphi (Round 1)
3.IOC

Research instruments

Delphi first round structured interview

1. Distribute questionnaires.
2. Collect questionnaires.
3. Data collation.

Data collection

Data analysis and statistics

1. Open coding.
2. Preliminary screening and integration.
3. Extraction of core elements.

The result of stage 1

Go to stage 2

Figure 3.1 Details of the research process stage 1

The sample group

21 experts are selected, and the personnel composition includes the following three categories:

3 educational Technologist: expert with higher vocational education background, familiar with mathematics teaching and digital technology application.

15 higher vocational mathematics teachers: mathematics teachers with rich teaching experience, especially teachers working in higher vocational colleges.

3 educational administrator: An educational administrator responsible for teaching management and reform, who understands the policy and actual situation of mathematics education in higher vocational colleges.

Research Instruments

Design the first round of Delphi structured interview outline

Structured Interview outline construction:

Current Situation Analysis: Ask experts to describe the main problems currently existing in mathematics teaching in higher vocational colleges, such as lack of student interest, outdated teaching methods, and limited application of digital technology.

Cause Analysis: Discuss the causes of these problems, such as insufficient teaching resources, inadequate teacher training, and inappropriate curriculum design.

Suggestions: Ask experts to offer suggestions for addressing these issues, such as strengthening teacher training, introducing advanced teaching technologies, and optimizing curriculum design.

Issue Ranking: Arrange the issues in a logical order, from the current situation to the proposed solutions.

Data Collection

Questionnaire Distribution: Questionnaires were distributed via email and an online survey platform (Wenwenxing) according to the experts' schedules.

Questionnaire Collection: Questionnaires were collected one week after distribution.

Data Collection: The first round of data collected consisted primarily of open-ended text, including descriptions of the problem, suggested solutions, and nominations of key elements.

Data Storage: Questionnaire and analysis data were stored in a secure database or folder to ensure data integrity and security.

Data Analysis

Open Coding: Researchers first open-coded the text provided by the experts, merging similar or repetitive statements and clarifying ambiguous items to ensure clarity.

Thematic Categorization: All items were categorized according to the five key areas of instructional analysis, resource matching, instructional implementation, learning support, and assessment enhancement.

Preliminary Screening and Integration: Based on the coding and categorization, items with low relevance to the research topic or excessive repetition were eliminated.

Core Element Extraction: Problems and solutions were mapped and integrated to extract proposed core elements. These elements were then analyzed for consistency with the IOC and used as the foundational items for the second round of Delphi consultation.

Reliability and Validity Assurance: Experts' original transcripts were retained to ensure data traceability and authenticity.

The Item-Objective Congruence (IOC) index is used to examine the degree of consistency between a measurement tool or questionnaire item and the research objective. Its core concept is to quantify the degree of fit between the item and the research objective by inviting domain experts to rate the relevance of each item.

Table 3.1 IOC value judgment criteria

IOC value range	Degree of consistency	Judgment Recommendations
IOC ≥ 0.80	High Congruence	The entry is highly consistent with the research objectives and can be directly retained for the next round
0.50 ≤ IOC < 0.80	Moderate Congruence	The items are generally relevant to the research objectives and are recommended to be revised based on expert opinions before entering the next round.
IOC < 0.50	Low Congruence	The item is not consistent with the research objectives and is recommended to be deleted or redesigned.

Note: 1.The threshold can be adjusted according to the actual research situation, but 0.80/0.50 is commonly used as the dividing point in education and social science research.

2.This standard helps to quickly screen items in the Delphi method and content validity test.

Stage 2 Delphi method is used to develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province

Delphi method is used to develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province, the specific research process is shown in Figure 3.2.
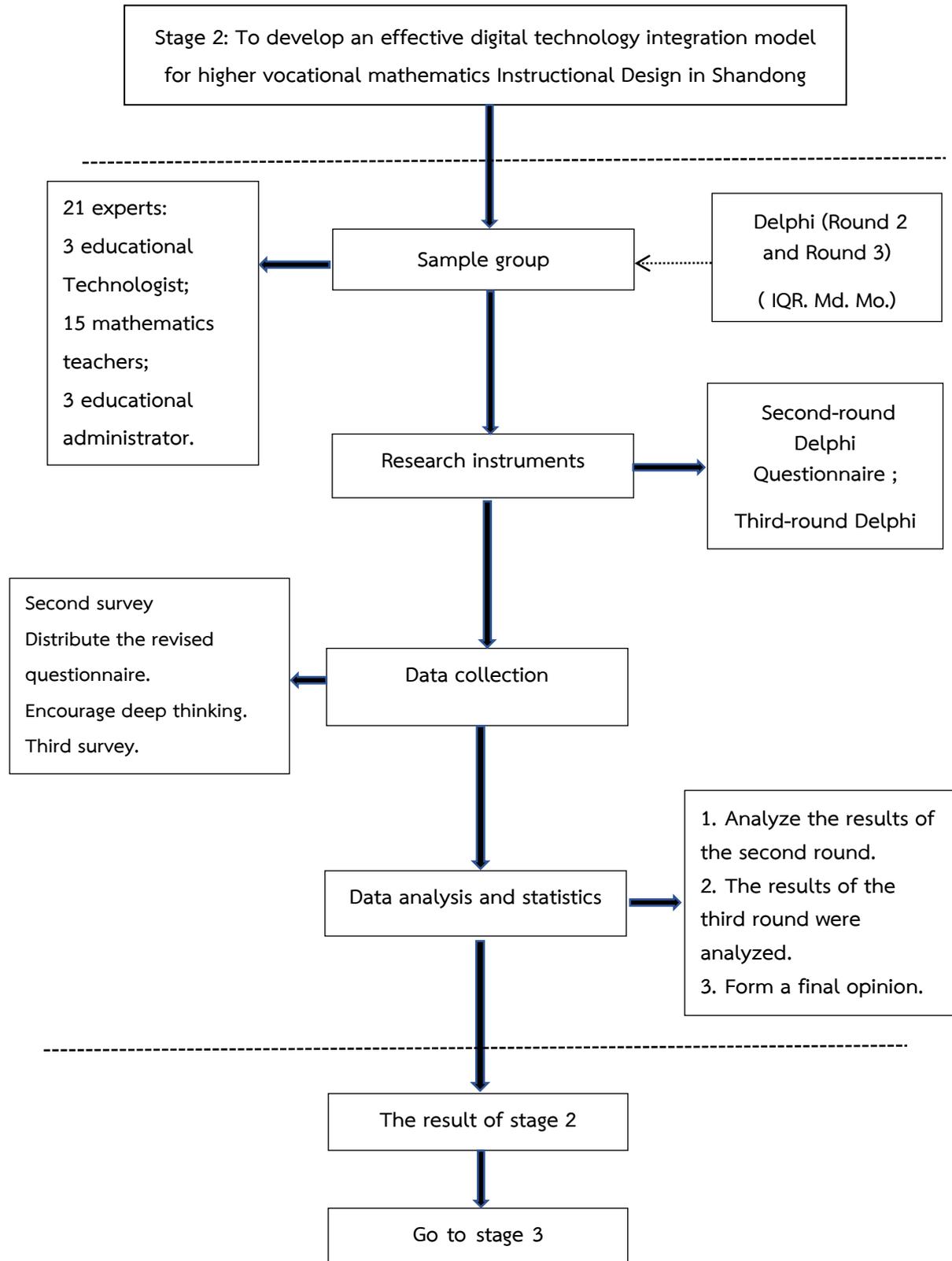
Figure 3.2 Details of the research process stage 2

The Sample group

Selection of experts: Select 21 experts from Shandong Province, who should have rich experience in higher vocational mathematics teaching and a deep understanding of the application of digital technology, and should cover the fields of educational technology, mathematics education and vocational education. The experts include 3 higher vocational education administrators, 15 mathematics teachers, and 3 educational technologists.

Research Instruments

This study used the Delphi questionnaire as the primary research tool to ensure consensus was reached through multiple rounds of expert consultation and to refine the core elements of the model.

Questionnaire Content

Round 2: Based on the results of the first round of Delphi and the IOC test, a total of 40 core elements were retained and revised. Scoring was performed using a 5-point Likert scale, and an open-ended comment section was included to collect expert feedback.

Round 3: Based on the statistical results of the second round and expert feedback, elements with high consensus were retained and presented to the experts again. Statistical information such as the median (Md), mode (Mo), and interquartile range (IQR) of each element from the previous round was also included to facilitate further scoring by experts based on a thorough understanding of group opinions.

Questionnaire Design Principles

Items were concise and professional, appropriate for the context of higher vocational mathematics teaching.

Each core element was independent and well-defined, avoiding double meanings.

Evaluation dimensions were comprehensive, focusing on both importance, feasibility, and presentation quality.

Structured closed-ended questions were combined with open-ended comments to obtain both quantitative and qualitative data.

Data Collection

Implementation Steps

Step 1: Distribute the second-round Delphi questionnaire (electronic version) to experts, collecting data simultaneously via email and online questionnaire platforms (e.g., WJX).

Step 2: Collect and summarize the results of the second round, analyze consistency based on Mean (MD), Mean (MO), and Interquartile Range (IQR), and revise the questionnaire items based on expert feedback.

Step 3: Distribute the third-round Delphi questionnaire to the same experts, providing the second-round statistical results next to each item for reference.

Step 4: Collect the third-round questionnaires, analyze the final consistency, and determine the final core element structure of the digital technology integration model.

Timeline

Round 2: 2 weeks (including distribution, completion, collection, and preliminary analysis);

Round 3: 2 weeks (including distribution, completion, collection, and final analysis).

Data Analysis

Quantitative Analysis

Median (Md): measures the central tendency of experts' responses to an item;

Mode (Mo): reflects the most frequently occurring value in expert ratings;

Interquartile Range (IQR): $IQR = Q_3 - Q_1$. Q_1 represents the first quartile (25th percentile), and Q_3 represents the third quartile (75th percentile). A smaller IQR indicates a higher level of consensus among experts.

Calculation Standard: $Md \geq 4.00$ indicates high importance or feasibility of the item; $IQR \leq 1.00$ indicates good agreement among experts.

Qualitative Analysis

Open-ended comments were analyzed thematically to summarize expert suggestions for revisions, additions, or mergers. Qualitative feedback was combined with quantitative results to inform model revisions and optimization. Judgment and Retention Criteria

Items meeting both the importance and feasibility criteria of Md ≥ 4.00 and IQR ≤ 1.00 were retained. Items that did not meet these criteria but were close to the threshold were retained after revision based on qualitative expert feedback. Items significantly below the threshold (Md < 3.50 or IQR > 1.50) were deleted or merged.

This article adopts the consensus standard from Wu Jianxin's (2014) viewpoint, as follows:

Table 3.2 Consensus Degree Based on Interquartile Range (IQR) in Expert Opinion Surveys

Interquartile range	Consensus Degree
0≤IQR≤1.0	High
1.0≤IQR≤2.0	Medium
IQR≥2.0	Low

Median (Md): The median is the score in the middle of the score data provided by all experts in order. It can describe the concentration trend of expert opinions, and then explain the meaning according to the standards set by the researcher as follows:

Table 3.3 Median-Based Expert Opinion Classification

Median	The possibility of this item
Md ≥ 4.50	Most likely
3.50 ≤ Md ≤ 4.49	More likely
2.50 ≤ Md ≤ 3.49	Moderate likely
1.50 ≤ Md ≤ 2.49	Less likely
Md ≤ 1.50	Least likely

The median was obtained from the Answers from all experts, Then interpret the meaning according to the criteria set by the researcher as follows:

The median of 4.50 and above means that the group of experts considers that the statement is most likely.

The median value is between 3.50-4.49 meaning that the group of experts considers that the statement is more likely.

The median value is between 2.50-3.49 meaning that the group of experts considers that the message is moderate likely.

The median value is between 1.50-2.49 meaning that the group of experts agrees that the message is less likely.

The median value is less than 1.50 indicating that the group of experts considers the message least likely.

Stage 3 Evaluate and improve the model using the focus group method

Focus group was used to evaluate the digital technology integration model for higher vocational mathematics instructional design in Shandong Province. The specific research process is shown in Figure 3.3.

Figure 3.3 Details of the research process stage 3

The sample group

9 focus group members selected.

2 Expert members: Scholars or education experts with in-depth research on the application of digital technologies to instructional design.

5 teacher representatives: teachers with rich experience in higher vocational mathematics teaching, who directly use digital technology to teach.

2 student representatives: Student representatives from different majors who are able to give feedback on students' actual experiences with digital technologies in their studies.

Research Instruments

Literature review: Provide team members with previously completed literature reviews, expert interviews, and Delphi results so that they are fully aware of the research background and previous findings.

Evaluation outline:

1. The application effect of digital technology in mathematics teaching in higher vocational colleges: including teaching efficiency, student participation, learning effect, etc.

2. Teachers' acceptance and use of digital technology: including teachers' proficiency in digital technology, effectiveness of teaching AIDS, etc.

3. The impact of digital technology on students' learning habits and learning results: including the improvement of students' learning interest, understanding ability and grades.

4. Current challenges in the application of digital technology: such as insufficient technical resources, inadequate teacher training, students' adaptability, etc.

5. Direction of future improvement: how to further optimize the integration of digital technology to improve teaching effect.

Recording tools: Prepare recording equipment to ensure that each discussion is fully recorded, and prepare notebooks to record important discussion points.

Data Collection

Organize a discussion

Discussion moderators: The discussion is led by a professional facilitator to ensure that the discussion is focused on the scheduled topic and that all members are able to express their opinions.

Discussion duration: Approximately 1.5 to 2 hours for each discussion. Discussions can be scheduled as many times as necessary to ensure that all issues are fully explored.

Discussion format: Face-to-face or video conferencing to discuss the application and integration effect of digital technology in instructional design.

Recording and recording: During the discussion, all members' statements are recorded and audio recordings are made to ensure the integrity of subsequent analysis.

Instant feedback: The moderator can summarize the main points of the discussion at the end of the discussion, and solicit immediate feedback and comments from the group members.

Data Analysis

Organize and categorize the discussion notes and use Thematic Analysis to identify recurring themes and issues in the discussion.

By summarizing the opinions of different panelists, it is determined which aspects are advantages in the application of digital technology and which areas need to be improved.

Through the analysis of the consensus and the points of disagreement among the members, the overall evaluation of the application effect of digital technology is obtained.

