

Research Article

Integrative Analytics for Technological Pedagogical Content Knowledge

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In this paper, we deeply analyze the general framework of technological pedagogical content knowledge (TPACK): it mainly involves technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and pedagogical content knowledge (PCK). Meanwhile, we also show that the conceptual framework of TPACK can help teachers to integrate a lot of complexity and tension in teaching and learning. Also, this study suggests that the framework of TPACK may be able to change the application mode of technology in education and the training mode of teachers and then provide a panoramic analysis for building a learning community.

1. Introduction

Teachers are an important factor for schools to achieve connotative development and improve education quality. Teachers' development is a necessary guarantee for teaching reform and educational innovation. Teachers' knowledge is the basis for teachers to carry out teaching activities. The composition and structure of teachers' knowledge will directly affect teachers' teaching behavior and students' learning effect. Since entering the new era, the continuous development of informatization technology has put forward higher requirements for teachers' knowledge structure and teaching ability. Only by actively adapting to technological changes such as informatization, networking, and artificial intelligence (AI), then teachers can effectively improve the quality of talent training and promote the vigorous development of education. As "Ten-Year Development Plan for Educational Informatization (2011–2020)" in China points out, we should promote the integration of informatization technology and teaching and then promote the professional development of teachers. The opinions issued by the Ministry of Education of China on the "Implementation of Excellent Teacher Training Plan 2.0" clearly propose to promote the all-round integration of new technologies such as AI and intelligent learning environment with teacher

education courses. The "Excellent Teacher Training Plan" proposed by China also aims to cultivate a large number of high-quality professional teachers with noble ethics, solid professional foundation, and outstanding educational and teaching ability. So we have to think about such a question: What knowledge does a teacher need to become a qualified teacher [1]? Since the mid-1980s, scholars have conducted in-depth research on pedagogical content knowledge (PCK) [1–3]. In recent years, for mathematics education, mathematics pedagogical content knowledge (MPCK) is one of the hot issues for educational studies in mathematics.

Knowledge learning is the core value pursuit of teachers' development. The rapid, continuous innovation and progress of informatization technology has reformed the education. With it, teachers' knowledge and ability need to be redefined and designed. Teachers' technical literacy has a direct impact on the behavioral intention of information-based teaching. The main obstacle to the use of technology in classroom is the lack of technical knowledge and skills. If teachers do not know how to operate technology, they will not use technology. We should pay attention to the cultivation of teachers' technical knowledge and help teachers master the use of basic technology. At the same time, teachers should be encouraged and supervised to apply the learned technical knowledge and skills to classroom

teaching. Therefore, for the promotion of educational informatization, one should pay particular attention to improving teachers' beliefs and attitudes toward the application of technology teaching, so as to improve teachers' intention of information-based teaching behavior. Today, informatization technology not only affects human thinking and behavior but also plays a great role in economic, cultural, and social activities. At present, informatization technology has been widely used in the field of education at all levels. With the more and more frequent application of digital technology for teaching in the Information Age, teachers generally lack the experience of using digital technology in teaching, which makes the professional knowledge of teachers difficult to meet the needs of students growing up in the Information Age. Teachers' development must pay attention to teachers' existing experience, environment, and surrounding colleagues, which is a circular process. Under the background of informatization, teachers in professional development must think about and pay attention to the effective integration of technology, PCK, and teaching method [4, 5]. That is, they ought to possess a professional knowledge: technological pedagogical content knowledge (TPACK). The hierarchical structure of traditional education (see Figure 1) is a dull and inappropriate structure. Learning under traditional education is always passive, and it is difficult to support today's learners to have rich knowledge, complex thinking ability, and cooperation ability. Contrary, TPACK is an important framework for reshaping teachers' professional development experience [6–8]. Restructuring teachers' knowledge development in pre-service and in-service teacher education to adapt to TPACK is a logical step in teacher education reform. Actually, the framework of TPACK is based on the concept of PCK. TPACK is the basis for teachers to use technology for effective teaching. It has become a more and more important mission for today's mathematics teachers to exert their imagination on the connection between technology and teaching, judge the advantages of relevant teaching strategies, and integrate all factors to achieve an effective mathematics class [9–12].

2. Integration of TPACK in Teachers' Professional Quality

TPACK is an important part of teachers' professional development. In normal education and in-service teacher training, teachers should have knowledge and skills, cultivate teachers' tendency to try new technologies and learn from their own teaching, foresee possible problems, and insist on using technology in a way that is conducive to students' learning. Next, we discuss the teachers' information technology literacy from three dimensions, i.e., informatization technology sentiment, informatization technology skills and informatization teaching ability, and analyzing the relationship between the three.

