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Research on Design Thinking and TPACK of Physical Education Pre-service Teachers

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Abstract: The main purpose of this study was to explore Chinese Physical Education Pre-service Teacher (PEPT) design thinking and the relationships between Technological Pedagogical Content Knowledge (TPACK). Two questionnaires were used to gather data from 316 pre-service teachers. Using the structural equation model, assess the validity and reliability of the two questionnaires. Then through path analysis, understand the prediction situation of design thinking and TPACK. The findings indicate that the instrument possesses good construct, discriminant and convergence validity, and reliabilities are all applying to PEPT. The design thinking questionnaire of all of the factors was significantly and positively correlated to the TPACK. The path analysis shows that divergent thinking of design thinking can predict TCK, TPK, and TPCK. It is worth noting that convergent thinking of design thinking also can predict TCK. The implications of this study suggest that design thinking maybe promote PEPT to ideate TPACK from the perspective of empathizing, and experiment with technological knowledge in the material.

Keywords: Design Thinking, TPACK, Physical Education, Pre-service Teachers

1. Introduction

With the rapid development of technology applications, it has become a basic quality that teachers teaching should use now. Facing the new opportunities and impacts brought by information technology and the internet to education, teachers in the 21st century should not only possess Content Knowledge (CK) and Pedagogy Knowledge (PK) but also could apply Technological Knowledge (TK) to enhance students' learning effectiveness. In order to help teachers effectively combine the CK, PK, and TK in the teaching process, and solve the complex teaching activities that may be faced with, Mishra and Koehler (2006) further proposed Technological Pedagogical and Content Knowledge (TPACK) based on pedagogic content knowledge.

The practical application of the integration of technology into physical education has been quite common. Compared with other disciplines, physical activity has the peculiarities of physical activity, and the nature of its teaching methods is quite different from other disciplines (Phillips, Rodenbeck, & Clegg, 2014). Therefore, technology-assisted physical education not only breaks the barriers of traditional physical education classrooms, but also extends the infinite horizon and space of physical education teaching, helping learners improve their learning motivation, and promote learners' learning effectiveness (Pasco, 2013). There are more diverse learners nowadays, so teachers should use technology to improve their teaching effectiveness for diverse learners (Arslan, 2015; Cengiz, 2015). Physical education teachers learn how to integrate technological knowledge into the teaching and make the TPACK knowledge support the physical education will be more important. The integration of material from the three knowledge components is mostly the responsibility of pre-service teachers. It is rarely explicitly addressed how to deal with pre-service teachers' situations about the skill and its structure, as well as how to employ creative ideas to encourage learning of the specific topic (Krause, O'Neil, & Jones, 2020). Pre-service and in-service physical education teachers, on the other hand, have been noted as being underprepared with the aforementioned technology (Kretschmann, 2015).

According to research, PEPTs' perspectives regarding technology and how they will utilize it in future classes are influenced by technology-rich field experiences and call for an integration of

knowledge facets within teacher education (Baek, Jones, Bulger, & Taliaferro, 2018). Stanford (2010) proposed a five-step conceptual framework for the design thinking process, which contains empathize, define, ideate, prototype, and test. This framework is commonly used to help teachers improve their design thinking skills in a variety of educational settings (Henriksen, Richardson, & Mehta, 2017) In particular, teachers' design beliefs have been discovered as a multidimensional concept related to TPACK in teachers, and teachers' design beliefs may predict TPACK in teachers (Chai & Koh, 2017). Given this, the purpose of this study is to explore the relationship between design thinking and TPACK.

1.1 Design Thinking of Physical Education Pre-service Teachers (PEPT)

Despite the fast development of education reform trends and technology abroad. The current Physical Education Teacher Education (PETE) teaching practice method urgently needs to be updated, for future teachers to guide students as the main body of learning and the purpose of developing literacy in the physical education curriculum, teaching, and assessment (Starck, Richards, & O'Neil, 2018). Therefore, the PEPT should try to modify the teaching content, to conform to the degree and ability of each student, to highlight the importance of "user (student)" (Armstrong & Johnson, 2019). Design thinking is a human-centered design approach that takes into account people's needs, behaviors, and the practicality of technology or business (Brown, 2008). This framework is commonly used to help students improve their design thinking skills in a variety of educational settings (Henriksen et al., 2017). To back up this claim, Goldman et al. (2012) claimed that design thinking is a constructive learning style that encourages students to investigate and solve problems while also encouraging them to be more open to new ideas, creative, and innovative. For PEPT, students are their users, it can be seen that design thinking can encourage pre-service teachers to think in terms of users, and constantly operate and update their own experience.