Stage 4 Independent sample t-test was used to implement the model

Independent sample t-test was used to implement the digital technology integration model for higher vocational mathematics instructional design in Shandong Province. The detailed research process is shown in Figure 3.4.
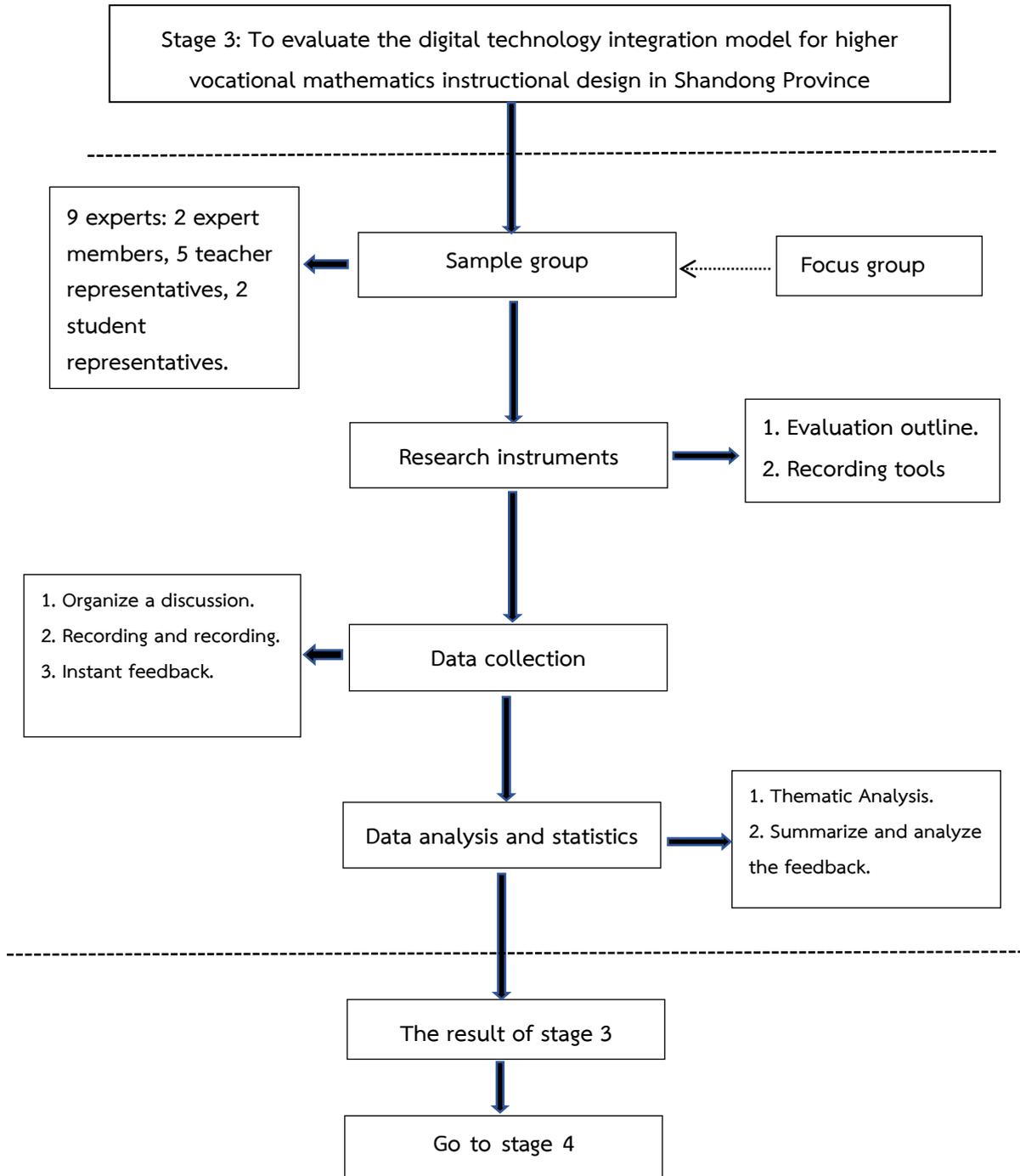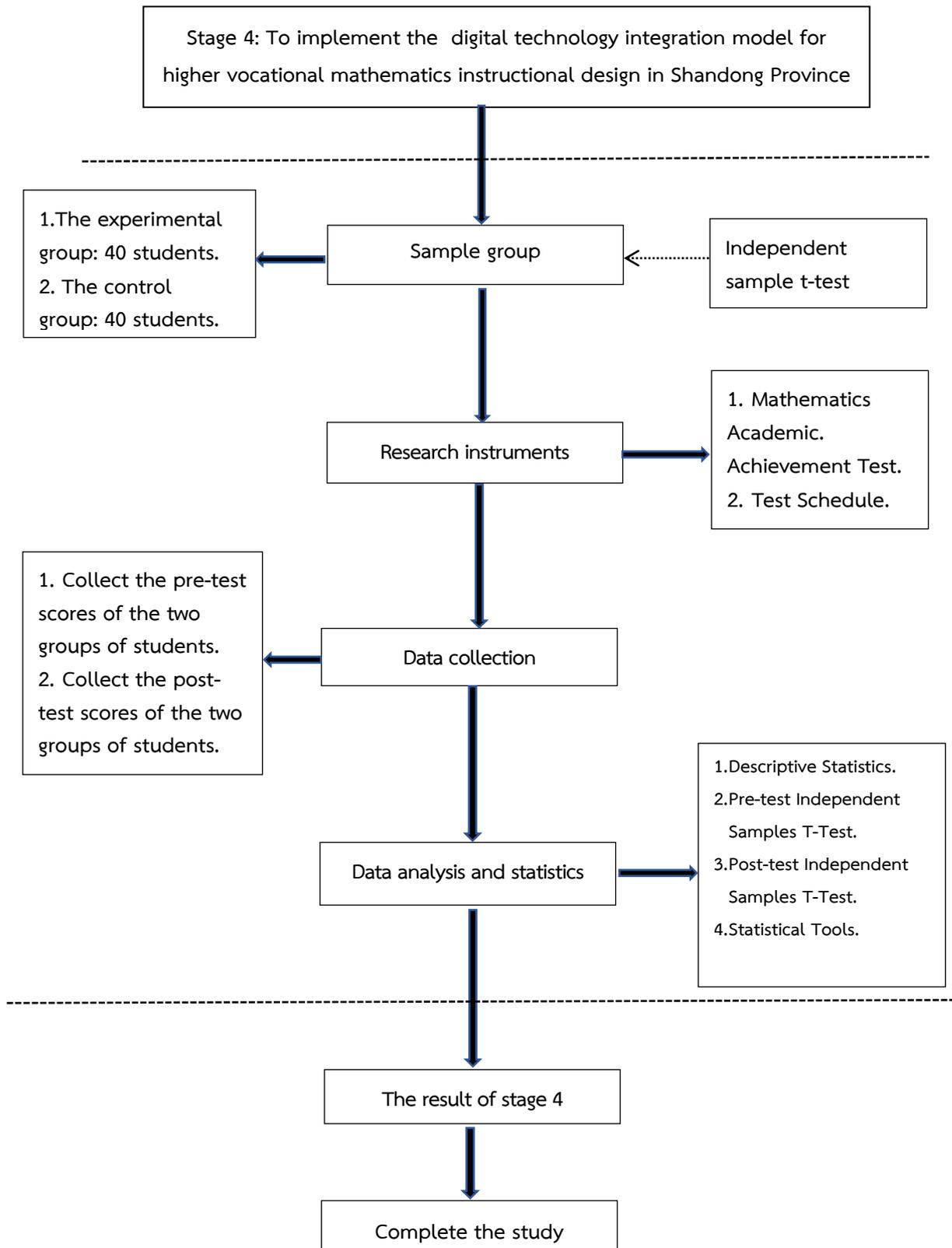
Figure 3.4 Details of the research process stage 4

The sample group

For the empirical phase of this study, first-year mathematics students majoring in mechatronics at Jinan Engineering Vocational and Technical College were selected. Based on their majors and course schedules, 40 students were selected from each of the experimental and control groups, for a total sample size of 80.

The experimental group received an instructional intervention based on the "Digital Technology Integration Instructional Design Model" developed in this study; the control group received instruction using a traditional vocational mathematics instructional design.

Convenience sampling was used to ensure comparability between the two groups in terms of gender ratio, major, and mathematical foundation, minimizing the impact of external variables.

Research Instruments

Mathematics Academic Achievement Test

Content Source: Designed based on the "Higher Vocational Education Mathematics Curriculum Standards" and the teaching objectives of the selected course (Higher Mathematics Basic Unit).

Question Types: Multiple-choice, fill-in-the-blank, calculation, and word problems.

Difficulty and Discrimination: Questions were reviewed by two experts in higher vocational mathematics teaching to ensure reliability and validity.

Score: Full score: 100.

Test Schedule

Pre-test: Conducted one week before the intervention to assess the mathematical foundation of the two groups of students.

Post-test: Conducted one week after the intervention to assess student learning outcomes.

Data Collection

Preliminary Preparation

Training on the use of the digital technology-integrated instructional design model was provided to the experimental group's teachers to ensure the correct implementation of the intervention.

Experimental Procedure

Phase 1: Pre-test

Both groups of students completed a 90-minute pre-test under identical conditions. The pre-test results were used to test whether there was a significant difference in mathematical proficiency between the two groups before the intervention.

Phase 2: Instructional Intervention

The experimental group conducted an eight-week mathematics course based on a digital technology-integrated instructional design model, integrating a smart teaching platform, online interactive tools, and a digital resource library. The control group completed the same instructional content using a traditional lecture-based blackboard teaching model.

Phase 3: Post-test

Students in both groups completed a 90-minute posttest under identical conditions. The post-test scores were used to evaluate the effectiveness of the model in improving learning outcomes.

Data Management

The collected answer sheets were independently graded by two instructors, and the average score was used as the final score. Data were entered into SPSS statistical software, ensuring double entry and proofreading to prevent input errors.

Data Analysis

Descriptive Statistics

The mean and standard deviation of the pretest and post-test scores of the two groups were calculated. A table was used to visually display the score distribution and trend.

The reliability of the test was calculated using the Kuder–Richardson Formula 20 (KR-20).

Kuder–Richardson 20 (KR-20) Calculation

$$KR - 20 = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k} p_i q_i}{s_x^2}\right)$$

Where k represents the total number of items, P_i is the proportion of correct responses for each item, $q_i = 1 - p_i$ and s_x^2 represents the variance of the total test scores. Using the formula, the pre-test and post-test KR-20 coefficients were calculated for the experimental and control groups to test the internal consistency of the test.

Post-test Independent Samples t-Test

This test examines the difference in post-intervention scores between the experimental and control groups.

Null Hypothesis (H_0): There is no significant difference in the mean post-test scores between the two groups.

Alternative Hypothesis (H_1): There is a significant difference in the mean post-test scores between the two groups.

The significance level is $\alpha = 0.05$, with $P < 0.05$ considered a significant difference.

Statistical Tools

Data analysis was performed using program computer, and an independent sample t-test table was generated. The results will be interpreted in light of educational implications.

Summarize

This study is mainly divided into the following four stages, which the researcher will complete one by one in chronological order:

1. The first stage: Use literature review and expert interview to achieve objective 1, that is, problems and solutions of the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

2. The second stage: Use Delphi method to achieve the second objective, that is, develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

3. The third stage: Use focus group to evaluate the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

4. The fourth stage: Use two independent sample t-test to achieve the third objective, that is, implement the digital technology integration model for higher vocational mathematics instructional design in Shandong Province.

Chapter 4

Results of Analysis

The research methods are described in Chapter 3 and focus on four research objectives: 1) Through a literature review and the first round of the Delphi method, the problems and corresponding countermeasures regarding the digital technology integration for higher vocational mathematics instructional design in Shandong Province were identified. Based on these findings, 40 core elements of the instructional design model were determined, and an Index of Item-Objective Congruence (IOC) test was conducted. 2) The second and third rounds of the Delphi method were employed to construct the digital technology integration model for higher vocational mathematics instructional design in Shandong Province. The median (Md), mode (Mo), and interquartile range (IQR) were used for data analysis. 3) A focus group method was adopted, and 9experts were selected to evaluate and improve the model. 4) Independent sample t-test was conducted to implement the model (experimental group n = 40; control group n = 40).

Symbols and Abbreviations

IOC   refers to the consistency index between items and objectives

IQR   refers to interquartile range

Md   refers to the median

Mo   refers to the mode

Phase 1: Identifying the problems and its solutions on digital technology integration for higher vocational mathematics instructional design in Shandong Province

Based on the comprehensive literature review presented in Chapter 2 and the first round of the Delphi expert consultation, this phase aimed to systematically identify the prevailing issues and potential solutions regarding digital technology

integration model for higher vocational mathematics instructional design in Shandong Province. The outcomes of this phase laid the foundational elements for the subsequent model construction.

1. List of Experts Participating in the Delphi Study

To ensure the scientific validity and reliability of the Delphi method, a total of 21experts were invited to participate in this study. All experts were selected according to strict criteria, including professional background in mathematics education, educational technology, or vocational education, rich teaching experience, and senior professional titles. Most experts have long-term experience in teaching and research in higher vocational colleges in Shandong Province.

The experts come from several representative vocational institutions, including Shandong Institute of Commerce and Technology, Jinan Vocational College, Jinan Engineering Polytechnic, Zibo Normal College, Qingdao Ocean Shipping Mariners College, Shandong Transport Vocational College, and Dongying Vocational Institute. Their professional titles mainly include Professor and Associate Professor, and their teaching experience ranges from 14 to 34 years, indicating a high level of professional expertise and academic authority.

Table 4.1 List of Experts Participating in the Delphi Study

Personal Information	Category	Frequency	Percentage(%)
Gender	Man	9	42.9
	Woman	12	57.1
	Total	**21**	**100**
Age	40–49 years old	19	90.5
	50–59 years old	2	9.5
	Total	**21**	**100**
Work Experience	10–20 years	9	42.9
	21–30 years	10	47.6
	31 years and above	2	9.5
	Total	**21**	**100**
Professional Title	Associate Professor	15	71.4
	Professor	6	28.6
	Total	**21**	**100**
Educational Level	Master's degree	18	85.7
	Doctoral degree	3	14.3
	Total	**21**	**100**

From Table 4.1, it can be seen that among the 21 experts participating in the Delphi consultation, 12 are women (57.1%) and 9 are men (42.9%), indicating a relatively balanced gender distribution.

In terms of age structure, the majority of experts are between 40 and 49 years old (19 experts, 90.5%), while 2 experts are between 50 and 59 years old (9.5%), suggesting that most experts are in the mature stage of their academic and professional careers.

Regarding working experience, most experts have rich teaching experience in vocational education. 9 experts have 10–20 years of experience (42.9%), 10 experts

have 21–30 years of experience (47.6%), and 2 experts have more than 31 years of experience (9.5%).

In terms of professional titles, 15 experts hold the title of Associate Professor (71.4%), while 6 experts are Professors (28.6%), reflecting a high level of academic expertise among the expert panel.

Regarding educational background, the majority of experts hold master's degrees (18 experts, 85.7%), while 3 experts hold doctoral degrees (14.3%). Overall, the experts possess strong academic qualifications and extensive teaching experience, which ensures the authority and reliability of the Delphi consultation results.

2. Identification of Problems and Solutions

In the first round of the Delphi study, 21 invited experts responded to an open-ended questionnaire covering five key instructional design stages. Through thematic analysis of the experts responses, 40 specific problems and their corresponding countermeasures were identified. These problems and solutions are categorized by instructional stage and listed in Table 4.2. To ensure clarity and operational value, each problem and solution is expressed as a complete sentence.

Table 4.2 Problems and solutions of digital technology integration model for higher vocational mathematics instructional design in Shandong Province

No.	Key Problems Identified	Proposed Solutions
Category : Teaching Analysis		
1	Current teaching analysis fails to utilize data to present a comprehensive profile of student differences.	Teachers should use digital tools to conduct a comprehensive analysis of learner profiles.
2	Teaching objectives are often vague and lack measurable digital standards.	Teaching objectives should be expressed digitally to ensure they are traceable and measurable.

Table 4.2 (Continued)

No.	Key Problems Identified	Proposed Solutions
3	Instructional cases lack context and fail to connect with professional scenarios.	Contextualized cases should be designed to integrate mathematical knowledge with professional applications.
4	Teaching resources are single-modal and lack diversity in presentation.	Multimodal teaching resources should be integrated to enrich content presentation.
5	There is a lack of design for interactive and collaborative tasks in the teaching analysis phase.	Collaborative learning tasks should be designed to utilize digital platforms for interaction.
6	A single learning path is provided for students with diverse backgrounds.	Digital learning paths should be planned to adapt to different student needs.
7	There is a lack of data-based teaching diagnosis before instruction.	Learning analytics tools should be applied to analyze pre-class data for instructional diagnosis.
8	There is a lack of effective interactive design mechanisms in the teaching plan.	A real-time interactive feedback mechanism should be established to enhance classroom engagement.
9	The teaching content structure is confusing and lacks visual support.	The presentation of teaching content should be visualized to improve comprehension.
Category : Resource Matching		
10	Learning support resources are not personalized enough to meet individual needs.	Adaptive learning systems should be applied to provide personalized resources for students.