2.1. Informatization Technology Sentiment. For normal students, with the growth of grade, the informatization technology sentiment of mathematics normal students is

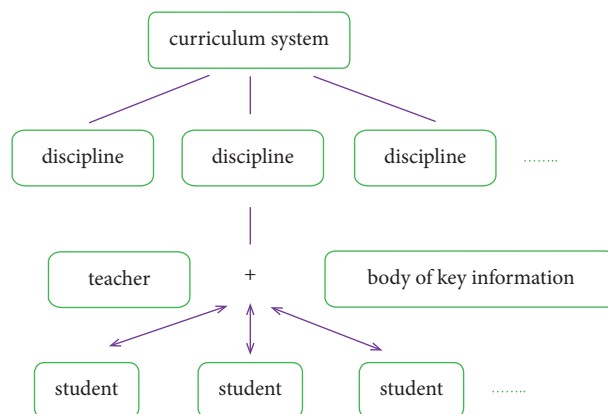


FIGURE 1: The hierarchical structure of traditional education.

rising. Because educational practice is different from tutoring and other relatively single guidance, strictly speaking, educational practice is the first time that normal students contact the formal classroom as teachers and carry out formal lesson preparation. It can be said that educational practice means that normal students enter another environment and role. What they see, hear, and experience accumulation during educational practice will certainly affect their views on teaching, including their views on information-based teaching. On the whole, educational practice can promote normal students' understanding and reflection on informatization technology. Therefore, the internship experience may make normal students more interested in informatization technology. Another important factor affecting normal students' informatization technology sentiment is whether they have made courseware or instructional design. After making courseware or instructional design, normal students will find that informatization technology is very helpful to present knowledge and promote students' understanding of knowledge. Using informatization technology to prepare lessons will not only improve the efficiency of lesson preparation but also diversify the presentation of knowledge and support novel teaching methods. Normal students who have made courseware or instructional design generally have higher informatization technology sentiment. For in-service teachers, one of the main factors affecting their informatization technology sentiment is teaching age. On the one hand, teachers with short teaching age are relatively young, and they are willing to accept new things, have higher enthusiasm for learning technology, and therefore have higher intentions for informatization technology. On the other hand, traditional teaching methods are still deeply rooted in the hearts of older teachers, and they are familiar with these methods, which may be one of the reasons for their low intentions for informatization technology.

2.2. Informatization Technology Skills. For any TPACK framework, technology is one of the main factors in its content. Therefore, for teachers, no matter how excellent application of teaching methods are, they should be closely linked with technology in order to integrate, and the basis of

all this is to be able to use technology. A survey of normal students and in-service teachers on the use of informatization technology shows that the score of software commonly used in daily office is relatively high. For example, network application, word processing software, office software, and PPT are the most familiar technologies and software for teachers. In addition, benefiting by the promotion of educational informatization carried out by government departments at all levels. By updating equipment, training teachers, and carrying out various teaching research activities, the majority of teachers are naturally familiar with Z+Z education platform, LATEX, SPSS, etc., which are professional mathematical software or statistical software. Although teachers seldom use these software, they can also help teachers' teaching. For instance, as statistical software, we can use SPSS to analyze the data, so as to obtain the development curve of students or make data-based evaluation on students.

2.3. Informatization Teaching Ability. Both normal students and in-service teachers are more optimistic about the presentation of knowledge through technology and the combination of technology and teaching method, while the integration of technology, knowledge, and teaching method and the evaluation of students through informatization technology are not optimistic. This shows that normal students and in-service teachers doubt whether technology can participate in the complete teaching process. The possible reasons may lie in: (1) the technical literacy and professional level of normal students and in-service teachers need to be improved; and (2) some teachers cannot accept the modern educational concept. This requires a long process and hard work to achieve the deep integration of technology, knowledge, and teaching. For the integration of technology and knowledge, normal students believe that technology is more suitable for presenting geometry, image, or dynamic knowledge. In-service teachers are also aware of the convenience of Geometer's Sketchpad in mathematics teaching and are willing to use it to draw geometric graphics or present the changes of function images. The application of informatization technology is diverse, which has incomparable advantages over traditional teaching methods in the teaching of algebra and probability. This requires normal students and in-service teachers to master more knowledge to support their teaching in more knowledge fields.

It is found that the informatization technology literacy of normal students and in-service teachers is significantly related to informatization technology sentiment, informatization technology skills, and informatization teaching ability. Whether for normal students or in-service teachers, the dimension of informatization teaching ability has the greatest impact on informatization technology literacy.

3. Application of TPACK in Teachers' Teaching Practice

TPACK is the basis for teachers to use technology for effective teaching. The National Council of Teachers of

Mathematics (NCTM) has pointed out that technology is an essential tool, and teachers must be prepared to ask more why in teaching practice. For example, why is this technology used in the class? How can this technology support the expansion of students' mathematical thinking to the greatest extent? To successfully make this technology as a tool for learning content knowledge, what should the students do to get started?

