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Research Article

Theoretical Analysis of TPACK Knowledge Structure of Mathematics Teachers Based on T-TPACK Mode

Zhaoxia Huang [1]
Ankang University

Abstract

In this paper, we explore the T-TPACK knowledge structure of mathematics teachers, and conduct questionnaire test on teachers who have a supportive attitude towards using information technologies and who are not active in applying information technologies. Based on the collected data, we conduct horizontal and vertical comparison analysis of the TPACK knowledge structure of mathematics teachers in each stage to understand the relationship between each element and find the general law of the TPACK structure of mathematics teachers, thereby distinguishing the teachers' enthusiasm for the use of information technology, and comparing the TPACK structure between teachers who consider information technology as a necessary literacy and who don't. All these provide references for the further improvement of teachers' TPACK knowledge structure, so that in the future teachers would apply their own TPACK knowledge structure and information technology environment to design their teaching and promote the development of students' mathematical thinking.

Keywords

T-TPACK • Mathematics Teacher • Information Technology • TPACK Knowledge Structure

[1]**Correspondence to:** Zhaoxia Huang (MSc), School of Mathematics and Statistics, Ankang University, Ankang 725000, China; Institute of Mathematics and Applied Mathematics, Ankang University, Ankang 725000, China. Email: Huangdoudou3333@163.com

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TPACK (Technological Pedagogical Content Knowledge) was proposed by Mishra & Koehler (2006) in 2006. TPACK consists of Technology Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technical Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPACK), it represents seven kinds of knowledge that teachers need to master in teaching. The TPACK framework is the basis for teachers to carry out effective teaching in the information age. It is of great significance to cultivate teachers' TPACK ability to comprehensively improve the teaching level of teachers in the information age.

The concept of TPACK is leading a new direction for the integration of information technology and subject curriculum. Gardner believes that subject thinking may be the greatest invention of mankind, and it is the most important and irreplaceable goal for school education. Through the process of developing knowledge, methods, purposes, and representations, subjects become a powerful perspective for understanding the world (Angeli & Valanides, 2009; Blase & Blase, 1999; Chai, Koh & Tsai, 2011a; Grandgenett, 2008; Hair, Black, Babin, Anderson & Tatham, 2010). Since the research objectives, research methods and research results of each subject are different, practice has proved that regardless of the characteristics of the subject, the pursuit of universal information technology in the informatization of subject education is not feasible. For the existing researches. If we want to give full play to the advantages of educational information technology in classroom teaching, the knowledge research of educational information technology should highlight the value appeal of "technology services subject teaching", and transform the universalized educational technology knowledge into “subject” educational information technology knowledge that pays attention to specific subject content and teaching methods (Koehler, Mishra & Yahya, 2007). Jimonyannis established the TPACK framework for science subject education - TPASK (Technological Pedagogical Science Knowledge) (Jimoyiannis, 2010), and Lesser and Groth proposed the TPACK framework for statistical science education - TPSK (Technological Pedagogical Statistical Knowledge) (Lesser & Groth, 1990). Focusing on the informatization of basic education is the embodiment of China's *Education Informationization Ten Year Development Plan (2011-2020)*. In 2014, the country officially launched the "Excellent Teacher Program", and the cultivation of excellent middle-and-high school mathematics digital teachers is one of the important sub-projects. Mathematics education is an important part of basic education. How to effectively use technologies in mathematics classroom teaching is a long-term problem that should be taken in to consideration by mathematics educators. Zhan Yi et al designed micro curriculum through design learning method and self-question strategies and conducted experiments, through the comparison before and after the experiment, we can see that the TPACK of pedagogical students was developed. In order to better implement the national will and promote the informationization of subject education, and to cultivate excellent mathematics digital teachers, we should go deep into the mathematics discipline to study TPACK, and pay attention to the TPACK of mathematics teachers.