Table 4.2 (Continued)

No.	Key Problems Identified	Proposed Solutions
11	The evaluation method is singular and relies too heavily on summative assessment.	Online tests and assessments should be designed to facilitate process-oriented evaluation.
12	There is insufficient support for learning resources on mobile devices.	Mobile learning platforms should be utilized to facilitate access to learning resources.
13	The integration and sharing of resources across multiple platforms are poor.	A cloud-based resource sharing and collaboration mechanism should be built to integrate quality resources.
14	New technologies such as VR/AR are insufficiently applied in resource construction.	Virtual simulation technology should be applied to enhance the learning experience.
15	There is a lack of methods to stimulate interest in the resource design.	Gamification learning elements should be integrated to boost student interest in learning.
16	Data on resource utilization lacks visualization and analysis.	Learning data should be collected and analyzed to monitor resource usage.
17	Teaching adjustments are often delayed due to slow feedback.	A teaching reflection and adjustment mechanism should be established to ensure timely improvement.
18	Teachers' digital literacy is insufficient for developing high-quality resources.	Teacher digital literacy should be developed to improve resource construction capabilities.
19	Learners lack guidance on how to use resources independently.	Support should be provided for learners' self-directed learning to cultivate autonomy.

Table 4.2 (Continued)

No.	Key Problems Identified	Proposed Solutions
Category : Instructional Implementation		
20	Resource management across different platforms is irregular.	Cross-platform learning resources should be integrated to optimize management.
21	The evaluation system has a single function during the implementation phase.	Digital assessment tools should be applied to support diversified evaluation methods.
22	Video resources lack specificity and are not targeted enough.	Video micro-courses should be produced and applied to target specific knowledge points.
23	Learning outcomes are single-dimensional and not analyzed deeply.	Course data-driven optimization should be implemented to improve teaching effectiveness.
24	There is a lack of lesson preparation templates and sharing mechanisms among teachers.	Collaborative lesson preparation and resource sharing should be organized to improve teaching quality.
25	The learning community has low activity during the implementation phase.	Classroom interaction data should be analyzed to enhance student engagement.
26	The efficiency of homework grading and feedback is low.	Digital assignment design and grading should be implemented to utilize auto-grading functions.
27	Learning warnings are not sensitive enough to detect student struggles.	Learner behavior should be tracked and analyzed to identify issues in a timely manner.
28	Teaching records are scattered and not utilized for decision-making.	Data-driven teaching decisions should be made to improve the scientific nature of instruction.

Table 4.2 (Continued)

No.	Key Problems Identified	Proposed Solutions
29	There are platform security risks and functional fragmentation.	Teaching platform functions should be integrated to ensure security and efficiency.
30	Resources do not match the specific needs of learners.	Personalized recommendations of course resources should be implemented to match student needs.
Category : Learning Support		
31	Evaluation does not adapt dynamically to student progress.	Adaptive evaluation systems should be applied to support dynamic assessment.
32	Student learning portfolios are incomplete or missing.	Student learning portfolios should be managed to record comprehensive growth.
33	There are insufficient accessible resources for diverse learners.	Interdisciplinary resources should be integrated to broaden the scope of learning support.
34	There is a lack of peer interaction in the support phase.	A peer assessment and collaborative feedback mechanism should be established.
35	Feedback on questions and answers is not timely.	An online question-and-answer support system should be constructed to provide timely help.
36	There are security risks in online examinations.	Digital examination security management should be implemented to ensure fairness.
Category : Evaluation Improvement		
37	There is a lack of process monitoring in teaching quality.	Online monitoring of teaching quality should be conducted to track the

Table 4.2 (Continued)

No.	Key Problems Identified	Proposed Solutions
		instructional process.
38	Learning outcomes are not visualized for easy understanding.	Learning outcomes should be visualized to clearly demonstrate student performance.
39	Teaching resources are outdated and not updated regularly.	A mechanism for the continuous updating of teaching resources should be established.
40	There is a lack of a closed-loop mechanism for continuous improvement.	A continuous improvement and optimization mechanism should be constructed to guarantee quality.

3. Extraction and Validation of Core Elements

Based on the problem-solution framework established in table 4.2, the researcher extracted the key actions from the "Proposed Solution" sentences to form 40 concrete core elements of instructional design. These elements are operational statements that teachers can directly implement in their digital teaching practice.

To ensure the content validity of these core elements, they were subjected to an Index of Item-Objective Congruence IOC evaluation by five independent experts who possessed rich experience in higher vocational mathematics teaching and educational technology. Each expert was asked to rate each element for its relevance and clarity.

The IOC evaluation results showed that all 40 core elements achieved values ranging from 0.80 to 1.00, indicating high content validity. As all items met the threshold of 0.80, they were determined to be "Reserved" for the subsequent second round of the Delphi consultation. The detailed list of elements and their IOC determination results are presented in table 4.3.

Table 4.3 The 40 Core Elements and IOC Validation Results

No.	Core elements	IOC	Action
Category : Teaching Analysis			
1	Learner Profile Analysis	1.0	Reserve
2	Digital Expression of Teaching Objectives	1.0	Reserve
3	Contextualized Case Design	0.8	Reserve
4	Integration of Multimodal Teaching Resources	1.0	Reserve
5	Collaborative Learning Task Design	1.0	Reserve
6	Digital Learning Path Planning	1.0	Reserve
7	Application of Learning Analytics Tools	0.8	Reserve
8	Real-Time Interactive Feedback Mechanism	1.0	Reserve
9	Visual Presentation of Teaching Content	1.0	Reserve
Category : Resource Matching			
10	Application of Adaptive Learning Systems	0.8	Reserve
11	Online Test and Assessment Design	1.0	Reserve
12	Utilization of Mobile Learning Platforms	1.0	Reserve
13	Cloud-Based Resource Sharing and Collaboration	1.0	Reserve
14	Application of Virtual Simulation Technology	0.8	Reserve
15	Integration of Gamification Learning Elements	1.0	Reserve
16	Learning Data Collection and Analytics	1.0	Reserve
17	Teaching Reflection and Adjustment Mechanism	1.0	Reserve
18	Teacher Digital Literacy Development	1.0	Reserve
19	Learner Self-Directed Learning Support	1.0	Reserve
Category : Instructional Implementation			
20	Cross-Platform Learning Resource Integration	1.0	Reserve
21	Application of Digital Assessment Tools	1.0	Reserve
22	Production and Application of Video Micro-Courses	0.8	Reserve
23	Course Data-Driven Optimization	1.0	Reserve
24	Collaborative Lesson Preparation and Resource Sharing	1.0	Reserve

Table 4.3 (Continued)

No.	Core elements	IOC	Action
25	Classroom Interaction Data Analytics	1.0	Reserve
Category : Instructional Implementation			
26	Digital Assignment Design and Grading	1.0	Reserve
27	Learner Behavior Tracking and Analytics	1.0	Reserve
28	Data-Driven Teaching Decision-Making	0.8	Reserve
29	Integration of Teaching Platform Functions	0.8	Reserve
30	Personalized Recommendation of Course Resources	1.0	Reserve
Category : Learning Support			
31	Application of Adaptive Evaluation Systems	1.0	Reserve
32	Student Learning Portfolio Management	1.0	Reserve
33	Integration of Interdisciplinary Resources	1.0	Reserve
34	Peer Assessment and Collaborative Feedback Mechanism	1.0	Reserve
35	Online Question-and-Answer Support System	1.0	Reserve
36	Digital Examination Security Management	0.8	Reserve
Category : Evaluation Improvement			
37	Online Monitoring of Teaching Quality	1.0	Reserve
38	Visualization of Learning Outcomes	1.0	Reserve
39	Continuous Updating of Teaching Resources	1.0	Reserve
40	Continuous Improvement and Optimization Mechanism	1.0	Reserve

The successful validation of the 40 core elements through the IOC procedure marked the completion of Phase 1. These elements formed the essential content for the structured questionnaire used in the second round of the Delphi method, where experts rated the importance and feasibility of each element to achieve consensus and build the integration model.

Phase 2 : Develop an effective digital technology integration model for higher vocational mathematics instructional design in Shandong Province

After completing the first round of Delphi and revising the core elements, this study conducted second and third rounds of Delphi to reach expert consensus and develop an effective model for integrating digital technology into higher vocational mathematics instructional design in Shandong Province. Data analysis used **median (Md), mode (Mo), and interquartile range (IQR)** to determine item significance and consistency.

Results of the second Delphi round

Table 4.4 summarizes the ratings of the 40 core elements by 21 experts in the second round of the Delphi process. Md reflects the median opinion on the importance of the element, Mo represents the most frequently occurring rating, and IQR reflects the degree of consensus. Retention of an element was determined based on an Md ≥ 4 and an IQR ≤ 1.

Table 4.4 Summary of Expert Consensus and Agreement (Round 2)

serial number	Core Elements	Md	Mo	IQR	Action
1	Learner Profile Analysis	5	5	0.50	Accept
2	Digital Expression of Teaching Objectives	5	5	0.50	Accept
3	Contextualized Case Design	5	5	0.75	Accept
4	Integration of Multimodal Teaching Resources	4	4	0.75	Accept
5	Collaborative Learning Task Design	4	4	0.75	Accept
6	Digital Learning Path Planning	4	4	1.25	
7	Application of Learning Analytics Tools	4	4	1.25	
8	Real-Time Interactive Feedback Mechanism	5	5	0.50	Accept
9	Visual Presentation of Teaching Content	5	5	0.50	Accept

Table 4.4 (Continued)

serial number	Core Elements	Md	Mo	IQR	Action
10	Application of Adaptive Learning Systems	4	4	1.50	
11	Online Test and Assessment Design	5	5	0.75	Accept
12	Utilization of Mobile Learning Platforms	4	4	1.25	
13	Cloud-Based Resource Sharing and Collaboration	4	4	0.75	Accept
14	Application of Virtual Simulation Technology	4	4	1.50	
15	Integration of Gamification Learning Elements	4	4	1.25	
16	Learning Data Collection and Analytics	5	5	0.50	Accept
17	Teaching Reflection and Adjustment Mechanism	5	5	0.50	Accept
18	Teacher Digital Literacy Development	5	5	0.50	Accept
19	Learner Self-Directed Learning Support	5	5	0.75	Accept
20	Cross-Platform Learning Resource Integration	4	4	1.25	
21	Application of Digital Assessment Tools	5	5	0.50	Accept
22	Production and Application of Video Micro-Courses	5	5	0.75	Accept
23	Course Data-Driven Optimization	5	5	0.50	Accept
24	Collaborative Lesson Preparation and Resource Sharing	4	4	1.25	
25	Classroom Interaction Data Analytics	5	5	0.50	Accept
26	Digital Assignment Design and Grading	5	5	0.50	Accept
27	Learner Behavior Tracking and Analytics	5	5	0.75	Accept
28	Data-Driven Teaching Decision-Making	4	4	1.25	
29	Integration of Teaching Platform Functions	4	4	1.25	
30	Personalized Recommendation of Course Resources	4	4	1.50	

Table 4.4 (Continued)

serial number	Core Elements	Md	Mo	IQR	Action
31	Application of Adaptive Evaluation Systems	4	4	1.25	
32	Student Learning Portfolio Management	5	5	0.50	Accept
33	Integration of Interdisciplinary Resources	4	4	1.50	
34	Peer Assessment and Collaborative Feedback Mechanism	5	5	0.50	Accept
35	Online Question-and-Answer Support System	5	5	0.50	Accept
36	Digital Examination Security Management	4	4	1.25	
37	Online Monitoring of Teaching Quality	5	5	0.75	Accept
38	Visualization of Learning Outcomes	5	5	0.50	Accept
39	Continuous Updating of Teaching Resources	5	5	0.50	Accept
40	Continuous Improvement and Optimization Mechanism	5	5	0.50	Accept

in Table 4.4, 26 items from the second round were retained, while 14 entered the revision phase. Common issues with these 14 items were insufficient specificity or lack of actionability. In the third round, these items will be refined through the addition of detailed indicators and the clarification of tools and processes to enhance consistency.

Figure 4.1 shows the median (Md) and interquartile range (IQR) distribution of the 40 core elements in the second round of Delphi expert consultation. Md reflects the degree of concentration of experts on the importance of the elements, and IQR reflects the degree of consistency of expert opinions.
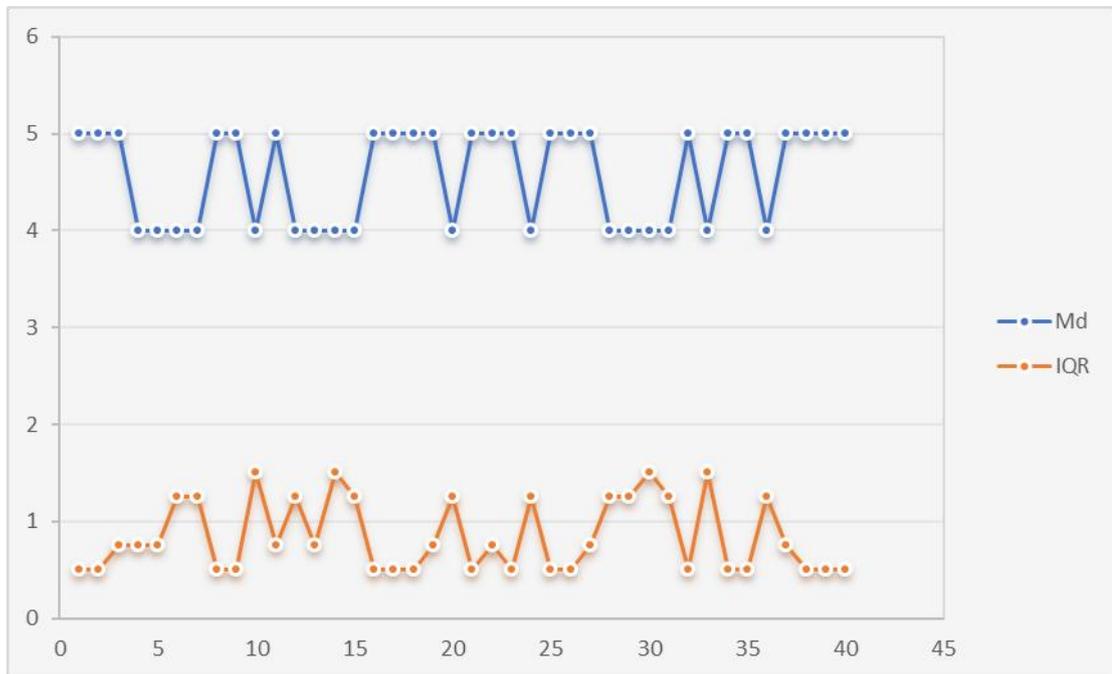
Figure 4.1 Md–IQR Scatter Plot

The Md values of most core elements were above 4 and had low IQR, indicating that experts had a high degree of consensus on the importance of core elements.