3.1. Overall Level of TPACK for Mathematics Teachers. Numerous studies have now found that the approach about learning and mastering informatization technology for teachers is mainly self-study. Due to the limited learning resources and learning channels, some teachers have fewer opportunities to receive training than listening to reports and lectures. From the six dimensions of TPACK, i.e., technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and PCK, as illustrated in Figure 2, the recent survey found that teachers' PK, CK, and PCK are relatively good, that is, PK, CK, and PCK are above the overall level. Among them, the PCK score is the highest. The mastery of TK and TCK is relatively low, among which the level of TK is the lowest, which indicates that teachers are relatively lacking technical knowledge. To a certain extent, it also reflects that teachers have not formed correct attitudes and habits in the aspect of application technique. Due to the relative lack of technical knowledge, the level of relevant technological knowledge is also relatively low. It can be seen that the lack of technical knowledge and technological barriers are the main factors affecting teachers' TPACK level.

3.2. Difference and Correlation of TPACK for Mathematics Teachers. From the perspective of gender, the average score of male teachers is higher than that of female teachers in the dimensions of TK, PK, CK, TCK, TPK, and PCK. As well, there are no significant differences in TK, PK, and CK, but there are significant differences in TCK, TPK, and PCK.

In terms of teaching age, for PK, CK, and PCK, the average score of teachers with teaching age of 11–15 years and more than 16 years is higher than that of teachers with teaching age of less than 3 years and 4–10 years, and there is a significant difference in PK and CK, but there is no significant difference in PCK. For TK and TCK, the average score of teachers with teaching age of 11–15 years is the highest. As far as the teaching age is concerned, there is no significant difference among TK, TCK, TPK, and PCK. In addition, there is a positive correlation between teaching age and PK, CK, and PCK.

In terms of professional titles, teachers' scores on PK, CK, and PCK are higher with the increase of professional titles, and there are significant differences. In TK, TCK, TPK, and PCK, the teachers with the lowest professional titles have the lowest average score. There is no significant difference in professional titles among TK, TCK, TPK, and PCK. In addition, professional titles are positively correlated with PK, CK, and PCK.

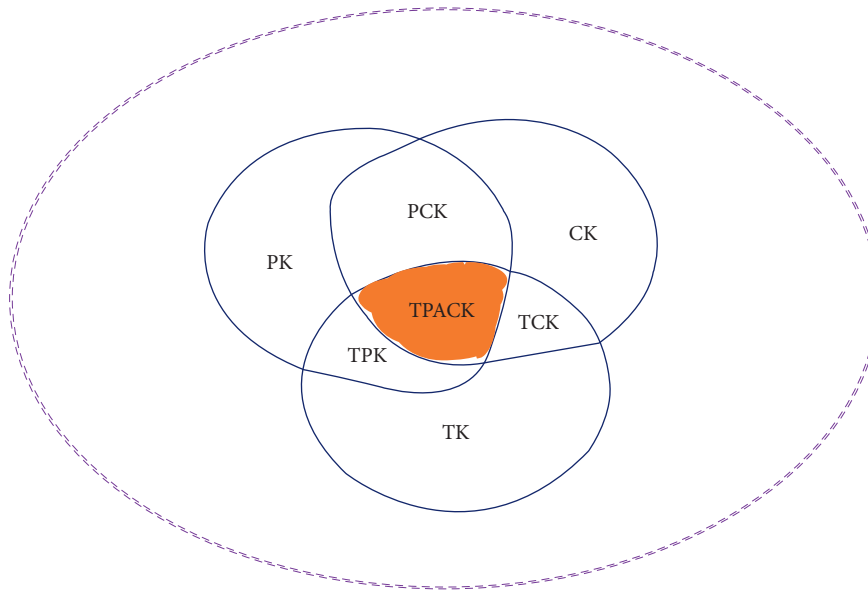


FIGURE 2: TPACK framework and its constituent components.

From the perspective of school types, teachers' scores on PK, CK, and PCK are related to the types of teaching school (key middle school and ordinary middle school). The better the school level is, the higher the average score is, but there is no significant difference. In terms of school types, there is no significant difference between TK and TCK, but there is significant difference between TPK and PCK.

In terms of the highest educational background, the average score of teachers with bachelor's degree in TK, PK, CK, TCK, and PCK is higher than that of teachers with master's degree, while the average score of teachers with master's degree on TPK is higher than that of teachers with bachelor's degree.