Although researchers have proposed a lot of TPACK conceptual frameworks, and the structural models of TPACK have been developed from different aspects (Marks, 1990; Koehler & Mishra, 2005; Shulman, 1986), when discussing TPACK in combination with the specific subject mathematics, it is also necessary to propose a TPACK structural model that suits its subject characteristics. For mathematics educators, defining how to apply technologies most effectively in mathematics teaching is a poorly structured problem. To cope with this dilemma, a framework is needed to think about the integration of technology and curriculum. Although some researchers in China have proposed a mathematics teacher TPACK structural model TPMK and interpreted it, the traces of transplantation and reference of this model are too obvious and need to be re-examined. Guerrero combined the characteristics of mathematics to refine TPACK into four components: concept & use of technology, technology-based mathematics instruction, technology-based classroom management, and depth & breadth of content. The concept and application of technology means that teachers have a comprehensive understanding of using technologies to support the learning and teaching of mathematics, and they know how to teach mathematics with the support of technology, and what kind of mathematics students should learn. This component is the basis for teachers to make teaching decisions, with functions of value orientation and goal orientation, so that the subject content is easier for students to understand with the support of technology. Teachers must decide how to better use technology to illustrate the relationship between learning psychology, learning content, and teaching method, and then decide which technology can better achieve these goals. They should know how to use technology in an appropriate way to truly support teaching rather than just a tool assisting in display and presentation. The TPACK structure model of mathematics teachers gives analysis from aspects of technical concept, technology management, the role of technology to teaching methods and the role of technology in subject contents, it emphasizes the uniqueness of TPACK for mathematics education. The mathematics teacher TPACK structural model transcends the learning of technical tools and technical operations in the sense of knowledge learning, and in essence achieves the realm of operating technologies to improve the teaching and learning of mathematics.

Measurement and analysis of TPACK level of mathematics teachers under T-TPACK mode

Tables 1
TTP Mode Analysis

TTP mode analysis	Average value	Standard deviation
TTP1- In algebra, I can use Geometric Sketchpad to geometrically abstract problems and teach them.	5.0	1.384
TTP2- In function problems, I can use dynamic graphics to show students the changing process of functions.	3.4	1.564
TTP3- I can use PPT, WORD, Geometric Sketchpad and other design teaching to enable students to experience the thinking process from concrete to abstract.	4.8	1.30
TTP4- I can use technology to design mathematical problems, and students can exercise divergent thinking from them.	3.9	1.24
TTP5- I can use technology to integrate the knowledge of mathematics history into teaching effectively, and arouse students' interest in learning mathematics.	4.5	1.78

Tables 2
TPCK Mode Analysis

TPCK mode analysis	Average value	Standard deviation
TPCK1- I grasped the core content of mathematics knowledge and imparted it to students.	5.58	0.996
TPCK2- I can integrate mathematical thinking into teaching and improve students' mathematical thinking ability.	6	0.74
TPCK3- I can guide students to improve their mathematical thinking ability in the process of learning mathematics.	4.0	0.76
TPCK4- I can refine the mathematical thinking of mathematics content and impart it to students, so that students can learn to think about mathematical problems.	5.1	0.9
TPCK5- I can impart mathematics contents to students, and students can use the methods they teach to solve mathematical problems.	6.3	0.76

The T-TPACK model describes the relationship between mathematics teachers and students in the teaching and learning of mathematics thinking. The mathematics teacher's TPACK knowledge structure is the foundation, because the mathematics teachers must transfer the mathematics ideas in the subject content to the students, and students should internalize them into their own mathematical ideas, and then improve their mathematical thinking. From the above data analysis, we give analysis from the aspect of the TPACK structure of teachers, besides this aspect, we could still analyze the three integrated elements of the mathematics teacher's TPACK structure and mathematical idea teaching in the T-TPACK model. The three elements are TTP (technological teaching pedagogy), TPCK (technological pedagogical content knowledge), and TTCK (technological teaching content knowledge). For mathematical teachers' understanding of these three elements and related factors analysis, and explanation of the relationship between the three, we also use questionnaires for testing, the specific questionnaire and data is shown in the Table 1, Table 2 and Table 3.

Tables 3
TTCK Mode Analysis

TTCK mode analysis	Average value	Standard deviation
TTCK1- I integrate students' mathematical thinking through discipline knowledge and information technology integration.	4.0	0.72
TTCK2- I think the integration of information technology and subject contents can effectively improve students' mathematical thinking.	6.0	0.66
TTCK3- I don't think subject knowledge and information technology exist in isolation. The ultimate goal is to improve students' mathematical thinking.	4.5	0.78
TTCK3- I think the integration of mathematical knowledge and information technology can abstract mathematics into concrete and then concrete to abstract. It is easier for students to accept mathematical knowledge and methods of thinking.	7.0	0.96
TTCK4- I think mathematics teaching teaches not only knowledge, but also the way of thinking. Under the integration of information technology, students are more able to experience a variety of image representations, and it is easier to establish their own mathematical thinking mode.	4.5	0.82

The analysis of the above data is given here:

TTP (technological teaching pedagogy): it can be seen from the table that the average value of the five options is lower than 5 (above 5 is excellent), indicating that the mathematics teacher is not very skilled in the technology, and he/she is not very confident in applying technology in teaching, but only considers the technology as a tool for teaching, and it cannot promote the students' mathematical thinking. It is further found that the teaching methods and teaching tools of most mathematics teachers are stuck in the traditional teaching methods such as blackboard and chalk. On the one hand, it's related to the hardware facilities of the school, on the other hand, it's related to the teachers' views on the status of technology in teaching. TPCK (technological pedagogical content knowledge): five questions, four of which have an average value higher than 5.0, and the starting point of these four questions is that whether teachers can impart mathematics ideas to the students. Teachers have a higher degree of this tendency, and they all think that their teaching can better improve students' mathematical thinking, but one item of whether they can guide the formation of students' mathematical thinking has an average lower than 5.0, indicating teachers are not confident enough in how to make students become the main body and actively form their own thinking mode. Although it is considered that their own teaching design can enhance students' mathematical thinking, it makes students accept passively rather than let them actively explore and form their mathematical thinking independently. TTCK (technological teaching content knowledge): as can be seen from the table, teachers have a positive opinion on the mode of information integration and subject knowledge. But in the test of their own teaching practice to achieve this goal, the scores are all lower than 5.0, indicating that the view of the integrated subject knowledge of technology merely stays in understanding rather than acting, so teachers are skeptical about the integration of technology into subject knowledge and thus affecting students' thinking.

In summary, in the T-TPACK mode, the mathematics teachers' TPACK knowledge structure is the foundation, and the mathematics teachers' confidence in technology is not fully reflected, and they only take the technology as a tool in the teaching, this indicates that under the current teaching situation, T is missing in most mathematics teachers' TPACK knowledge. Although in the curriculum standards, it emphasizes the use of information technology to integrate with teaching, in practice, this goal can hardly be achieved. In the follow-up test, we will explain to teachers the basic idea of this teaching model, allowing teachers to use the technologies to actively integrate with the subject knowledge, and adopt comparative experiments to analyze students' thinking levels before and after the test, we will also analyze the changes in students' thinking mode under the technology-integrated teaching mode designed carefully by the teachers.

Table 4
Comparative Analysis of the Teacher's TPACK Knowledge Structure

option	Average (front)	Standard deviation (front)	Mean value (rear side)	Standard deviation (rear side)
technical knowledge	5.22	1.36	5.935	0.66308
TK1- I have the technical knowledge of using computers effectively.	5.64	1.02	6.12	0.99
TK2- I can master technical knowledge very easily.	5.68	1.08	6.34	0.86
TK3- When I use computers, I know how to deal with technical problems.	5.02	1.30	5.98	1.2
TK4- I always updates my computer knowledge.	4.28	1.73	4.67	0.78
TK5- I can build new learning pages or websites.	5.31	1.55	6.2	0.997
TK6- I can use social information media.	5.41	1.48	6.3	0.78
Integrating pedagogy knowledge of Technology	5.09	1.03	6.114	0.6878
TPK1-I can use information technology to show real scenes to students.	5.28	1.20	6.8	1.23
TPK2- I can make it easier for my students to use information technology to discover more knowledge.	5.38	1.06	6.24	1.02
TPK3- I can make it easier for students to use information technology to plan and practice their plans.	4.87	1.28	5.23	1.15
TPK4- I can enable students to use information technology to effectively establish different forms of knowledge.	4.94	1.30	5.6	0.89
TPK5- I can make it easier for students to collaborate with different information technologies.	4.96	1.31	6.7	1.03
Integration of technical knowledge	5.07	1.32	6.47	0.395
TCK1- I can use software to make teaching content different.	5.08	1.37	6.12	0.79
TCK2- I can use technology to explore what I have taught.	4.99	1.31	6.9	0.86
TCK3- I am able to present subjects in various technologies.	5.13	1.30	6.4	0.84
Knowledge of discipline in integrating technology	5.17	1.18	5.82	0.5692
TPACK1- My teaching can connect technology, knowledge and teaching methods.	5.25	1.16	6.0	1.21

Relationship analysis of each component element in mathematics teacher T-TPACK model

After tracking and observing for one semester, once again we conduct a second test on teachers who had participated in the previous test, and the same questionnaire observation is adopted. This kind of test mainly observes the teachers' TPACK knowledge structure changes after the teaching practice when they have experienced the learning of technologies and used the technology to integrate with knowledge to design the teaching plan. Through comparative analysis of whether the teacher's TPACK knowledge structure has changed, and whether there has been a more fundamental change in applying technology into teaching, we mainly take the TK, TPK and TPACK to compare teachers' knowledge structure changes under T-TPACK mode in Table 4.