Results of the third Delphi round

The third round focused on the 14 items with an IQR > 1 in the second round, clarifying wording and refining operationalization (e.g., clarifying the technical list, thresholds, and steps). Twenty-one experts were again asked to rate the items using a 5-point scale. Md (median) was used to measure overall importance, Mo (mode) to reflect the prevailing opinion, and IQR (interquartile range) to assess consistency. The decision threshold was Md ≥ 4 and IQR ≤ 1. The goal of this round was to reduce non-convergent items to an IQR ≤ 0.5.

Table **4.5** Summary of Expert Consensus and Agreement (Round 3)

serial number	Core Elements	Md	Mo	IQR
1	Learner Profile Analysis	5	5	0.25
2	Digital Expression of Teaching Objectives	5	5	0.25
3	Contextualized Case Design	5	5	0.50
4	Integration of Multimodal Teaching Resources	5	5	0.50
5	Collaborative Learning Task Design	5	5	0.50
6	Digital Learning Path Planning	4	4	0.50
7	Application of Learning Analytics Tools	4	4	0.50
8	Real-Time Interactive Feedback Mechanism	5	5	0.25
9	Visual Presentation of Teaching Content	5	5	0.25
10	Application of Adaptive Learning Systems	4	4	0.50
11	Online Test and Assessment Design	5	5	0.50
12	Utilization of Mobile Learning Platforms	4	4	0.50
13	Cloud-Based Resource Sharing and Collaboration	5	5	0.50
14	Application of Virtual Simulation Technology	4	4	0.50
15	Integration of Gamification Learning Elements	4	4	0.50
16	Learning Data Collection and Analytics	5	5	0.25
17	Teaching Reflection and Adjustment Mechanism	5	5	0.25
18	Teacher Digital Literacy Development	5	5	0.25
19	Learner Self-Directed Learning Support	5	5	0.50
20	Cross-Platform Learning Resource Integration	4	4	0.50
21	Application of Digital Assessment Tools	5	5	0.25
22	Production and Application of Video Micro-Courses	5	5	0.50
23	Course Data-Driven Optimization	5	5	0.25
24	Collaborative Lesson Preparation and Resource Sharing	4	4	0.50
25	Classroom Interaction Data Analytics	5	5	0.25
26	Digital Assignment Design and Grading	5	5	0.25
27	Learner Behavior Tracking and Analytics	5	5	0.50

Table 4.5 (Continued)

serial number	Core Elements	Md	Mo	IQR
28	Data-Driven Teaching Decision-Making	4	4	0.50
29	Integration of Teaching Platform Functions	4	4	0.50
30	Personalized Recommendation of Course Resources	4	4	0.50
31	Application of Adaptive Evaluation Systems	4	4	0.50
32	Student Learning Portfolio Management	5	5	0.25
33	Integration of Interdisciplinary Resources	4	4	0.50
34	Peer Assessment and Collaborative Feedback Mechanism	5	5	0.25
35	Online Question-and-Answer Support System	5	5	0.25
36	Digital Examination Security Management	4	4	0.50
37	Online Monitoring of Teaching Quality	5	5	0.50
38	Visualization of Learning Outcomes	5	5	0.25
39	Continuous Updating of Teaching Resources	5	5	0.25
40	Continuous Improvement and Optimization Mechanism	5	5	0.25

All 40 items in the third round met the criteria of Md ≥ 4 and IQR ≤ 0.5, with 24 reaching the high agreement zone with an IQR ≤ 0.25, indicating a high degree of expert convergence. Fourteen elements (numbered 6, 7, 10, 12, 14, 15, 20, 24, 28, 29, 30, 31, 33, and 36) that had not converged in the second round entered the pass zone in this round after refinement of indicators, specification of processes, and grading of technical lists, supporting the full retention and finalization of model elements.

Figure 4.2 compares the changes in IQR values of the 40 core elements in the second and third rounds of Delphi, which is used to reflect the degree of improvement in the consistency of expert opinions.
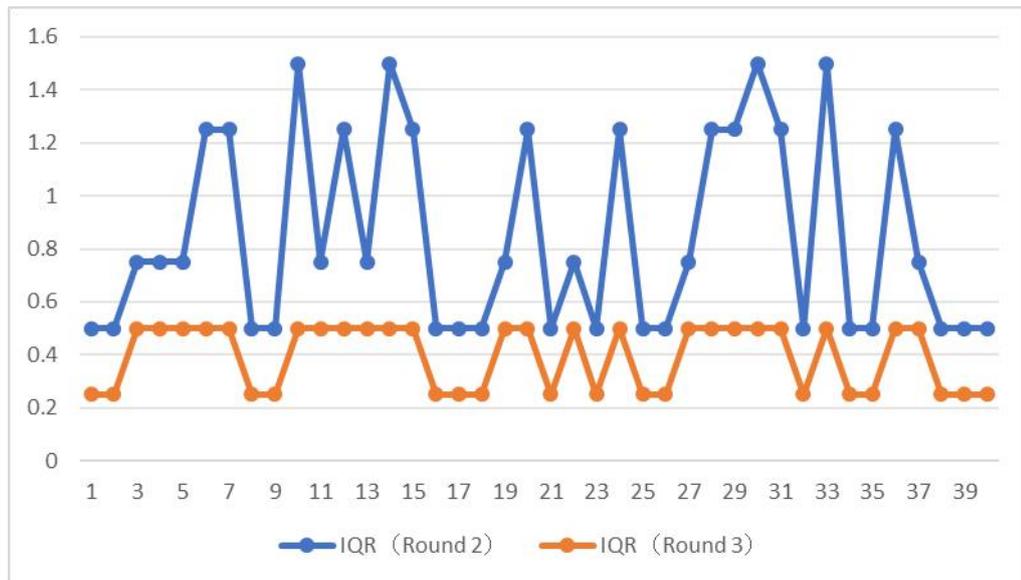
Figure 4.2 Comparison of Interquartile Range (IQR) Values Between Two Rounds

As can be seen from the figure, the IQR values of the third round are generally lower than those of the second round, and all dropped to 0.5 or below, indicating that after revision and feedback, the consistency of experts in evaluating the importance of core elements has been significantly improved.

Model building and presentation

Drawing upon the findings of the third round of the Delphi study, a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province was systematically developed. The model comprises five modules and 40 core elements, as illustrated in Figure 4.3.

Figure 4.3 Digital technology integration model for higher vocational mathematics instructional design in Shandong Province

Model Description

Teaching analysis: data-based learner profiling, goal decomposition and assessment alignment.

Resource matching: contextualized cases, cross-platform resource integration, and formative assessment tools.

Teaching implementation: hybrid learning paths, interactive collaboration, AR/VR technology embedding, and intelligent assessment.

Learning support: adaptive learning support, learning warning and feedback, and multi-dimensional records.

Evaluation and improvement: data-driven decision-making, platform training, and continuous improvement mechanisms.

In this stage, the second and third rounds of Delphi method were used to achieve convergence of expert opinions, determine the final version of 40 core elements, and develop a digital technology integration model for higher vocational mathematics instructional design of in Shandong Province, laying the foundation for subsequent T-tests and focus group evaluations.

Phase 3 : Use focus groups to evaluate and improve the model

To further evaluate and optimize the model, a focus group of nine experts was invited, including 5 front-line mathematics teachers in higher vocational schools (with rich experience in integrating digital technology), 2 educational technology and informatization experts, and 2 student representatives.

The meeting was conducted in the form of a semi-structured interview, lasting approximately 120 minutes. The interviews were recorded simultaneously through face-to-face discussions and online collaboration platforms (Tencent Meeting + Collaborative Documents), and the minutes were reviewed and confirmed after the meeting.

Table 4.6 summarizes the focus group discussion outline, follow-up questions, expert response summaries, and expected outputs on five topics: model structure, core elements, technological advancement, implementation guarantees, and

promotion strategies. The aim is to comprehensively evaluate the scientific nature and feasibility of the model.

Table 4.6 Focus group discussion outline, expert responses and expected outputs

Subject Areas	Core Issues	Questioning points	Summary of Expert Answers	Expected outputs
Model structural integrity	Does the model cover the entire teaching process?	Are there logical breakpoints between links? Is there a feedback loop?	The model covers the entire process from teaching analysis to evaluation optimization, and its structure is logically complete. It is recommended to add a clear feedback loop between "evaluation" and "teaching analysis" to facilitate continuous improvement.	Model structure optimization suggestion list
Core elements operability	Can the 40 core elements be implemented in actual classrooms?	Which elements are most/least operational? How can they be flexibly adjusted across different courses?	Most elements are highly operational, such as "learner portraits", "contextualized cases", and "visual feedback". Some new technologies are difficult to implement in institutions with insufficient hardware	Element implementation priorities and application scenario recommendations

Table 4.6 (Continued)

Subject Areas	Core Issues	Questioning points	Summary of Expert Answers	Expected outputs
			conditions. It is recommended to list mandatory and optional lists to adapt to different conditions.	
Advanced digital technology	Does the technology selection take into account both cutting-edge nature and availability?	Are there low-cost alternatives? How to cope with technological updates and iterations?	The overall technical configuration is balanced, covering common platforms and some cutting-edge technologies; it is recommended to provide low-cost alternatives to high-cost technologies and establish a technology update evaluation cycle (evaluated every 2 years).	Digital Technology Optimization and Update Suggestion Form
Implementation conditions and guarantees	Are teachers, resources and institutional guarantees in place?	What is the biggest obstacle in the implementation process? How to balance costs and benefits?	The main obstacles are the differences in teachers' digital literacy and the long resource construction cycle; it is recommended to establish centralized training, build a	Condition guarantee and resource support plan

Table 4.6 (Continued)

Subject Areas	Core Issues	Questioning points	Summary of Expert Answers	Expected outputs
			shared resource library, and use regional platforms to reduce the development pressure of individual schools.	
Promotion and application strategy	Can the model be applied in different colleges and majors?	How will the phased promotion path be set? How will teacher training be supported?	The model has the potential to be promoted across institutions and disciplines; a three-stage promotion is recommended: pilot program - regional promotion - province-wide popularization, with a tiered teacher training and evaluation mechanism for different stages.	Promotion roadmap and training plan

As can be seen from Table 4.6, the experts highly evaluated the structural integrity of the model and the operability of its core elements, and put forward specific optimization suggestions in terms of feedback loops, technical alternatives, condition guarantees, and promotion paths.

Table 4.7 summarizes the optimization suggestions put forward by the focus group on the model structure, focusing on closed-loop design, link connection, stage review, flowchart update and inspection mechanism.

Table 4.7 List of model structure optimization suggestions

Optimization direction	Specific recommendations
Increase feedback loop	Establish a feedback arrow between "evaluation" and "teaching analysis" to achieve continuous improvement
Link connection	Strengthen the information flow between links to avoid logical breakpoints
Stage review	Set up review and adjustment nodes at the end of each stage
Flowchart Update	Highlight loop structure identifiers in model diagrams
Inspection mechanism	Increase regular structural review and optimization plans

As can be seen from Table 4.7, these suggestions are intended to strengthen the model's ability to continuously improve and the logical fluency between links, ensuring that the model can maintain dynamic optimization in practice.

Table 4.8 categorizes the implementation priorities and applicable scenarios of the 40 core elements based on the feedback from the focus groups, providing a reference for flexible application in different institutions and course types.

Table 4.8 Implementation priorities and application scenario recommendations for
the elements

Priority	Core Elements	Applicable course types	Teaching environment description
high	Learner portraits, contextualized cases, and visual feedback	Science and engineering, technical skills	Complete digital equipment and online platform
middle	Collaborative learning design, real-time data analysis	Most courses	Requires stable network and projection equipment
Low	Advanced AI-assisted, adaptive learning paths	Innovative courses and experimental courses	High hardware resource configuration

As shown in Table 4.8, the implementation priorities of core elements vary in different course types and technical environments. Hierarchical management can help improve the targetedness and efficiency of implementation.

Table 4.9summarizes the focus group's recommendations for optimizing digital technology selection in the model, covering technology alternatives, upgrade cycles, and division of responsibilities.

Table **4.9** Digital technology optimization and update suggestions

Technology Category	Current technology used	Alternatives	Upgrade cycle	Person in charge
Learning Platform	Wisdom Tree, Rain Classroom	Ding Talk Classroom, Smart Vocational Education, Super Star	2 years	Academic Affairs Office
Data Analysis	Excel, SPSS	Python Data Analysis	2 years	Teaching and Research Group
AI-assisted	Bean bag, secret tower	DeepSeek	1 year	Information Center

As can be seen from Table 4.9, experts recommend taking into account both availability and technological advancement, and maintaining the applicability and cutting-edge nature of the technology through regular updates.

Table 4.10 summarizes the implementation plans proposed by the focus group regarding faculty, resources, and institutional guarantees, aiming to provide institutional and resource support for the implementation of the model.

Table **4.10** Conditions and resource support plan

Protection Type	content	Implementation measures
Teacher Training	Improving digital technology literacy	Tiered training + online learning platform
Resource Construction	Provincial shared resource library	Centralized development + inter-school sharing
Institutional incentives	Teaching Innovation Award	Performance bonus + achievement awards

As can be seen from Table 4.10, centralized training, shared resource pool, and incentive mechanism are the three core guarantees for the effective implementation of the model.

Table 4.11 shows the model promotion roadmap and supporting training plan proposed by the focus group, covering the entire process from pilot to province-wide coverage.

Table 4.11 Promotion roadmap and training plan

Stage	Time Range	Promotion scope	Training Objectives	Evaluation Method
pilot	Year 1	2-3 higher vocational colleges	Familiar with model structure and operation	Classroom observation + teacher feedback
Regional Promotion	Year 2	5-8 higher vocational colleges	Improve implementation results	Student performance analysis + interviews
Province-wide coverage	Year 3	Vocational colleges across the province	Normalization of model application	Third-party evaluation report

As shown in Table 4.11, phased promotion and tiered training can help improve promotion effectiveness and ensure the quality and consistency of the model at different implementation stages.

Table 4.12 summarizes the focus group's consensus opinions and typical suggestions on each evaluation dimension of the model, covering five aspects: structure, elements, technology, conditions and promotion feasibility.

Table 4.12 Focus group evaluation and suggestions on the model

Evaluation Dimensions	Expert consensus	Typical suggestions
Model structure	The structure is clear and the five steps (analysis - design - implementation - evaluation - optimization) are logically sound.	It is recommended to add feedback loop identification between links to highlight the continuous improvement mechanism.
Core Elements	The 40 core elements are broad in coverage and concrete and feasible.	Incorporate student-led data analysis guidance into personalized learning paths to enhance learners' self-regulation abilities.
Digital Technology	Technology selection takes into account both general and disciplinary characteristics	Introduce AI-assisted grading and learning analysis tools to reduce the burden of grading and data processing on teachers.
Implementation conditions	Teachers' digital literacy and resource construction are key	It is recommended to establish a provincial-level digital teaching resource sharing library for higher vocational mathematics to reduce the pressure on resource development in individual schools.
Promotion feasibility	Performed well in pilot institutions and has potential for promotion	Develop a phased promotion plan and provide a tiered teacher training plan to ensure the quality of promotion.