3.3. Application and Value of Informatization Technology. Mathematics teachers generally believe that informatization technology is useful for teaching, but their awareness of the use of informatization technology is not strong, and they are not proficient in using all kinds of informatization technology software. The roles of informatization technology in mathematics teaching include enriching classroom teaching methods, obtaining curriculum resources, enriching students' learning methods, improving teachers' professional quality, evaluating students' learning, and others. Teachers also believe that the main advantages of integrating informatization technology into mathematics teaching are (1) informatization technology can replace traditional blackboard writing, save blackboard writing time, and increase classroom capacity; (2) informatization technology can provide more situational materials and learning resources; (3) we can use informatization technology to analyze and evaluate students' learning situation and carry out dynamic tracking evaluation; (4) informatization technology can present knowledge more vividly, improve students' visual expression and visual control ability, make students more willing to accept and explore, enrich the depth and breadth

of teaching topics, and promote students' exploration ability and in-depth understanding of knowledge; and (5) informatization technology can not only enhance the interaction between teachers and students but also improve students' interest in learning.

4. Systematic Characteristics of TPACK Knowledge Framework

The TPACK knowledge framework possesses systematic characteristics, which can be summarized as follows:

4.1. Integrality. The system is composed of more than two elements according to a certain structure, but not the random stacking of these elements. The change of one element in the system will cause the change of other elements, and the change of any element also depends on the change of other elements. The three core elements in TPACK are dynamic and interactive. If any of these elements changes, the other two elements will change to compensate.

4.2. Openness. Knowledge exists and arises in a certain semantic environment. The environment and condition on which this process depends is the knowledge field. Knowledge realizes the acquisition, aggregation, and transformation of information through the interaction between knowledge and knowledge field (environmental conditions). TPACK is an open system, and it is very important to build a benign information environment, which directly affects the input, internal transformation, and output of the system.

4.3. Dynamics. Knowledge is a dynamic mixture of experience, values, background information, expert views, and basic intuition, and its spatial structure changes with time. Teachers'

knowledge category, knowledge level, and knowledge relevance always develop and change continuously and affect the structure of knowledge. In different contexts, TK, PK, and CK play different roles, which makes the integration of education and technology widely changeable.

4.4. Hierarchy. The hierarchical structure is the fundamental nature of the system. The level of knowledge is like a pyramid. From bottom to top, the knowledge space is gradually reduced and the complexity level of knowledge is gradually improved. The lower layer is the foundation of the upper layer, and the upper layer is the promotion of the lower layer. TK, PK, and CK are hierarchical knowledge. For example, TK contains two meanings: (1) technology of materialized form and (2) methods and skills of intelligent form. When TK is integrated with PK and CK, it also has hierarchy. The lowest level of integration of informatization technology and teaching is the renewal of teaching media. As a tool of materialization, technology has produced new teaching media during integration.

4.5. Self-Organization. The self-organizing process refers to the spontaneous transformation from disorder to order. This process of transition is from an ordered state to a higher ordered state. Order and disorder are some kinds of structure of the system. The essence of knowledge organization is a series of orderly organizational activities aimed at the disordered state of objective knowledge. The integration process of knowledge is also a spiral process of chaos-order-chaos-order. We expect that teachers' knowledge structure is a self-organizing system with a higher degree of order. When the internal elements of the system reach certain threshold conditions (such as the accumulation of knowledge, the improvement of knowledge level), the internal elements of the system can spontaneously transform to order or more order.

Based on the above, the teacher knowledge system model with systematic structure can be visually represented as the three-dimensional space and hierarchical structure of knowledge, as shown in Figure 3. TPACK comes into being in an open semantic environment, which realizes the acquisition, aggregation, and transformation of information into knowledge. TPACK comes from the multiple interactive integration of three kinds of knowledge. Knowledge is hierarchical. From bottom to top, the knowledge space is gradually reduced and the level of knowledge complexity is gradually improved. When the elements and external environment of TPACK reach certain threshold conditions, it will cause self-organization and promote the transformation of knowledge to order or more order. In addition, when one element of the system changes, in order to maintain the dynamic balance of the whole system, the other two elements will also change to compensate. The lack of elements leads to the weak connection between the elements in the system. This relationship structure is conducive to obtaining information because the weak connection is related to two different types of knowledge. Such two different types of

knowledge have different information sources, which is conducive to transmitting fresh or heterogeneous information and knowledge. Figure 4 shows the absence of elements in the TPACK system. Figure 4(a) is missing the content material of TK, so TK and PK, TK and CK constitute a weak connection. Teachers need to obtain new information to supplement the missing parts and re-establish and strengthen the connection. In this system, of the original three knowledge variables, PK and CK become known and independent variables and TK becomes a dependent variable (changing with the combination of PK and CK). Teachers need to design the missing part according to the known content and reset the function of technology according to the purpose of teaching, so as to improve the level of technology application. In Figure 4(b), CK is missing. When PK and TK are independent variables, CK can change multiple results according to different combinations of PK and TK. Even for the same teaching content, when technology is used as tools for presentation, expression and communication, information processing, cognition, and cooperation, different teaching methods can be used accordingly. In Figure 4(c), when there are two missing elements, there are more variable factors, more complex integration methods, and more difficult integration, which can be used as high-level training materials for teachers. By adding the missing part, teachers constantly excavate knowledge and establish the connection of knowledge in the process of self-construction, so as to improve the ability of knowledge integration.