The design thinking method provides physical education teachers an option of how to approach the curriculum, pedagogy, and assessment to understand the fundamental teaching principles (Chambers, Aldous, & Bryant, 2020). PETE also recognizes that problems are often chaotic and complicated, necessitating serious and imaginative creative thinking to solve them, as demonstrated by the design thinking process (Armstrong & Johnson, 2019). PEPT's teaching practice can be closer to the scene, construct a good teaching foundation. Even that, it also can update the teaching practice method of PETE, and cultivate the professional qualities of pre-service teachers, by revising and experimenting with the steps and concepts of design thinking.

1.2 TPACK of Physical Education

Gawrisch et al. (2019) propose a four-phase approach to establishing TPACK in physical education teacher education that allows PEPT to deliver technology-integrated lessons and experiences. The research emphasizes the need to improve teachers' use of innovative methods to value and build up TK. In addition, it needs to be implemented through experiments to evaluate its effectiveness, so that PEPT can be confident in using it in future teaching. PEPT assessed their capacity to use technology during instruction as high due to their exposure to TPACK (Jones, Baek, & Wyant, 2017). Increased adoption of technology-specific professional development is critical for overcoming the challenges connected with the use of technology in physical education. PEPT, in particular, are expected to exhibit excellent practices in technology-infused education (O'Neil & Krause, 2019). Overall, the more familiar and consistent TPACK integration is in teacher education, the more likely PEPT will adopt technology into their teaching efforts. However, physical education is a subject in which tradition has a stronghold. Various educational reforms and new curricula do not seem to have had little influence, content, forms of assessment and teaching stay the same (Ekberg, 2016). To conform to the educational trend of the twenty-first century, it is required to find a new strategy to try to reverse this tradition.

However, there have been some criticisms of the TPACK framework since it is complex and may not be useful to teachers in their day-to-day work (Dobozy & Campbell, 2016). Furthermore, Angeli, Valanides, and Christodoulou (2016) argue that the integrated method will not result in meaningful TPACK. The scholars advocate for the transformative approach, which encourages teachers to synthesize isolated PK, CK, and TK into new teaching and learning approaches (Angeli & Valnides, 2009). Thus, significant assistance is required to challenge teachers' preconceptions about what constitutes effective technology integration and to assist them in transforming isolated information.

Chai, Hwee Ling Koh, & Teo (2019) also confirmed that if pre-service teachers have good design beliefs, they will have a positive prediction and development of their TPACK. Base on the previous discussion, the purpose of this study was to explore Chinese PEPT's design thinking and their relationships with TPACK, and the questions are following:

- What is the validity of the questionnaires for measuring the two constructs?
- What are the relationships between PEPTs' design thinking and their TPACK?

2. Method

2.1 Participants

The participants in this study were 316 physical education pre-service teachers from selected universities in China. There were 221 males and 95 female pre-service teachers. These pre-service teachers included sophomores to senior students. However, in the department of physical education and sport sciences, males are typically slightly more than females. All participants were asked to answer to the two instruments used in this study.

2.2 Instrument

In this study, two questionnaires, including Design thinking and TPACK were used. The two questionnaires were filled out at the same time and both with bipolar strongly agree/strongly disagree choices were provided on a 5-point Likert scale. First, the TPACK questionnaire was a consultation to Liang, Chai, Koh, Yang, and Tsai (2013)'s questionnaire that focuses on the TPACK framework to understand in-service teachers' perceptions of their TPACK competencies (α = .96, total explained variation = 72.6%) Second, the design thinking questionnaire was designed based on Chen, Hong, Chai, Liang, & Lin (2020) design thinking engagement framework to understand early childhood teachers' perceptions of their design thinking (α = .97, total explained variation = 70.0%). To assess PEPTs' design thinking dispositions in physical education teaching, the current study designed the design thinking questionnaire based on the design thinking process of Chen et al. (2020) and Stanford (2010): empathize, define, ideate, prototype, and test. According to Council (2021) re-explain the concept of design thinking, emphasizing "The Double Diamond Design Process". In comparison to traditional design thinking, the double diamond design process places a greater emphasis on divergent and convergent thinking in the design process to improve design thinking. Design thinking frequently skips over the problem-solving stage and overlooks other better options. As a result, it is as such to empathize and ideate from the perspective of divergent thinking. Define, prototype and test are all elements of convergent thinking. As a result, this study elevates design thinking to a second-order level, with more emphasizing the process and framework of design thinking.

2.3 Data Analyses

In this study, the Confirmatory Factor Analysis (CFA) with all of the items and dimensions of the two questionnaires included in one model was performed to clarify the reliability and validity of all of the questionnaires. Moreover, to further understand the relationships among the dimensions of these two questionnaires, correlation analysis, and SEM were performed.