As can be seen from Table 4.12, experts generally recognize the scientific nature and operability of the model, and propose improvement directions in terms of structural optimization, element refinement, technology update, condition guarantee and promotion strategy.
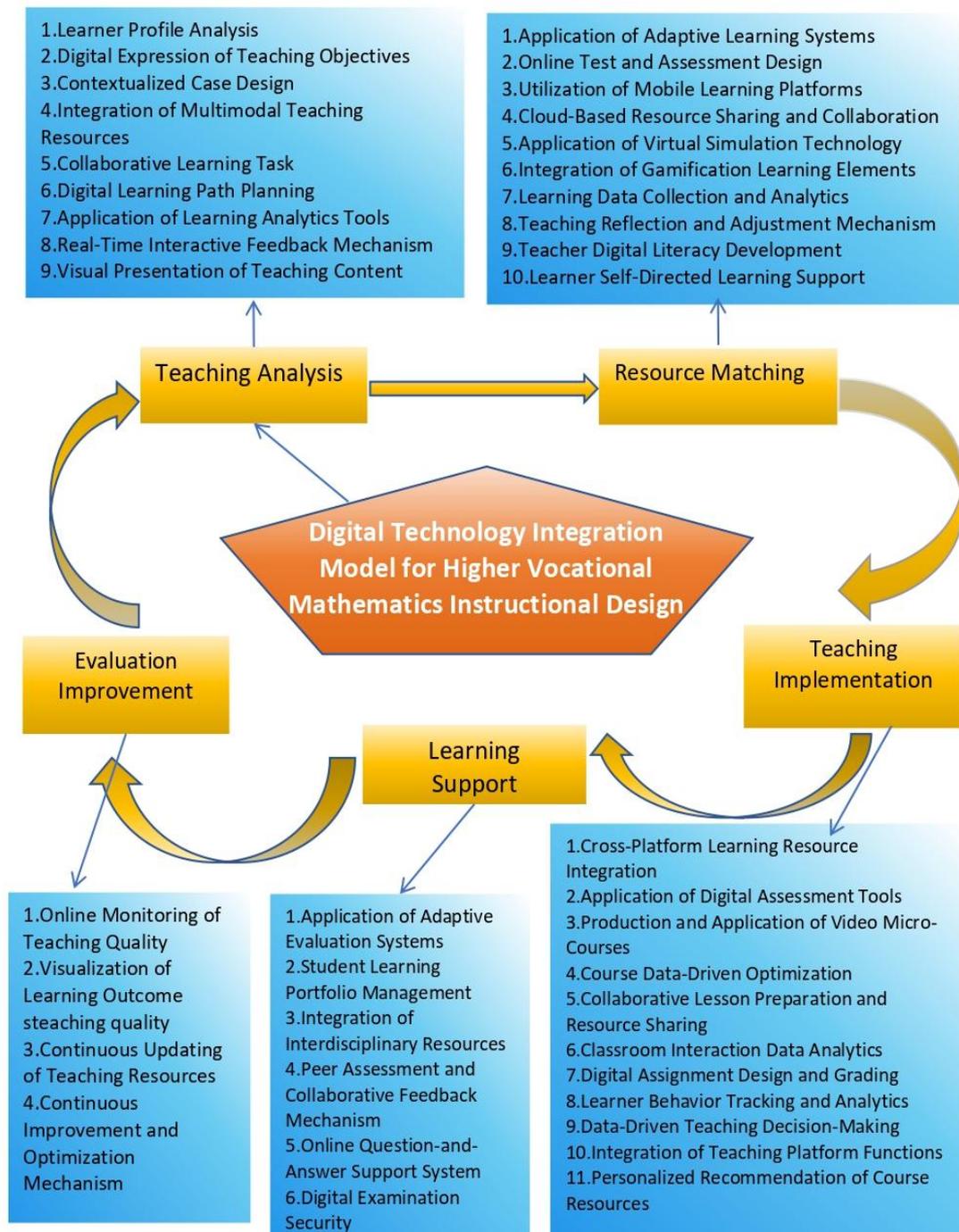
Figure 4.4 Improved the Digital technology integration model for higher vocational mathematics instructional design in Shandong Province

Conclusion and improvement directions

1. Structural optimization: Add feedback loop arrows to the original flow chart to strengthen the concept of continuous improvement.

2. Element refinement: Add guidance for teachers and students on elements related to personalization and learning analytics.

3. Technology updates: Incorporate options for emerging tools such as AI grading and predictive learning analytics.

4. Condition guarantee: It is recommended to establish a regional digital resource sharing platform and a long-term teacher training mechanism.

5. Promotion strategy: Implement in three phases (pilot - regional promotion - province-wide coverage), and regularly evaluate the promotion effect.

Overall, the focus group unanimously agreed that the model has a

reasonable structure, complete elements, and strong operability, and can be promoted and applied in higher vocational mathematics teaching across the province after appropriate optimization.

Phase 4: The implementation results of the digital technology integration model for higher vocational mathematics instructional design in Shandong Province

To examine the effectiveness of the Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province in enhancing students' academic performance, this study employed an independent-samples t-test to compare the pre-test and post-test scores of students in the experimental and control groups. Prior to conducting the mean comparison, the reliability of the achievement test was assessed to ensure the validity and credibility of the empirical results. The internal consistency of the test instrument was evaluated using the Kuder–Richardson Formula 20 (KR-20).

The study involved 80 students from Jinan Engineering Vocational and Technical College, divided into an experimental group (40 students) and a control group (40 students). During the pretest, the two groups had identical learning

content, instructors, and class schedules; neither group received the digital technology-integrated teaching model designed in this study. The experimental group used the research-developed digital technology -integrated model for instruction over the subsequent eight weeks, while the control group used a traditional teaching model.

Data collection is divided into two stages.

Pre-test: A unified test conducted before teaching is implemented to measure the initial level of the two groups of students.

Post-test: A test of the same difficulty is conducted after 8 weeks of teaching to compare the differences in learning outcomes between the two groups of students under different teaching modes.

Study Results

Test Reliability Analysis

Before comparing means, the reliability of the test instrument was first tested to ensure data reliability. This study used the Kuder–Richardson formula (KR-20) to conduct reliability analyses on the pre-test and post-test data for both the experimental and control groups. The results are shown in Table 4.12.

Table 4.13 KR-20 Coefficients of the Experimental Group and the Control Group in Pre-test and Post-test

Group	Pre-test KR-20	Post-test KR-20
Experimental group	0.81	0.87
control group	0.80	0.85

The results showed that the experimental group's pre-test KR-20 was 0.81, and the post-test KR-20 was 0.87; the control group's pre-test KR-20 was 0.80, and the post-test KR-20 was 0.85. All coefficients were greater than 0.80, indicating a high level of reliability. This indicates that the test tool has stable internal consistency across both groups and time points, and can accurately reflect students'

mathematical proficiency. The reliability results provide a solid measurement foundation for subsequent statistical inference.

Independent sample t-test results

Figure 4.5 shows a histogram of the average scores of the experimental and control groups before and after the implementation of the teaching model. The average score of the experimental group increased by 15 points, and the average score of the control group increased by 3.9 points.
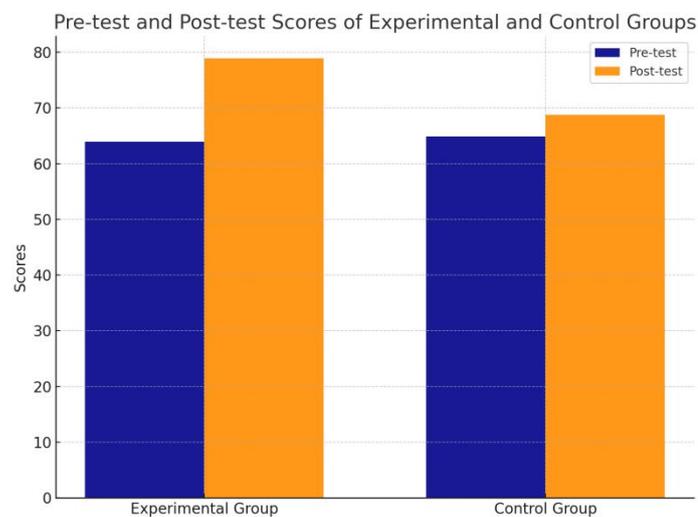
Figure 4.5 Histograms of Pre-test and Post-test Scores for the Experimental
Group and the Control Group

Table 4.14 shows the mean scores and standard deviations for the experimental and control groups before and after implementing the teaching model, as well as the statistical results of a two-sample t-test. The p-value was used to determine the significance of the difference between the two groups, with $p < 0.05$ considered a significant difference.

Table 4.14 Pre-test and post-test scores and t-test results of the experimental group
and the control group

Testing phase	Group	Sample size	Average value	Standard deviation	t-value	p-value
Pre-test	Experimental group	40	63.93	4.83	-0.88	0.41
	control group	40	64.88	4.87		
Post-test	Experimental group	40	78.93	5.48	8.18	0.00
	control group	40	68.78	5.62		

Table 4.14 shows that in the pretest phase, the mean scores of the two groups were not significantly different (t = -0.88, p = 0.41 > 0.05), indicating that the academic levels of the experimental and control groups were roughly the same before the model was implemented. In the posttest phase, the mean score of the experimental group was significantly higher than that of the control group (t = 8.18, p = 0.00 < 0.05), indicating that the digital technology-integrated instructional design model has a significant effect on improving academic performance.

Research Conclusions

Based on two rounds of testing and statistical analysis, the digital technology-integrated instructional design model effectively improves mathematics learning performance in higher vocational colleges, with the experimental group showing a significantly greater improvement in post-test performance than the control group. This result validates the model's applicability and promotional value in higher vocational mathematics instruction.

Chapter 5

Conclusion Discussion and Recommendations

The previous chapters have comprehensively described the process of problem identification, the procedures for model construction, the achievement of expert consensus, and the analysis of empirical data. Based on these findings, this chapter provides a concise summary of the overall research process and its key results, explores in depth the theoretical foundations and practical significance of the model, objectively analyzes the limitations encountered during the research process, and proposes targeted recommendations and future research directions. The aim is to provide scientific evidence and practical guidance for the digital transformation of mathematics education in higher vocational colleges.

Conclusion

This study systematically developed and validated a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province through a four-stage research process involving literature review, Delphi expert consultation, focus group evaluation, and quasi-experimental implementation. The conclusions are summarized as follows:

Identification of Problems and Solutions: Through literature synthesis and the first round of the Delphi method with 21 experts, 35 critical issues and corresponding solutions concerning digital technology integration in higher vocational mathematics instruction were identified. These were categorized into five key areas: teaching analysis, resource matching, teaching implementation, learning support, and evaluation improvement. The problems centered on inadequate digital resource utilization, weak student foundation, lack of interest, disconnect between content and practice, outdated teaching models, and singular assessment methods. The

proposed solutions emphasized content integration, method reform (blended learning, flipped classroom), interest stimulation, teacher capacity building, and assessment innovation.

Development of the Integration Model: Subsequent rounds of Delphi consultation achieved a high level of expert consensus, leading to the finalization of a structured model. The model comprises five interconnected modules and 40 core elements, systematically covering the entire instructional design cycle: Teaching Analysis, Resource Matching, Teaching Implementation, Learning Support, and Evaluation Improvement. This model provides a practical framework for integrating digital technology to enhance teaching quality and student engagement.

Evaluation and Optimization of the Model: A focus group of nine experts (including teachers, education technologists, and student representatives) evaluated the model's scientific soundness and practical feasibility. Their feedback led to specific optimizations, including strengthening feedback loops between stages, refining operational guidelines for core elements, updating technology recommendations, and enhancing support mechanisms. The group affirmed the model's reasonable structure and strong operability.

Validation of Model Effectiveness: A quasi-experimental design with an experimental group (n=40) and a control group (n=40) demonstrated that students taught using the digital technology-integrated model achieved significantly higher post-test mathematics scores compared to the traditional teaching group. The independent samples t-test results confirmed the model's effectiveness in improving academic achievement, validating its practical value in the higher vocational mathematics context.

Discussion

Discussion of Objective 1: Identification of Problems and Solutions

The first objective of this study was to identify the problems and potential solutions related to digital technology integration in higher vocational mathematics instructional design in Shandong Province. The findings of this research confirm many of the challenges identified in the literature reviewed in Chapter 2.

Previous studies have reported that vocational students often encounter significant difficulties in mathematics learning. Wang Qian (2019) and Gao Jie (2023) found that vocational students typically have weak mathematical foundations and low confidence in learning mathematics. Similarly, Zhang Bin and Yang Miaomiao (2020) emphasized that traditional mathematics teaching methods often fail to connect mathematical knowledge with practical applications, resulting in low learning motivation among students.

The findings of this study are consistent with these observations. Experts participating in the Delphi consultation indicated that many vocational mathematics classes still rely heavily on lecture-based teaching methods that emphasize theoretical explanations rather than interactive learning experiences. As a result, students may struggle to understand abstract mathematical concepts and fail to recognize the relevance of mathematics to their future professional development.

Another major issue identified in this study is the limited integration of digital technologies into mathematics teaching. Although digital technologies are widely used in many educational contexts, their application in vocational mathematics teaching remains relatively limited. This finding supports the argument presented by Clark and Mayer (2016), who suggested that many teachers lack sufficient training in technology-enhanced instructional design, which limits the effective use of digital technologies in teaching.

The solutions identified in this study also align with recommendations proposed in previous research. Scholars such as Han Jie (2023) emphasized the importance of adopting diversified teaching strategies, including problem-based learning, flipped

classroom approaches, and blended learning environments. These approaches encourage active student participation and promote deeper learning.

Digital technologies provide effective tools for implementing these innovative teaching strategies. For example, online learning platforms allow teachers to distribute learning materials and interactive exercises, while dynamic mathematics software enables students to visualize mathematical relationships. Roschelle et al. (2010) argued that digital learning environments can significantly enhance collaborative learning and student engagement. Similarly, Anderson (2008) emphasized that digital technologies provide flexible learning environments that allow students to access learning resources anytime and anywhere.

Therefore, the identification of problems and solutions in this study confirms the findings of previous research and further highlights the importance of integrating digital technologies into vocational mathematics instructional design.

Discussion of Objective 2 : Development of the Digital Technology Integration Model

The second objective of this study was to develop a Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design in Shandong Province. The model developed through the Delphi method consists of five modules: Teaching Analysis, Resource Matching, Teaching Implementation, Learning Support, and Evaluation Improvement.

The structure of this model reflects the principles of systematic instructional design discussed in Chapter 2. Instructional design theories emphasize that effective teaching requires careful planning, implementation, and evaluation. The five modules of the proposed model correspond closely with the stages commonly found in instructional design frameworks such as ADDIE.

The Teaching Analysis module focuses on identifying learning objectives, analyzing student characteristics, and determining appropriate teaching strategies. This component reflects the importance of learner analysis in instructional design theory. According to instructional design scholars, understanding learners' needs and learning contexts is essential for designing effective instructional activities.

The Resource Matching module highlights the importance of selecting appropriate teaching resources and digital technologies. Previous studies have emphasized that digital technologies should be carefully selected to support specific learning objectives rather than used simply for technological innovation. Clark and Mayer (2 0 1 6) argued that technology-enhanced learning environments must be designed to align with instructional goals and pedagogical strategies.

Another important theoretical foundation for the model is the TPACK framework proposed by Mishra and Koehler (2006). The TPACK framework suggests that effective technology integration requires the interaction of technological knowledge, pedagogical knowledge, and content knowledge. The instructional model developed in this study operationalizes the TPACK framework by embedding digital technologies within mathematics teaching strategies and curriculum content.

The Teaching Implementation module focuses on the actual teaching process, including the use of digital platforms, interactive teaching tools, and blended learning strategies. This component reflects the increasing importance of blended learning environments in modern education. Boelens et al. (2017) suggested that blended learning can combine the strengths of online learning and traditional classroom instruction, creating more flexible and effective learning experiences.

The Learning Support module emphasizes the importance of providing continuous guidance and support for students during the learning process. Digital technologies such as learning management systems and online discussion platforms can facilitate communication between teachers and students and support collaborative learning.