5. AI-TPACK

In the context of AI, teachers should actively use new technologies such as big data to understand students' cognitive state, analyze students' learning characteristics, evaluate students' advantages, potential, and best learning methods, and design personalized learning recommended schemes. We should study how students learn and grow and understand students' noncognitive state, including motivation, emotion, quality, values, etc. Only in this way can we truly respect students and meet their personalized learning and development needs. In the era of AI, does TPACK need to inject new connotation? What new changes will TPACK bring to the teaching form and learning environment after integrating AI technology? In short, re-exploring the relationship among technology, teaching method, and subject content and constructing a new TPACK framework based on AI technology has become an urgent problem to be solved. Isolated AI-TK, AI-PK, and AI-CK are all not enough to support teachers to effectively apply AI technology to teaching. Only the AI-TPACK knowledge formed by the combination of the three is the most effective knowledge basis for teachers to integrate AI technology with classroom teaching. Therefore, there are three main development paths of teachers' AI-TPACK: from PCK to AI-TPACK, from AI-TPK to AI-TPACK, and the synchronous development of AI-TPACK and PCK.

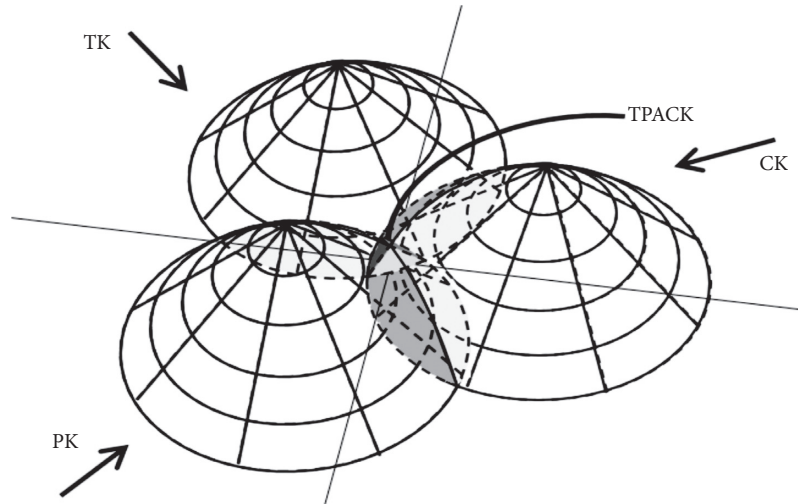


FIGURE 3: Knowledge system model.

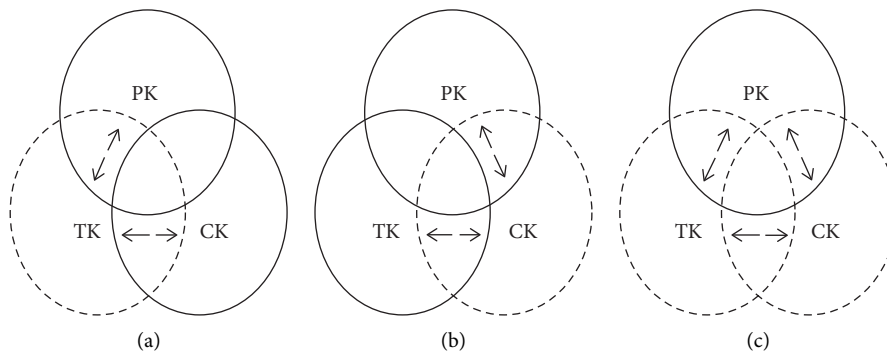


FIGURE 4: The absence of elements in TPACK system.

5.1. From PCK to AI-TPACK. On the basis of teachers' original PCK, by introducing AI technology, the integration of PCK and AI technology is one of the development ways of teachers' AI-TPACK. For teachers with teaching experience, they not only have a deep understanding of the subject content but also have a lot of accumulation about teaching and learning methods used in the classroom. More importantly, they can quickly establish a relationship between specific teaching contents and teaching and learning methods, that is, they already have rich PCK knowledge. For such teachers, they need to understand the teaching functions of various AI technologies and try to integrate AI technologies into teaching activities related to specific subject contents, so as to realize the development of AI-TPACK. It can be seen that the development from PCK to AI-TPACK is gradual. We can divide this process into five stages: cognition, acceptance, adaptation, exploration, and advancement.