It can be seen from the figure that the change in the teacher's TPACK knowledge structure is quite obvious. Basically, the average of all elements shows an upward trend, indicating that under the T-TPACK mode, teachers' approval for technologies can be considered as an integral part of teaching to combine with the knowledge content. However, there are also a few of terms that grew not so obvious, such as whether a teacher will help other teachers to design the teaching process together, indicating that there are few teachers using technologies to explore with other teachers. In addition, teachers still have a low average in whether they will learn the most updated computer knowledge in time, indicating that teachers are still uncertain about the active learning of computer knowledge, and there's no fundamental change in their confidence of applying technologies into teaching.

Through the teaching cases designed by teachers and the performance of the students in the classroom, and their reaction of the exercises after the class, we interviewed the students to understand their specific views on this teaching mode and their fundamental views on their own mathematical thinking. The main changes are concentrated in these aspects:

First: the improvement of intuitive thinking. Intuitive thinking is generally considered to be a kind of thinking that gives quick responds to things according to one's own experience and intuition. Although intuitive thinking can't get the essential answer to the problem, the improvement of intuitive thinking can help students improve their sensitivity to mathematics. That is, they can quickly select the correct answer when encountering similar mathematical problems, or they can guess the approximate intention of the topic.

Second: visualized thinking uses computer to demonstrate complex mathematical symbols and mathematical problems, or it can represent a kind of dynamic graphs to help students build up their visualized thinking during their early mathematics studies, and it's quite beneficial. After experiencing the T-TPACK model, students can use computers to help themselves think about math problems. At the same time, they can design models to understand mathematics. Most students say that their understanding of mathematics is no longer abstract under this teaching mode, and mathematics can be represented by interesting graphics or can be shown directly in function curves in the first place.

Regression analysis

Questionnaire reliability test

After Cronbach's α reliability test, the α values of TK, PK, CK, PCK, TPK, TCK, and TPACK are 0.819, 0.751, 0.646, 0.753, 0.747, 0.784, and 0.859, respectively. Except CK, the α values of all variables have exceeded 0.7, and the α value of CK is 0.646, which is close to 0.7. Therefore, the scale has good internal consistency and can be statistically analyzed.

Related analysis

The basic situation of the samples is, the proportion of male and female teachers are 51.7% and 48.3%, respectively; for undergraduate education background, the proportion of pedagogical students and non-pedagogical students are 44.2% and 55.8%, respectively; the proportion of teachers with titles of assistant lecturer, lecturer, associate professor and professor are 14.1%, 34.6%, 34.2% and 17.1%, respectively. The average values of teachers in each knowledge dimension of TK, PK, CK, PCK, TPK, TCK and TPACK are 3.56, 3.96, 3.85, 3.91, 3.63, 3.67, and 3.72, respectively. From the average values, it can be found that the knowledge-related knowledge structures TK, TPK, and T are significantly lower.

Table 5
Correlation Analysis of Each Element of TPACK

		TK	PK	CK	PCK	TPK	TCK	TPACK
TK	Pearson	1						
	Sig.							
PK	Pearson	.242**	1					
	Sig.	.000						
CK	Pearson	.173**	.364**	1				
	Sig.	.004	.000					
PCK	Pearson	362**	.418**	.564**	1			
	Sig.	.000	.000	.000				
TPK	Pearson	.459**	.275**	.418**	.541**	1		
	Sig.	.000	.000	.000	.000			
TCK	Pearson	.515**	.010**	.203**	.385***	.441**	1	
	Sig.	.000	.000	.001	.000	.000		
TPACK	Pearson	.525**	.372 **	.276**	.508**	.634**	.617**	1
	Sig.	.000	.000	.000	.000	.000	.000	

Table 6
Correlation Analysis between TPACK and Teaching Age, Training and Other Elements

		Training frequency	Is it anormal student?	Teaching age
TK	Pearson	-.043	-.234**	-.160**
	Sig.	.479	.000	.008
PK	Pearson	-.078	-.250**	.284**
	Sig.	.195	.000	.000
CK	Pearson	.038	.134*	.249**
	Sig.	.533	.026	.000
PCK	Pearson	.172**	-.177**	.276**
	Sig.	.004	.003	.000
TPK	Pearson	-.004	-.204**	.177**
	Sig.	.952	.001	.003
TCK	Pearson	-.063	-.320**	-.036
	Sig.	.295	.000	.045
TPACK	Pearson	.095	-.364**	.163**
	Sig.	.117	.000	.007