Finally, the Evaluation Improvement module focuses on monitoring learning outcomes and improving instructional effectiveness through digital evaluation tools. This component reflects the growing importance of learning analytics and data-driven instruction in modern education. Learning analytics technologies allow teachers to collect and analyze student learning data, which can help improve teaching strategies and learning outcomes.

Overall, the model developed in this study integrates digital technologies into all stages of instructional design, providing a systematic framework for improving vocational mathematics teaching.

Discussion of Objective 3: Evaluation of the Model

The third objective of this study was to evaluate the proposed model using the focus group method. The focus group participants included experts, teachers, and students, providing multiple perspectives on the applicability of the model.

The results of the focus group evaluation indicate that the model is both feasible and practical. Participants emphasized that the model provides clear guidance for teachers to integrate digital technologies into instructional design.

One important strength of the model identified by participants is its emphasis on student-centered learning. Modern educational theories emphasize that students should play an active role in the learning process rather than passively receiving knowledge from teachers. Digital technologies can support this approach by providing interactive learning environments and encouraging collaborative learning activities.

Another strength of the model is its integration of digital learning resources with classroom teaching activities. Participants noted that digital learning platforms can provide students with additional learning opportunities outside the classroom. Students can review instructional materials, complete assignments, and participate in online discussions at their own pace.

These findings are consistent with the literature on blended learning discussed in Chapter 2. Boelens et al. (2017) emphasized that blended learning environments can enhance student engagement and improve learning outcomes by combining the advantages of online learning and face-to-face instruction.

However, the focus group evaluation also identified several challenges related to the implementation of the model. Participants suggested that teachers may require additional training to effectively implement digital teaching strategies. This observation supports previous research indicating that teachers' digital competencies play a crucial role in technology-enhanced teaching.

Another issue raised during the discussion was the availability of digital teaching resources. Some vocational institutions may lack sufficient digital infrastructure to support technology-enhanced teaching. Therefore, educational institutions should invest in digital teaching platforms and learning resources to support the implementation of digital instructional models.

Discussion of Objective 4: Effectiveness of the Model

The fourth objective of this study was to examine the effectiveness of the digital technology integration model through a quasi-experimental study.

The results of the independent sample t-test indicated that the experimental group achieved significantly higher mathematics scores compared with the control group. This finding demonstrates the effectiveness of the proposed instructional model.

Several factors may explain this improvement in learning outcomes. First, digital technologies can increase student engagement in the learning process. Interactive learning tools, digital simulations, and online learning platforms create more dynamic learning environments that encourage active participation.

Second, digital technologies can improve students' conceptual understanding of mathematics. Abstract mathematical concepts can be difficult for vocational students to understand through traditional teaching methods. Digital visualization tools can present mathematical concepts in more intuitive ways, allowing students to explore relationships between mathematical variables and observe dynamic changes.

Third, digital learning environments support personalized learning. Online learning platforms allow students to review instructional materials and complete exercises at their own pace. Students who need additional practice can spend more time on difficult topics, while those who master concepts quickly can move on to more advanced material.

Fourth, digital evaluation tools allow teachers to monitor students' learning progress more effectively. Learning analytics technologies can collect and analyze

data on student learning behavior, allowing teachers to identify learning difficulties and provide targeted support.

Theoretical Implications

The findings of this study contribute to the theoretical development of digital technology integration in vocational education in several important ways.

First, this study extends the application of instructional design theory in the context of vocational mathematics education. Instructional design theories emphasize that effective teaching should follow systematic processes including analysis, design, implementation, and evaluation. The digital technology integration model developed in this study reflects these principles by incorporating five interconnected modules: Teaching Analysis, Resource Matching, Teaching Implementation, Learning Support, and Evaluation Improvement. These modules form a systematic framework that guides teachers in integrating digital technologies into instructional design.

Second, the study contributes to the development of the TPACK framework in vocational mathematics education. The TPACK model, proposed by Mishra and Koehler (2006), highlights the importance of integrating technological knowledge, pedagogical knowledge, and content knowledge. The findings of this study demonstrate how the TPACK framework can be operationalized in higher vocational mathematics teaching. The proposed model integrates digital tools with pedagogical strategies and mathematics content, enabling teachers to design more effective learning experiences.

Third, this study provides further support for blended learning theory in vocational education. Blended learning emphasizes the integration of online learning environments with traditional classroom instruction. The instructional model developed in this research incorporates digital platforms, interactive tools, and online learning resources alongside face-to-face teaching activities. This combination creates flexible learning environments that can enhance student engagement and improve learning outcomes.

Fourth, this study contributes to the growing body of literature on data-driven instruction and learning analytics. The evaluation improvement module of the model integrates digital assessment tools and learning data analysis into the instructional process. Learning analytics technologies allow teachers to monitor student learning progress, identify learning difficulties, and adjust teaching strategies accordingly. This approach reflects the increasing importance of educational data in improving teaching effectiveness.

Finally, this study enriches the theoretical understanding of digital technology integration in vocational mathematics education. While many studies have explored digital technology in general education contexts, relatively few have focused specifically on vocational mathematics teaching. By developing and validating a digital technology integration model tailored to vocational education, this research provides a theoretical framework that can support future studies in this field.

Practical Implications

In addition to its theoretical contributions, this study also provides several important practical implications for higher vocational education institutions, teachers, and educational policymakers.

First, the findings highlight the importance of systematic instructional design for digital teaching. The integration of digital technology into mathematics teaching should not be limited to the use of technological tools. Instead, digital technologies should be embedded within structured instructional design processes. The five-module model proposed in this study provides a practical framework that teachers can use to design technology-enhanced mathematics instruction.

Second, the results emphasize the need to improve teachers' digital teaching competencies. Effective technology integration requires teachers to possess not only subject knowledge but also technological and pedagogical knowledge. Many teachers may lack sufficient training in using digital tools for instructional purposes. Therefore, vocational institutions should provide professional development programs that help teachers develop digital teaching skills and instructional design competencies.

Third, educational institutions should strengthen the construction of digital teaching infrastructure. Successful implementation of digital instructional models depends on the availability of digital learning platforms, online teaching resources, and technological support systems. Schools should invest in developing digital learning environments that enable teachers and students to effectively use digital technologies in teaching and learning.

Fourth, the findings suggest the importance of curriculum reform in vocational mathematics education. Traditional mathematics curricula often emphasize theoretical knowledge while neglecting practical applications. Digital technologies can support the integration of mathematics with professional contexts by providing simulation tools, mathematical modeling software, and real-world problem-solving activities. Such approaches can enhance students' understanding of mathematics and increase their motivation to learn.

Fifth, the study highlights the need to reform evaluation systems in vocational education. Traditional evaluation methods often rely primarily on final examinations, which may not fully reflect students' learning processes. Digital evaluation tools and learning analytics technologies can support formative assessment by providing continuous feedback on students' learning progress. This approach allows teachers to identify learning difficulties early and provide targeted support.

Finally, the findings of this study have important implications for educational policy in vocational education. Policymakers should encourage the integration of digital technologies into vocational education by supporting teacher training programs, investing in digital infrastructure, and promoting innovative teaching practices.

By implementing these practical recommendations, vocational education institutions can improve the quality of mathematics teaching and better prepare students for the demands of the modern workforce.

Recommendations

Based on the conclusions and discussion, the following recommendations are proposed for various stakeholders:

For Policy-Makers and Educational Administrators:

Promote as a Quality Standard: The model should be promoted as a guideline for digital teaching quality standards in higher vocational mathematics within Shandong Province. Policies can encourage its adoption through funding for pilot programs and resource construction.

Establish Support Mechanisms: Administrations should establish sustained support systems, including regular professional development programs focused on the model's elements, technical support teams, and incentive structures for teachers who successfully implement digital-integrated designs.

Foster Resource Sharing: Support the development of provincial-level digital resource repositories aligned with the model's "Contextualized Case Design" and "Integration of Interdisciplinary Resources" elements, reducing the burden on individual institutions.

For Higher Vocational Institutions:

Strategic Implementation Plan: Institutions should develop phased implementation plans, starting with pilot courses and gradually expanding. This should include assessing current infrastructure and teacher capacity gaps.

Integrate into Teacher Evaluation: Incorporate competence in digital technology integration and the use of such instructional design models into teacher professional development plans, performance appraisals, and promotion criteria.

Create Interdisciplinary Teams: Form teams comprising mathematics teachers, educational technologists, and industry professionals to collaboratively design and update contextualized cases and projects, ensuring relevance to professional skills.

For Mathematics Teachers and Instructional Designers:

Embrace the Framework: Teachers should use the five-module, 40-element model as a systematic checklist and guide for designing their courses, moving beyond the ad-hoc use of digital tools.

Focus on Pedagogical Alignment: Priority should be given to elements that strengthen the alignment between learning objectives, digital activities, and assessment, such as "Digital Expression of Teaching Objectives" and "Application of Digital Assessment Tools."

Engage in Collaborative Design: Actively participate in collaborative lesson preparation and resource sharing communities to collectively address challenges in implementing complex elements like adaptive learning or simulation technology.

Future Research Directions

Longitudinal Impact Studies: Conduct longitudinal studies to assess the model's impact on students' long-term mathematical proficiency, problem-solving abilities, and professional competency development.

Cross-Cultural and Cross-Institutional Replication: Test the model's applicability and effectiveness in different cultural contexts and various types of higher vocational institutions across China and internationally.

Integration of Emerging Technologies: Research how to effectively and ethically integrate emerging technologies like Generative AI, Advanced Learning Analytics, and Immersive VR/AR into the model's framework for enhanced personalization and engagement.

Mechanism Exploration: Employ qualitative and mixed-methods research to deeply investigate how specific interactions between technological tools, pedagogical strategies, and mathematical content within the model influence student learning processes and outcomes.

In conclusion, this study has developed a theoretically grounded, empirically validated, and contextually refined Digital Technology Integration Model for Higher Vocational Mathematics Instructional Design. It provides a comprehensive blueprint for transforming mathematics education in vocational settings from a traditional, teacher-centered model to a dynamic, learner-centered, technology-enriched ecosystem. While challenges in implementation and scale remain, the model offers a significant step forward in leveraging digital technology to enhance the quality and relevance of mathematics education for the future workforce.

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Appendices

Appendix A

List of Specialists and Letters of Specialists Invitation

for IOC Verification

List of Experts for the IOC Content Validity Assessment

No	Experts Name	Professional Title	Work years	Working College
1	Mr Liu Baodong	Professor	35	Shandong University
2	Mrs Wang Xiujuan	Professor	23	Weifang University
3	Mr Gu Zhentao	Professor	21	Shandong Yingcai University
4	Mr Wang Hao	Professor	20	Shandong Polytechnic
5	Mrs Wang Wei	Professor	21	Shandong Electronic Vocational and Technical College

Lists of experts in Delphi

No	Experts Name	Professional Title	Work years	Working College
1	Mrs Wang Wenjing	Professor	22	Shandong Institute of Commerce and Technology
2	Mrs Zhu Yanyan	Associate Professor	18	Shandong Institute of Commerce and Technology
3	Mrs Yuan Haijun	Associate Professor	14	Shandong Institute of Commerce and Technology
4	Mr Kong Fanqing	Professor	26	Jinan Vocational College
5	Mrs Ren Xiaoyan	Professor	34	Jinan Vocational College
6	Mrs Wang Yue	Professor	22	Jinan Vocational College
7	Mrs Li Haixia	Associate Professor	15	Jinan Vocational College
8	Mrs Liu Yuhan	Professor	20	Jinan Engineering Polytechnic
9	Mrs Yu Xiuping	Associate Professor	19	Jinan Engineering Polytechnic
10	Mr Chen Yunfeng	Associate Professor	19	Jinan Engineering Polytechnic
11	Mr Wang Dong	Associate Professor	22	Jinan Engineering Polytechnic
12	Mrs Li Xiaomin	Associate Professor	19	Jinan Engineering Polytechnic
13	Mr Wang Heng	Associate Professor	22	Zibo Normal College
14	Mr Sha Xudong	Associate Professor	22	Zibo Normal College
15	Mr Zhang Mingcheng	Associate Professor	20	Qingdao Ocean Shipping Mariners College

No	Experts Name	Professional Title	Work years	Working College
16	Mr Fan Hongjun	Associate Professor	24	Qingdao Ocean Shipping Mariners College
17	Mr Li Haitao	Associate Professor	24	Shandong Transport Vocational College
18	Mr Wang Gang	Associate Professor	23	Shandong Transport Vocational College
19	Mrs Liu Yanan	Associate Professor	22	Shandong Transport Vocational College
20	Mrs Lv Nan	Associate Professor	22	Dongying Vocational Institute
21	Mrs Wei Shuyun	Associate Professor	20	Dongying Vocational Institute

Lists of experts in Focus group

No	Experts Name	Professional Title	Work years	Working College
1	Mr Xu Shaobo	Professor	19	Shandong Vocational College of Information Technology
2	Mr Qi Mingzhe	Professor	27	Weifang Engineering Vocational College
3	Mrs Wang Wenjing	Professor	22	Shandong Institute of Commerce and Technology
4	Mrs Wang Yue	Professor	22	Jinan Vocational College
5	Mrs Liu Yuhan	Professor	20	Jinan Engineering Polytechnic
6	Mr Wang Heng	Associate Professor	22	Zibo Normal College
7	Mr Wang Gang	Associate Professor	23	Shandong Transport Vocational College
8	Mr Ju Hanchen	/	/	Jinan Engineering Polytechnic
9	Mr Xu Shibo	/	/	Jinan Engineering Polytechnic

Appendix B

Official Letter

Ref.No. MHESI 0643.14/ 2ꝋ

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

14 October 2024

Subject: Invitation to validate research instrument

Dear

  Mrs. Zhang Pengfei is a graduate student in doctor of Digital Technology Management for Education of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Digital Technology Integration in Higher Vocational Mathematics Instructional Design in Shandong Province". There is a thesis advisory committee as follows:

    1. Assistant Professor Dr.Kanakorn Sawangcharoen   Major Advisor
    2. Associate Professor Dr.Pong Horadal   Co-Advisor
    3. Associate Professor Dr.Sombat Teekasap   Co-Advisor

  The thesis advisory committee has considered that you are an expert in this topic. Your recommendations would be useful for further improvement of this research instrument.

  With your expertise, we would like to ask your permission to validate the attached research instrument. In this regard, we would like to avail ourselves of this opportunity to express our sincere thanks and appreciation for your help.

      Yours faithfully,

    (Assistant Professor Dr.Thanaput Chancharoen)
    Vice Dean of Graduate School for Dean of Graduate School

Graduate School
Tel.+662-473-7000 ext. 1814
E-mail: grad@bsru.ac.th

Ref.No. MHESI 0643.14/ 2 74

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

16 December 2024

Subject: Request permission to collect data by attending Interviews and Questionnaires

Dear

Mrs. Zhang Pengfei is a graduate student in doctor of Digital Technology Management for Education of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Digital Technology Integration in Higher Vocational Mathematics Instructional Design in Shandong Province". There is a thesis advisory committee as follows:

1. Assistant Professor Dr.Kanakorn Sawangcharoen   Major Advisor
2. Associate Professor Dr.Pong Horadal   Co-Advisor
3. Associate Professor Dr.Sombat Teekasap   Co-Advisor

In this regard, the student has applied the Delphi Method in her research. The thesis advisory committee and the student have considered that you are an expert in this field. Therefore, Graduate School would like to invite you to be an expert to provide the student with suggestions for her research.

Thank you for your kind considerations.