In the cognition stage, teachers begin to understand and use some common AI teaching tools in education and can realize that these tools are suitable for the subject content and teaching activities. In the acceptance stage, teachers will analyze the impact of the application of AI technology on subject teaching, so as to decide whether to adopt AI technology in class. In the adaptation stage, teachers try to

select appropriate AI technology to support subject teaching according to the teaching activities. In the exploration stage, teachers will actively integrate AI technology into subject teaching, design the teaching and learning process supported by AI technology in detail, and creatively give full play to the role of AI technology in promoting teaching and learning. In the advancement stage, teachers comprehensively evaluate the teaching and learning supported by AI technology and judge the effectiveness of the integration of AI technology and classroom teaching by analyzing the data information and student feedback in the process of teaching and learning. AI technology has gradually become an integral part of daily teaching and learning activities.

5.2. From AI-TPK to AI-TPACK. Based on the existing AI-TPK, developing teachers' AI-TPACK through the so-called technology mapping method is another feasible path. With the continuous penetration of AI technology in the field of education, teachers have more and more opportunities to learn courses as regards educational application of AI technology in the pre-service education stage. Therefore, we need to pay attention that how to use AI technology to support students' inquiry-based learning and to diagnose students' learning, etc. In this kind of course learning,

teachers mainly obtain AI-TPK knowledge, and the technology mapping method can help teachers realize the development from AI-TPK knowledge to AI-TPACK knowledge in subsequent courses.

5.3. Synchronous Development of AI-TPACK and PCK. In order to promote the synchronous development of AI-TPACK and PCK, the following strategies can be adopted: (1) to design artificial products integrating AI technology, such as teaching plans and learning resources supported by AI technology, so as to help learners understand the complexity of the integration of AI technology and classroom teaching in the design process; (2) to critically analyze the design cases of the integration of AI technology and classroom teaching, which promotes learners to deeply think about the relationship among AI technology, teaching methods, and curriculum content; (3) to reflect on the design experience, which can help learners further refine the experience gained in the design process, determine the difficulties encountered, and conduct the self-assessment of AI-TPACK; (4) to apply the design results into the real environment, so as to help teachers further sublimate their understanding about how AI-TPACK to be implemented.

6. Suggestions on Improving Teachers' Informatization Technology Literacy and Application Ability

6.1. Building Teachers' TPACK Belief and Enhancing Their Awareness of the Use of Informatization Technology. Belief is an important factor that determines individual behavior. Teacher knowledge and teacher belief are intertwined. Under the condition of informatization, TPACK is a necessary knowledge framework for teachers. In the classroom, integration technology is a complex and poorly structured problem, including a variety of factors and hovering interactions. There are few fixed and rapid planning methods, which can be applied to various situations and cases. To fully understand the complexity of the integration of teaching and technology, teaching under informatization technology needs teachers' active participation and exploration. New teachers have newer informatization technology knowledge. So the older teachers can learn newer knowledge and technology from new teachers, and new teachers can learn teaching method knowledge and classroom management knowledge from older teachers, so as to promote the integration of informatization technology and classroom teaching and promote the improvement of teachers' TPACK belief. For the development of teachers' TPACK, it is not enough to just train them to master specific operational knowledge. More importantly, we should guide them to form a correct attitude of using technology and the awareness of actively integrating technology.

6.2. Optimizing the Information Resource Environment and Enhancing the Application Ability of Informatization Technology. High-quality informatization technology hardware is the external factor of teachers' TPACK development.

Hardware facilities and information resource environment are the premise of technological teaching. Hardware is one of the important reasons for regional differences. In order to speed up the informatization construction, rural schools must provide a good environmental guarantee for the development of teachers' TPACK. Meanwhile, we should provide teachers with a variety of learning resources and constantly update informatization technology resources. Moreover, we can guide teachers to cobuild some technical resource databases for obtaining the required technical support and create an environment for using informatization technology to assist teaching. To effectively improve teachers' understanding of technology and ability of using technology in mathematics teaching, we also construct some teaching strategies, which is helpful for enhancing teachers' confidence about using applied sciences in the actual teaching process, and then will improve teachers' TPACK level.

6.3. Paying Attention to the Selection of Technical Training Mode and Strategy to Enhance the Training Effect. Both pre-service teachers and in-service teachers should make full use of the TPACK framework to formulate corresponding training modes and strategies. The purpose of training is not only to let teachers master technology but also to let teachers learn to use technology for teaching and learn how to integrate technology into teaching, including the integration of technology and teaching content, as well as the integration of technology and teaching method. The choice of training form also has a profound impact on the training effect. Teachers should realize the importance of technical training and understand the focus of training content. Then, the training of hardware equipment and teaching software is carried out, which promotes teachers to achieve a more skilled application level of educational technology. Viewed from the different needs of teachers with different teaching ages, the dimension training of TPACK is performed according to their teaching ages. Besides, typical integration cases of TPACK are selected for in-depth analysis, so as to inspire teachers to master the methods about when to use technology, what technology to use, and how to use technology. Teachers should not only use informatization technology to improve teaching means and methods but also use informatization technology to change the traditional classroom teaching structure. It is important that teachers ought to give full play to the leading role of teachers and reflect the dominant position of students.