Note. ** The correlation coefficient of the above two tables is significant at the 0.01 level (two-tailed)

The correlation between the elements of TPACK is shown in Table 5. The correlation analysis between the teacher's teaching age, the frequency of training, and the teacher's pedagogical education background (whether the undergraduate education is pedagogy or not) and the TPACK elements are shown in Table 6. The results show that there are significant correlations among the seven elements of TK, PK, CK, TPK, TCK, PCK and TPACK in the TPACK knowledge structure. There are correlations between the teaching age and each element of teacher's TPACK; there are correlations between whether the teacher's undergraduate education is pedagogy and each element of TPACK. See from the average values, for college teachers who had received pedagogical undergraduate education, except for CK knowledge, the rest knowledge elements are all higher than those of college teachers who had received non-pedagogical undergraduate education. For the training frequency, except for the PCK, it has no correlation with other knowledge elements.

Regression analysis

In this paper, multiple linear regression is used to test the model hypothesis. The final regression coefficients are shown in Table 7. In the TPACK regression equation, TK, PK, TPK, TCK, and CK are substituted into the regression equation.

Table 7
Regression Coefficients

		Nonstandardized regression coefficient: B	Nonstandardized regression coefficient: standard error	Standardized regression coefficient Beta	Saliency
PCK	constant	.821	.253		.001
	PK	.278	.058	.245	.000
	CK	.518	.056	.474	.000
TPK	constant	1.296	.305		.000
	TK	.397	.052	.417	.000
	PK	.233	.074	.172	.002
TCK	constant	1.677	.260		.000
	TK	.419	.044	.496	.000
	CK	.129	.061	.111	.035
TPACK	constant	.463	.211		.029
	TK	.074	.035	.102	.037
	PK	.219	.047	.207	.000
	CK	-.101	.049	.100	.039
	PCK	.097	.050	.104	.055
	TPK	.269	.039	.351	.000
	TCK	.318	.041	.369	.000

Conclusion

The TPACK knowledge structure of college teachers includes seven elements of TK, CK, PK, TCK, TPK, PCK, and TPACK, and there are correlations between these seven elements. TPACK is a complex knowledge framework, and the integration of TK with CK and PK involves many other factors, such as the teaching theme and the teaching methods of teachers reflected on their teaching experience. Especially the college teachers, most of them are in lack of pedagogical knowledge and psychological knowledge, and other factors such as the particularity of college teaching content, will affect the effective integration of TPACK's various knowledge elements. Develop context-based learning activities to enhance the TPACK knowledge structure of teachers. For the content of teacher training, the integration of information technology knowledge and teaching method knowledge should be popularized, technology-based learning activities should be developed, and technical knowledge should be transformed and integrated into subject content and teaching methods to promote students' understanding and learning of knowledge. At the same time, we should encourage teachers to recognize that the application of information technology knowledge can provide help for the teaching knowledge and content knowledge, so that they would willingly and actively seek the development and exploration of teaching mode. In the TPACK knowledge structure, the three knowledge bodies of TK, CK and PK are complex interactions. In order to effectively and purposefully integrate technology into teaching, for these three knowledge bodies, in addition to mastering theoretical and practical knowledge, teachers should also pay attention to the teaching situation. Teachers with good TPACK literacy must be able to integrate the teaching situation into their own PCK, TPK, and TCK. In the subject content knowledge, the knowledge imparted to students by teachers is lack of leading-edge knowledge or interdisciplinary knowledge. College teachers themselves are very concerned about the interdisciplinary subject content knowledge, its application and whether the subject content is leading edge.

However, in the actual teaching process, there is a breakpoint in the PCK of the teacher's knowledge structure. Besides basic knowledge of the subject, teachers haven’t cited or interspersed enough knowledge of other fields during their teaching process, their emphasis on the integration of scientific research results and teaching content is much less than on other knowledges. The application of subject knowledge imparted in the classroom is far from sufficient and these knowledges are not edge-cutting. Teacher collaboration teams can be formed to explore how to transform new-beginner teachers to expert teachers. Developing a development path from new-beginner teachers to expert teachers is a critical part of improving the TPACK knowledge structure of teachers. It can help new-beginner teachers effectively play their functions in their future careers, reducing their frustration in teaching. This study believes that colleges and universities should form teacher collaboration teams to strengthen the teaching of technical content knowledge. Expert teachers and new-beginner teachers can form collaboration teams by analyzing specific teaching problems together, sharing teaching resources together, and observing and discussing on-the-spot teaching together, so as to further promote teachers’ self-examination and construct an effective application mode for TPACK knowledge structure.

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