Yours faithfully,

(Assistant Professor Dr.Thanaput Chancharoen)
Vice Dean of Graduate School for Dean of Graduate School

Graduate School
Tel.+662-473-7000 ext. 1814
E-mail: grad@bsru.ac.th

Ref.No. MHESI 0643.14/ 101

Bansomdejchaopraya
Rajabhat University
1061 Itsaraparb Hirunrujee
Thonburi Bangkok 10600

12 May 2025

Subject: Invitation to join a focus group discussion as an expert

Dear

Attachment: A focus group discussion schedule

Mrs. Zhang Pengfei is a graduate student in doctor of Digital Technology Management for Education of Bansomdejchaopraya Rajabhat University. She is undertaking research entitled "Digital Technology Integration in Higher Vocational Mathematics Instructional Design in Shandong Province". There is a thesis advisory committee as follows:

1. Assistant Professor Dr.Kanakorn Sawangcharoen
2. Associate Professor Dr.Pong Horadal
3. Associate Professor Dr.Sombat Teekasap

In this regard, the student has applied the Delphi Method in her research. The thesis advisory committee and the student have considered that you are an expert in this field. Therefore, Graduate School would like to invite you to be an expert to join the focus group discussion to provide the student with suggestions for the his/her research.

Thank you for your kind considerations.

Yours faithfully,

Assistant Professor Dr.Thanaput Chancharoen
Vice Dean of Graduate School for Dean of Graduate School

Graduate School
Tel.+662-473-7000 ext. 1814
E-mail: grad@bsru.ac.th

Appendix C

Research Instrument

First Round Delphi Expert Consultation Questionnaire (Open-ended)

Dear Experts, Thank you for participating in this research. This questionnaire aims to leverage your professional experience to identify challenges and potential solutions for integrating digital technology into mathematics instructional design in higher vocational schools in Shandong Province. Based on your practical experience, research findings, and observations, please provide as detailed and specific feedback as possible on each aspect. There is no fixed word limit; please be creative.

Part I: Basic Information (for statistical analysis only)

1. Name (optional) :

2. Work unit and position :

3. Years of experience in higher vocational mathematics teaching or research :

4. Main research/teaching areas :

Part II: Open-ended questions (categorized into five categories)

1. Teaching analysis

(1) In your opinion, what are the main problems in the teaching analysis link of digital technology integration in higher vocational mathematics teaching?

(2) In response to the above problems, what effective improvement strategies or countermeasures do you think there are?

2. Resource matching

(3) With the support of digital technology, what are the shortcomings in the resource matching process of higher vocational mathematics teaching?

(4) How do you suggest optimizing resource matching to better serve teaching objectives?

3. Teaching implementation

(5) In the process of teaching implementation, what challenges or obstacles have you observed in the integration of digital technology?

(6) In response to these challenges, what feasible teaching methods or technical means do you think can be used to improve them?

4. Learning support

(7) What are the shortcomings in the application of digital technology in learning support?

(8) What measures do you think should be taken to enhance the role of digital technology in learning support?

5. Evaluation and improvement

(9) What are the main problems in the application of digital technology in the process of teaching evaluation and improvement?

(10) In response to the above issues, how do you think improvements should be made to enhance the effectiveness of evaluation and improvement?

Part III: Additional Comments - Do you have any other suggestions, cases, or research results you would like to share regarding the integration of digital technology in higher vocational mathematics teaching?

Thank you for your participation and support!

Delphi Method Second Round Questionnaire (40 Core Elements)

Dear experts:

Thank you for participating in the second round of Delphi consultations for the " Digital Technology Integration Model in Mathematics Instructional Design for Higher Vocational Colleges in Shandong Province." This round of consultations is based on the results of the first round and the 40 core elements of the IOC test. Please rate the importance of each element on a 5-point Likert scale (1 = very unimportant, 5 = very important). For items rated below 4, please provide specific suggestions in the " Revision Suggestions " column.

Part 1: Basic Information

1. Name: _____ (For research records only, not publicly available)

2. Gender: ☐ Male ☐ Female

3. Age: ☐ Under 30 ☐ 31-40 ☐ 41-50 ☐ 51 and above

4. Highest degree: ☐ Bachelor's degree ☐ Master's degree ☐ Doctorate

5. Job Title/Position:_____

6. Type of unit: ☐ Vocational college ☐ Undergraduate college ☐ Industry enterprise ☐ Other: _____

7. Years of experience in vocational mathematics education or related fields: _____ years

8. Have you participated in any teaching design or research projects related to digital technology? ☐ Yes ☐ No

9. Contact information (optional): _____ (only used to confirm questionnaire information when necessary)

Part II: 40 Core Factor Scoring Table and Modification Suggestions

Serial number	Core Elements	Rating					Suggested Modifications
		1	2	3	4	5	
1	Learner Profile Analysis						
2	Digital Expression of Teaching Objectives						
3	Contextualized Case Design						
4	Integration of Multimodal Teaching Resources						
5	Collaborative Learning Task Design						
6	Digital Learning Path Planning						
7	Application of Learning Analytics Tools						
8	Real-Time Interactive Feedback Mechanism						
9	Visual Presentation of Teaching Content						
10	Application of Adaptive Learning Systems						
11	Online Test and Assessment Design						
12	Utilization of Mobile Learning Platforms						
13	Cloud-Based Resource Sharing and Collaboration						
14	Application of Virtual Simulation Technology						
15	Integration of Gamification Learning Elements						
16	Learning Data Collection and Analytics						
17	Teaching Reflection and Adjustment Mechanism						

Serial number	Core Elements	Rating					Suggested Modifications
		1	2	3	4	5	
18	Teacher Digital Literacy Development						
19	Learner Self-Directed Learning Support						
20	Cross-Platform Learning Resource Integration						
21	Application of Digital Assessment Tools						
22	Production and Application of Video Micro-Courses						
23	Course Data-Driven Optimization						
24	Collaborative Lesson Preparation and Resource Sharing						
25	Classroom Interaction Data Analytics						
26	Digital Assignment Design and Grading						
27	Learner Behavior Tracking and Analytics						
28	Data-Driven Teaching Decision-Making						
29	Integration of Teaching Platform Functions						
30	Personalized Recommendation of Course Resources						
31	Application of Adaptive Evaluation Systems						
32	Student Learning Portfolio Management						
33	Integration of Interdisciplinary Resources						
34	Peer Assessment and Collaborative Feedback Mechanism						
35	Online Question-and-Answer Support System						

Serial number	Core Elements	Rating					Suggested Modifications
		1	2	3	4	5	
36	Digital Examination Security Management						
37	Online Monitoring of Teaching Quality						
38	Visualization of Learning Outcomes						
39	Continuous Updating of Teaching Resources						
40	Continuous Improvement and Optimization Mechanism						

Delphi Method Round 3 Questionnaire (Revised Version of 40 Core Elements)

Dear experts:

Thank you for participating in the third round of Delphi consultations for the "Digital Technology Integration Model in Mathematics Instructional Design for Vocational Colleges in Shandong Province" study. Based on the results of the second round, this round of questionnaires has revised 14 items with an IQR greater than 1 or requiring refinement. These items are presented alongside the remaining 26 approved items. Please continue to rate the importance of each element using a 5-point Likert scale (1 = very unimportant, 5 = very important) and provide suggestions for further revisions. If consensus is achieved (Md ≥ 4 and IQR ≤ 1), the element will be included in the final model.

Part 1: Basic Information

1. Name: _____ (For research records only, not publicly available)

2. Gender: ☐ Male ☐ Female

3. Age: ☐ Under 30 ☐ 31-40 ☐ 41-50 ☐ 51 and above

4. Highest degree: ☐ Bachelor's degree ☐ Master's degree ☐ Doctorate

5. Job Title/Position: _____

6. Type of unit: ☐ Vocational college ☐ Undergraduate college ☐ Industry enterprise ☐ Other: _____

7. Years of experience in vocational mathematics education or related fields: _____ years

8. Have you participated in any teaching design or research projects related to digital technology? ☐ Yes ☐ No 9. Contact information (optional): _____ (only used to confirm questionnaire information when necessary)

Part II: 40 Core Factor Scoring Table and Modification Suggestions

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
1	Learner Profile Analysis	5	5	0.50						
2	Digital Expression of Teaching Objectives	5	5	0.50						
3	Contextualized Case Design	5	5	0.75						
4	Integration of Multimodal Teaching Resources	4	4	0.75						
5	Collaborative Learning Task Design	4	4	0.75						
6	Digital Learning Path Planning	4	4	**1.25**						
7	Application of Learning Analytics Tools	4	4	**1.25**						
8	Real-Time Interactive Feedback Mechanism	5	5	0.50						

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
9	Visual Presentation of Teaching Content	5	5	0.50						
10	Application of Adaptive Learning Systems	4	4	**1.50**						
11	Online Test and Assessment Design	5	5	0.75						
12	Utilization of Mobile Learning Platforms	4	4	**1.25**						
13	Cloud-Based Resource Sharing and Collaboration	4	4	0.75						
14	Application of Virtual Simulation Technology	4	4	**1.50**						
15	Integration of Gamification Learning Elements	4	4	**1.25**						
16	Learning Data Collection and Analytics	5	5	0.50						

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
17	Teaching Reflection and Adjustment Mechanism	5	5	0.50						
18	Teacher Digital Literacy Development	5	5	0.50						
19	Learner Self-Directed Learning Support	5	5	0.75						
20	Cross-Platform Learning Resource Integration	4	4	**1.25**						
21	Application of Digital Assessment Tools	5	5	0.50						
22	Production and Application of Video Micro-Courses	5	5	0.75						
23	Course Data-Driven Optimization	5	5	0.50						

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
24	Collaborative Lesson Preparation and Resource Sharing	4	4	**1.25**						
25	Classroom Interaction Data Analytics	5	5	0.50						
26	Digital Assignment Design and Grading	5	5	0.50						
27	Learner Behavior Tracking and Analytics	5	5	0.75						
28	Data-Driven Teaching Decision-Making	4	4	**1.25**						
29	Integration of Teaching Platform Functions	4	4	**1.25**						
30	Personalized Recommendation of Course Resources	4	4	**1.50**						

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
31	Application of Adaptive Evaluation Systems	4	4	**1.25**						
32	Student Learning Portfolio Management	5	5	0.50						
33	Integration of Interdisciplinary Resources	4	4	**1.50**						
34	Peer Assessment and Collaborative Feedback Mechanism	5	5	0.50						
35	Online Question- and-Answer Support System	5	5	0.50						
36	Digital Examination Security Management	4	4	**1.25**						
37	Online Monitoring of Teaching Quality	5	5	0.75						

Serial number	Core Elements (revised edition)	Round 2 Md	Round 2 Mo	Round 2 IQR	Rating					Suggested Modifications
					1	2	3	4	5	
38	Visualization of Learning Outcomes	5	5	0.50						
39	Continuous Updating of Teaching Resources	5	5	0.50						
40	Continuous Improvement and Optimization Mechanism	5	5	0.50						

Advanced Mathematics Pre-Test Paper

Part I Multiple Choice and True/False Questions (60 points)

I. Multiple-Choice Questions

(15 questions, 3 points each, total 45 points. For each question, only one option is correct.)

1. $f(x) = \dfrac{\sqrt{x+2}}{x-1}$,the domain of the function is (   ).

   A. $(-2,+\infty)$ B. $[-2,+\infty)$ C. $(-2,1)\cup(1,+\infty)$ D. $[-2,1)\cup(1,+\infty)$

2. $\lim\limits_{x\to 0}\dfrac{sinx}{x} = $ (   ) .

   A. ∞ B. -1   C. 1   D. 0

3. $f(x) = x^3 - 3x^2 + 1$, the interval on which the function is increasing is (   ).

   A. $(0,2)$ B. $(-\infty,0)\,and\,(2,+\infty)$ C. $(-\infty,1)$ D. $(1,+\infty)$

4. As $x \to 0$, which of the following functions is an equivalent infinitesimal to the given function? (   ).

   A. $1 - \cos x$ B. $e^{x^2} - 1$ C. $\ln(1+2x)$ D. $\sin x$

5. $\lim\limits_{x\to\infty}\dfrac{1}{x^2}\cos x^2 = $ (   ).

   A. 1   B. 2   C. 0   D. 3

6. $f(x) = \dfrac{x^2 - 1}{x^2 + 1}$,the limit at the given point is (   ).

   A. -1   B. 0   C. 1   D. Does not exist

7. Which of the following limits equals to e? (   ).

A. $\lim_{x\to\infty}(1+\frac{1}{x})^{-x}$ B. $\lim_{x\to\infty}(1+x)^{\frac{1}{x}}$ C. $\lim_{x\to0}(1+x)^{\frac{1}{x}}$ D. $\lim_{x\to0}(1-x)^{\frac{1}{x}}$

8. $f(x) = \begin{cases} x\sin\frac{1}{x}, & x\neq0 \\ 0, & x=0 \end{cases}$ A, at x = 0 (   ).

A. Discontinuous   B. Continuous but not differentiable

C. Differentiable   D. The derivative is 1

9. $y = x^2 - 2x$, the equation of the tangent line at the point (1, -1) is (   ).

A. $y = 0$ B. $y = 2x - 1$ C. $y = -1$ D. $y = x + 1$

10. $f(x) = \frac{x-1}{x^2-3x+2}$, what kind of discontinuity point does x = 1 represent for the function? (   ).

A. Jumping   B. Reachable   C. Infinite   D. Vibration

11. $y = \frac{3x^2+2x}{x^2-1}$, the horizontal asymptote of the curve is (   ).

A. $x = 1$ B. $y = 3$ C. $x = 3$ D. $y = 1$

12. $f(x) = \ln(\sin x)$, $f'(x) = ($).

A. $\cot x$ B. $-\tan x$ C. $\tan x$ D. $-\cot x$

13. $y = ax^3 - x^2 - 2x + 3$, if point (1, a) is an inflection point of the curve, then a = ( ).

A. $\frac{1}{3}$ B. 1   C. 3   D. 2

14. Given the conditions, $\lim\limits_{x\to\infty}[f(x)+2g(x)]=5$, $\lim\limits_{x\to\infty}[f(x)-g(x)]=8$, then

$\lim\limits_{x\to\infty}f(x)g(x)=($ $)$.

   A. 11   B. 6   C. 25   D. -7

15. $f(x)=x^3+3x$, then the maximum value of f(x) on the interval [-2, 2] is ( ).

   A. -2   B. 0   C. 14   D. 4

II. True or False Questions

(5 questions, 3 points each, total 15 points. Choose A for True and B for False.)

16. $y=|x|$, the function is differentiable at the point x = 0. (   )

17. If the function is continuous at a point, then it must be differentiable at that

point. (   )

18. $y=x^3$, the inflection point of the curve is at x = 0. (   )

19. $f(x)=2x^3+3x^2+1$, the minimum value point of the function is x = -1. (   )

20. A stationary point of a function is not necessarily an extreme point. (   )

Part II: Non-Multiple-Choice Questions (40 points)

III. Calculation Problems (Show necessary steps)

(5 questions, 8 points each, total 40 points.)

21. Find the limit, $\displaystyle\lim_{x\to 3}\frac{x^3-2x^2+3}{x^2-2}$.

22. Given the function $y=9x^3-3x^2+6x-6$, find the value $y''(\frac{2}{3})$.

23. $\displaystyle\lim_{x\to 0}\frac{e^{5x}-e^{-x}}{\sin 2x}$, identify the type of the limit and compute it.

24. $f(x)=\dfrac{2}{3}x^3-5x^2+12x-\dfrac{1}{3}$, find the extreme values of the function and

determine whether they are maxima or minima.