6.4. Strengthening the Cooperation between Universities and Primary and Secondary Schools to Promote Mutual Development. Primary and secondary schools should cooperate more with local universities and carry out more exchanges about educational informatization in order to promote the mutual development of both sides. Both sides between universities and primary and secondary schools carry out specific and effective seminars and constantly discuss technology, teaching methods, and teaching knowledge. Through this mutual-assistance mode, the knowledge level of normal students and in-service teachers can be improved, and it can

also lay a foundation for normal students to become excellent teachers as soon as possible. With the help of in-service teachers, normal students can deepen their understanding of the subject and learn how to think about the subject content from the perspective of students.

6.5. Strengthening the Integration of Informatization Technology and Mathematics Teaching. In the actual teaching, some teachers blindly use modern informatization technology in pursuit of innovation, which weakens the knowledge penetration in the process of mathematics teaching and cripples the students' understanding of mathematics knowledge. If the process of students' learning mathematical knowledge is completely replaced by computers, it will not be conducive to the cultivation of students' thinking ability. The application of modern informatization technology in mathematics teaching is only an auxiliary means of classroom teaching in order to promote students' mathematical understanding and improve teaching efficiency. We select appropriate technical means for different mathematical contents and find the best bonding point of mathematics teaching and informatization technology in teaching. The integration of informatization technology and curriculum should focus on the improvement of teachers' professional quality, in order to effectively integrate the essence of traditional teaching with the application of informatization technology and handle the relationship between subjectivity and leading. There is a very close relationship between informatization technology and mathematics curriculum. Teachers should try to use STEM courses to integrate the teaching characteristics of informatization technology and mathematics curriculum, formulate scientific and reasonable teaching plans according to teaching contents and teaching requirements, display mathematical knowledge with the help of informatization technology, and then carry out informatization technology education around mathematical concepts to realize the in-depth integration between disciplines.

With knowledge reformation and technological innovation, a new era of education based on big data and Internet+ has come. In addition, how to delimitate the influencing factors of TPACK and the collaborative relationship between the influencing factors and the constituent elements of TPACK, as shown in Figure 5, will become an important breakthrough in the field of TPACK in the future. For MPCK, informatization technology has become an indispensable tool, which is very important to mathematics teaching. The deep integration of informatization technology and mathematics teaching has become a beautiful vision for the development of mathematics education. Under the background of the close combination of informatization technology and mathematics teaching, how to improve teachers' professional quality, how to better serve mathematics teaching with informatization technology, and how to promote students' mathematical understanding are topics that we should explore deeply.

7. Discussion

The research hotspots in the field of TPACK mainly include informatization technology, teacher professional development, teacher education, teacher knowledge, and pre-service teachers. From the perspective of centrality, in recent years, the research in the field of TPACK has mainly focused on teacher education and curriculum construction under the background of informatization technology. As the designer of integrating informatization technology, teachers should find the entry point between informatization technology and classroom teaching, so as to make informatization technology effectively integrate into teaching. In teaching practice, through the integration of technical means, teaching methods, and subject content, teachers create a multimodal learning environment, which can not only enhance their ability of technology learning and technology integration in the real situation but also design teaching activities that help improve learners' ability development. All of these contribute to promote the change of teachers' teaching behavior and the optimization of teaching process.

In addition, formally, the TPACK framework composed of three knowledge rings and a context is relatively easy to understand. From a theoretical point of view, TPACK has a certain complexity: It originates from the concept of PCK containing uncertainty and is essentially a fuzzy and complex concept; as a top-level design model, TPACK only provides teachers with a way of thinking and does not tell them what to do and how to do. A framework is required to satisfy the simplicity of the structure of basic model and reflect the complexity of the essence, and then the theoretical tension of a perfect framework will be unavoidable. Developing brand-new TPACK through design-based learning, design thinking, and knowledge creation is a new research perspective.

AI-TPACK goes beyond TPACK, which looks at technology from the tool level. The connotation of AI-TPACK is the interactive relationship among AI technology, subject content, and teaching methods under human-machine cooperation. The AI-TPACK theoretical framework has certain reference significance for the development of teachers' application ability of AI technology, the integration of AI technology and curriculum teaching practice, and the development of intelligent learning environment. Teachers' development is a long-term process. Teachers should have the consciousness of practice and reflection and actively develop independently. Academic groups should help each other and make mutual improvement. Schools should provide institutional and informatization technological support. Only by doing so can teachers change their role as soon as possible and play the role of multidirectional collaborator.