25. $f(x)=\begin{cases}\dfrac{a}{(x-1)^2}+b, & x<0 \\ 3, & x=0 \\ b(x+1)^{\frac{1}{x}}, & x>0\end{cases}$, the function is continuous at the point x = 0, find the

values of a and b.

Advanced Mathematics Post-Test Paper

Part I Multiple Choice and True/False Questions (60 points)

I. Multiple-Choice Questions

(15 questions, 3 points each, total 45 points. For each question, only one option is correct.)

1. If one of the antiderivatives of f(x) is x^3, then $\int f(x)dx = ($ $)$.

   A. $2x^2$ B. x^3 C. $2x^3$ D. $x^3 + C$

2. $\Phi(x) = \int_0^x e^t dt$, then $\Phi'(x) = ($ $)$.

   A. $2e^x$ B. e^t C. e^x D. $e^x + C$

3. The founders of calculus are (   ).

   ① Newton   ② Leibniz   ③ Lagrange   ④ L'Hospital

   A. ① ②   B. ① ③   C. ② ③   D. ① ④

4. If vector $\vec{a} = (k,5,1)$ and $\vec{b} = (3,1,1)$ Vertical, then $k = ($ $)$.

   A. 3   B. 2   C. -2   D. 15

5. Plane $2x - 4y - z + 3 = 0$, the normal vector is (   ).

   A. (2,4,-1)   B. (-2,-4,-1)   C. (2,-4,-1)   D. (-2,4,1)

6. $z = \dfrac{1}{\sqrt{\ln(x+y)}}$, the domain of the function is (   ).

   A. $\{(x,y)|x+y>0\}$ B. $\{(x,y)|x+y\geq 1\}$

   C. $\{(x,y)|x+y>1\}$ D. $\{(x,y)|x+y\neq 1\}$

7. If the limit of the function exists at the given point, then the function at that point

is ( ).

A. Continuous   B. Differentiable

C. Discontinuous   D. Not necessarily continuous

8. The partial derivative of the function $z = f(x, y)$ with respect to x at the point

(x_0, y_0) is ( ).

A. $\lim\limits_{\Delta x \to 0} \dfrac{f(x_0 + \Delta x, y_0 + \Delta y) - f(x_0, y_0)}{\Delta x}$ B. $\lim\limits_{\Delta y \to 0} \dfrac{f(x_0 + \Delta x, y_0 + \Delta y) - f(x_0, y_0)}{\Delta y}$

C. $\lim\limits_{\Delta x \to 0} \dfrac{f(x_0 + \Delta x, y_0) - f(x_0, y_0)}{\Delta x}$ D. $\lim\limits_{\Delta y \to 0} \dfrac{f(x_0, y_0 + \Delta y) - f(x_0, y_0)}{\Delta y}$

9. Given the condition $z = x^3 y^4$, then $dz = ($).

A. $x^3 y^4 dx + y^4 x^3 dy$ B. $3x^2 y^4 dx + 4x^3 y^3 dy$

C. $12x^2 y^3 dx + 12x^2 y^3 dy$ D. $3x^2 y^3 dx + 4x^2 y^3 dy$

10. From the geometric meaning of double integrals, $\iint\limits_{x^2+y^2 \le 9} \sqrt{9 - x^2 - y^2}\, d\sigma = ($).

A. π B. 3π C. 9π D. 18π

11. $3y^2 dy + 3x^2 dx = 0$, the differential equation is of order ( ).

A. 1   B. 2   C. 3   D. 4

12. $\dfrac{dy}{dx} = 3x^2 y$, the general solution of the differential equation is ( ).

A. $C_1 + C_2 e^{x^3}$ B. $x^3 + C$ C. Ce^{x^3} D. e^{x^3}

13. $xdx + ydy = 0$, $y\big|_{x=1} = 1$, the solution of the differential equation is (   ).

A. $2x^2 - y^2 = 1$ B. $x^2 + y^2 = 2$ C. $x^2 - y^2 = 2$ D. $x^2 + y^2 = 1$

14. If the series $\sum\limits_{n=1}^{\infty} |u_n|$ converges, then $\sum\limits_{n=1}^{\infty} u_n$ (   ).

A. Convergent and equal to the sum of $\sum\limits_{n=1}^{\infty} |u_n|$ B. Diverge

C. Convergent and the sum with $\sum\limits_{n=1}^{\infty} |u_n|$ may not be the same.

D. All of the above judgments are incorrect.

15. The integral symbol was derived from the elongated letter "s" in the Latin word

"sum" and was invented by the German mathematician (   ).

A. Newton B. Leibniz C. Lagrange D. L'Hôpital

II. True or False Questions

(5 questions, 3 points each, total 15 points. Choose A for True and B for False.)

16. If point $P(x, y)$ approaches $P_0(x_0, y_0)$ in a certain way and the limit of the binary

function does not exist, then it can be concluded that the double limit does not

exist. (   )

17. $y' + 2y^2 = \sin x$, it is a first-order linear differential equation. (   )

18. If the total differential of the function $f(x, y)$ exists at the point (x_0, y_0), then

the two partial derivatives of $f(x, y)$ exist at the point (x_0, y_0). (   )

19. $\lim\limits_{(x,y)\to(0,0)} \dfrac{xy}{x^2+y^2}$, the limit does not exist. (   )

20. The normal vector of the sphere $x^2+y^2+z^2=14$ at the point $(1,2,3)$ is $(2,4,6)$. (   )

Part II: Non-Multiple-Choice Questions (40 points)

III. Calculation Problems (Show necessary steps)

(5 questions, 8 points each, total 40 points.)

21. Find the derivative of the function $\Phi(x)=\displaystyle\int_0^{x^2} \sqrt{1+t^3}\,dt$.

22. Calculate the indefinite integral of $\displaystyle\int \dfrac{(\ln x)^2}{x}\,dx$.

23. Given that $u=2x+3y+4z$, find du .

24. Find the general solution of the differential equation $y''-2y'-3y=0$.

25. Calculate the double integral of $\displaystyle\iint_D \dfrac{x^2}{y^2}\,dxdy$, where D is the region enclosed by $y=x, x=2, xy=1$.

Focus Group Discussion Outline

Discussion Subject

2 Expert members, 5 teacher representatives, 2 student representatives

Discussion duration

120 minutes (including a 10-minute intermission)

Discussion format

Offline centralized discussion (with recording equipment and note-taker to simultaneously organize key points throughout the discussion)

Core discussion topics

1. Scientific Evaluation of the Model

(1) Do you think the current three-dimensional framework of "Technology Layer - Teaching Layer - Resource Layer" fully covers the elements of integrating digital technology with higher vocational mathematics teaching? Are there any core dimensions missing (such as teacher ability and student feedback)?

(2) Do the settings for each secondary indicator (e.g., VR/AR technology, professional case library) conform to the "career-oriented, application-first" teaching principle of higher vocational mathematics? Please provide examples to illustrate the rationality or indicators that need adjustment.

(3) Is the weight distribution of the technology layer, teaching layer, and resource layer in the model (30%, 45%, and 25%) reasonable? If adjustment is necessary, what is your recommended weight ratio and the reasoning?

2. Model operability analysis

(4) From the perspective of school implementation, are the hardware investment and maintenance costs of the digital technologies mentioned in the model (such as smart platforms and VR equipment) within the general affordability of higher vocational colleges in Shandong Province?

(5) Do teachers have the basic requirements to apply this model (e.g., ability to use digital tools, time invested in instructional design, etc.)? What supporting measures are needed (e.g., specialized training, resource package sharing)?

(6) How should the implementation path of the model be designed differently for different types of colleges (e.g., comprehensive vocational colleges, industry-specific vocational colleges)? (Examples may be given for the focus of engineering and liberal arts colleges.)

3. Regional Adaptability Verification

(7) Do the "Professional Case Library" and "Interactive Question Bank" in the model align with the higher vocational majors corresponding to Shandong Province's key industries (such as equipment manufacturing, modern logistics, and marine engineering)? Please list one or two regional case studies that require additional information.

(8) In conjunction with Shandong Province's vocational education digitalization policies (such as the "Shandong Province Vocational Education Informatization Construction Action Plan (2023-2025)"), how can the model be connected with local policies to obtain support when it is implemented?

(9) The mathematical foundations of vocational college students in Shandong Province vary greatly (for example, those from general high schools and those from secondary vocational schools). How can the model take this level of diversity into account to improve its applicability?

4. Optimization Suggestions and Promotion Paths

(10) If the model needs to be optimized in one or two key areas, which do you think should be prioritized? (e.g., adding a "teacher digital competency training" module, refining technology application scenarios, etc.)

(11) Regarding the promotion of the model, do you recommend a step-by-step strategy of "piloting - summarizing - province-wide rollout" or a gradual rollout by discipline category? What factors should be included in the selection criteria for pilot institutions?

(12) In addition to hardware and resource support, what other mechanisms do you think are needed to ensure the long-term operation of the model? (For example, resource sharing mechanisms between institutions, teacher assessment and incentive mechanisms, etc.)

Summary

Please ask each expert to summarize the overall evaluation of the model and core recommendations in one sentence.

(Note: During the discussion, you can ask further questions based on the experts' speeches to ensure that opinions are fully expressed)

Appendix D

The Results of the Quality Analysis of Research Instruments

IOC (Index of Item-Objective Congruence) Evaluation Table

No.	Variable	Expert					IOC	determination
		1	2	3	4	5		
Category : Teaching Analysis								
1	Learner Profile Analysis	1	1	1	1	1	1.0	reserve
2	Digital Expression of Teaching Objectives	1	1	1	1	1	1.0	reserve
3	Contextualized Case Design	1	0	1	1	1	0.8	reserve
4	Integration of Multimodal Teaching Resources	1	1	1	1	1	1.0	reserve
5	Collaborative Learning Task Design	1	1	1	1	1	1.0	reserve
6	Learning Path Design	1	1	1	1	1	1.0	reserve
7	Use of Learning Analysis Tools	1	1	1	1	0	0.8	reserve
8	Real-Time Interactive Feedback Mechanism	1	1	1	1	1	1.0	reserve
9	Visual Presentation of Teaching Content	1	1	1	1	1	1.0	reserve
Category : Resource Matching								
10	Application of Adaptive Learning Systems	1	1	0	1	1	0.8	reserve
11	Online Test and Assessment Design	1	1	1	1	1	1.0	reserve
12	Mobile Learning Platform Use	1	1	1	1	1	1.0	reserve
13	Cloud-Based Resource Sharing and Collaboration	1	1	1	1	1	1.0	reserve
14	Virtual Simulation Use	1	0	1	1	1	0.8	reserve
15	Gamification Design	1	1	1	1	1	1.0	reserve
16	Learning Data Collection and Analytics	1	1	1	1	1	1.0	reserve
17	Teaching Reflection and Adjustment Mechanism	1	1	1	1	1	1.0	reserve

No.	Variable	Expert					IOC	determination
		1	2	3	4	5		
18	Teacher Digital Literacy Development	1	1	1	1	1	1.0	reserve
19	Learner Self-Directed Learning Support	1	1	1	1	1	1.0	reserve
Category : Instructional Implementation								
20	Cross-Platform Resource Sharing	1	1	1	1	1	1.0	reserve
21	Application of Digital Assessment Tools	1	1	1	1	1	1.0	reserve
22	Production and Application of Video Micro-Courses	1	1	1	0	1	0.8	reserve
23	Course Data-Driven Optimization	1	1	1	1	1	1.0	reserve
24	Lesson Preparation Sharing	1	1	1	1	1	1.0	reserve
25	Classroom Interaction Data Analytics	1	1	1	1	1	1.0	reserve
26	Digital Assignment Design and Grading	1	1	1	1	1	1.0	reserve
27	Learner Behavior Tracking and Analytics	1	1	1	1	1	1.0	reserve
28	Big Data Drives Teaching Decisions	1	1	0	1	1	0.8	reserve
29	Teaching Platform Integration	1	1	1	0	1	0.8	reserve
30	Personalized Course Recommendation	1	1	1	1	1	1.0	reserve
Category : Learning Support								
31	Adaptive Evaluation System	1	1	1	1	1	1.0	reserve
32	Student Learning Portfolio Management	1	1	1	1	1	1.0	reserve
33	Interdisciplinary Integration	1	1	1	1	1	1.0	reserve
34	Peer Assessment and Collaborative Feedback Mechanism	1	1	1	1	1	1.0	reserve
35	Online Question-and-Answer Support System	1	1	1	1	1	1.0	reserve
36	Online Examination Security	1	0	1	1	1	0.8	reserve
Category : Evaluation Improvement								
37	Online Monitoring of Teaching Quality	1	1	1	1	1	1.0	reserve
38	Visualization of Learning Outcomes	1	1	1	1	1	1.0	reserve

No.	Variable	Expert					IOC	determination
		1	2	3	4	5		
39	Continuous Updating of Teaching Resources	1	1	1	1	1	1.0	reserve
40	Continuous Improvement and Optimization Mechanism	1	1	1	1	1	1.0	reserve

Appendix E

Certificate of English

BSRU BANSOMDEJCHAOPRAYA
RAJABHAT UNIVERSITY

This is to certify that

Mrs.Zhang Pengfei

Achieved BSRU English Proficiency Test (BSRU-TEP) level

C1

Given on 15th August 2025o

(Assistant Professor Dr Kulsirin Aphiratvoradej)

Director

Appendix F

The Document for Acceptance Research

African Educational Research Journal

Date: February 17, 2026

Ref: AERJ-2026-012
Title: *Digital Technology Integration in Higher Vocational Mathematics Instructional Design in Shandong Province*

Pengfei Zhang
Bansomdejchaopraya Rajabhat University
Bangkok
Thailand

<u>Acceptance Letter</u>

Dear Pengfei Zhang,

We are pleased to inform you that your manuscript, titled "*Digital Technology Integration in Higher Vocational Mathematics Instructional Design in Shandong Province*," by authors "**Pengfei Zhang, Sombat Teekasap, Pong Horadal and Kanakorn Sawangcharoen**," has been accepted for publication in the *African Educational Research Journal*.

The manuscript will be published in Volume 14, Issue 1, February 2026.

The final Galley Proof will be sent to you via email as an Acrobat PDF (Portable Document Format) file. Please note that at this stage, only essential corrections to errors in the text or figures will be permitted. Any other alterations will not be acceptable.

We congratulate you on this achievement and thank you for choosing the *African Educational Research Journal* as the platform for your research. Should you have any questions or require further assistance, please do not hesitate to contact us.
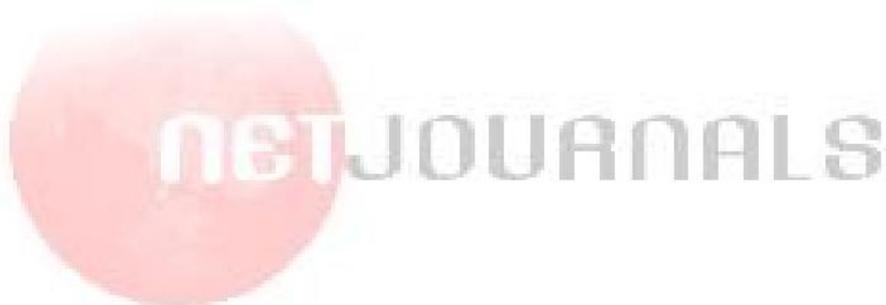
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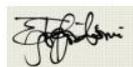
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Researcher Profile

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Educational background:

- Master of Applied Mathematics, graduated from Shandong University, in June 2012
- Mathematics education, Jinzhou Normal University, in 2002

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