8. Future Works

In future works, the following topics may become irreversible trends:

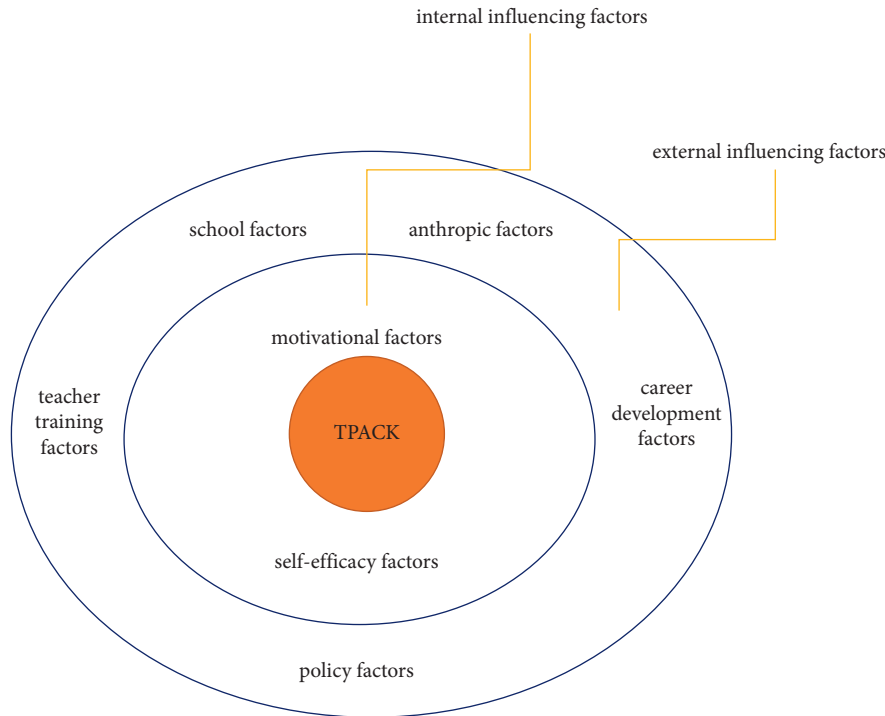


FIGURE 5: Influencing factors of teachers' TPACK.

- (1) Strengthening the subjectivity research on students' closely related to teachers' TPACK. Using educational informatization technology to optimize classroom teaching is the purpose of teachers' TPACK internalization. Therefore, in the future, we can measure teachers' TPACK level from the perspective of students and think about the relationship between TPACK and students' knowledge representation, knowledge system construction, academic achievement, and problem-solving ability. Combined with students' physiological characteristics and cognitive laws, we will explore the impact of teachers' TPACK level on students with different learning stages and characteristics in order to further promote the process of educational informatization.
- (2) With the development of informatization technology, great changes have taken place in the way of teaching activities. From the aspect of teaching by educators, teachers' mastery and flexible application of TK in TPACK have become necessary knowledge and skills. The rapid development of informatization technology will cause revolution in the field of education and improve the timeliness of TPACK essence, which is also an important direction of TPACK integrating technology. In addition, one should also pay attention to the practice of informatization technology and curriculum integration based on teaching. The integration strategy of informatization technology and curriculum can start from the entry of knowledge points, the construction of teaching environment, the way of cooperative exploration, and the construction of teaching resources. The specific integration teaching practice can be carried out through group cooperative learning, expanding learning resources, and carrying out diversified evaluation.
- (3) For different types of teachers, AI-TPACK promotion strategies should also be different. We should not only continue to pay attention to the development path of AI-TPACK for teachers with different knowledge and experience but also explore the promotion strategies of AI-TPACK for teachers with different cognitive structures, different subject backgrounds, different teaching beliefs, and different thinking ways.
- (4) The improvement and expansion of TPACK theoretical framework not only provides a more scientific reference framework for teachers' educational beliefs, knowledge, and skills but also brings important enlightenment to the resource allocation, teaching design, and strategy selection of teaching practice. Therefore, we should take some effective steps for the measurement and evaluation of TPACK framework. The measurement and evaluation of TPACK framework has become an important link in the teaching process. Simultaneously, combined with the application of various measurement tools, we ought to promote the improvement of teachers' knowledge and skills and the teaching activities. In addition, the application research of teacher educational training and instructional design based on TPACK theory is an important direction. The guiding role of theoretical results should be played to realize the development of teaching practice.

9. Concluding Remarks

With the continuous improvement of China's educational informatization level, there are more expectations and challenges for future teachers' knowledge structure and teaching literacy. Under the environment of modern informatization technology, how to better cultivate the knowledge, skills, and professional quality of pedagogics has a direct impact on the future of teacher education reform in China. This paper aims to explore and understand the knowledge required for teachers to effectively integrate technology in a specific pedagogical content field, including all levels from teachers' professional quality to teachers' teaching practice. In addition, this paper enriches and deepens the research of TPACK in the field of teacher education at the two levels of theory and practice.

Data Availability

No data were used to support this study.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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