3. Result

3.1 Verification of the Validity of the Two Questionnaires

A total of 29 items were retained in the version (i.e. 18 items for design thinking, and 11 items for TPACK) as shown in Table 1. It shows the results of the confirmatory factor analysis for the two questionnaires in one model as well as the descriptive statistics for each variable. The goodness of fit for the CFA of the structure, Chi-square = 1434.24, $p < .001$, degree of freedom = 366, GFI = .82, IFI

= .90, TLI = .89, CFI = .91, RMSEA = .054, RMR = .062, Factor loadings = .67-.86, CR = .84-.92, AVE = .51-.69, and Alpha value = .87-.91. Hair Jr, Hult, Ringle, and Sarstedt (2016) indicated that the model construct can be considered acceptable if all the CR values are higher than .6 and the AVE for each factor is higher than .40. The fit scale indicated a satisfactory fit for this model since these indices were approaching the criterion of a good fit, confirming both the convergent and construct validity of this single model for the two questionnaires.

Table 1. *The CFA analysis for the Design Thinking and TPACK (N= 316)*

Construct and measurement items	Factor loadings	*t*-value	CR	AVE	Alpha value
Design Thinking					
Empathize, mean = 4.21, S.D. = .59	-------	-------	0.90	0.69	0.90
Empathize1	0.79	-------			
Empathize2	0.86	16.58***			
Empathize3	0.85	16.37***			
Empathize4	0.83	15.96***			
Define, mean = 4.14, S.D. = .55	-------	-------	0.88	0.64	0.87
Define1	0.83	-------			
Define2	0.76	16.48***			
Define3	0.83	16.36***			
Define4	0.77	16.49***			
Ideate, mean = 4.16, S.D. = .57	-------	-------	0.90	0.69	0.90
Ideate1	0.79	-------			
Ideate2	0.84	15.33***			
Ideate3	0.84	17.39***			
Ideate4	0.85	15.66***			
Prototype, mean = 4.13 S.D. = .56	-------	-------	0.91	0.71	0.89
Prototype1	0.86	-------			
Prototype2	0.79	16.33***			
Prototype3	0.85	14.83***			
Prototype4	0.77	16.44***			
Test, mean = 4.19, S.D. = .58	-------	-------	0.91	0.71	0.90
Test1	0.81	-------			
Test2	0.86	18.16***			
Test3	0.85	17.77***			
Test4	0.84	17.44***			
TPACK					
TCK, mean =4.08, S.D. = .55	-------	-------	0.84	0.51	0.88
TCK1	0.67	-------			
TCK2	0.69	15.07***			
TCK3	0.76	13.17***			
TCK4	0.74	13.03***			
TCK5	0.71				

Construct and measurement items	Factor loadings	*t*-value	CR	AVE	Alpha value
TPK, mean =3.98, S.D. = .65	-------	-------	0.92	0.70	0.91
TPK1	0.83	-------			
TPK2	0.83	15.07***			
TPK3	0.86				
TPK4	0.84				
TPK5	0.81				
TPCK, mean =3.94, S.D. = .60	-------	-------	0.91	0.66	0.90
TPCK1	0.78	-------			
TPCK2	0.80				
TPCK3	0.85				
TPCK4	0.80				
TPCK5	0.82				

Note: Asterisk is for the probability note, and three asterisks indicate $p < .001$. AVE: average variance extracted, CR: composite reliability

3.2 Correlation between Design Thinking and TPACK

As shown in Table 2, the findings of the correlation study revealed that all of the design thinking factors were significantly positively correlated with all of the TPACK's factors. To be more specific, that all five factors in the design thinking questionnaire (empathize, define, ideate, prototype, and test) were equally, in the same way, and significantly associated with all three factors in the TPACK questionnaire (TCK, TPK, and TPACK) (r =.59-.74, $p < .001$).

In the other hand, the statistical results also showed that all of the factors of the design thinking were highly and significantly correlated to each other (r =.72–.83, $p < .001$). The Pearson's correlation findings showed that all of the factors were associated to some extent between or within both questionnaires. This also echoes that every stage of design thinking is related to practice. Table 2 includes the square root of the AVE value as well as the correlation matrix for each factor. The results showed that the square root of the AVE values for all variables was greater than the Pearson's correlation coefficients between the factor and all other factors (r =.82-.93). Moreover, the discriminative validity proved that each dimension existed individually and independently (Hair et al., 2016).

Table 2. The correlation between Design Thinking and TPACK

	Empathize	Define	Ideate	Prototype	Test	TCK	TPK	TPCK
Empathize	.83	.76***						
Define		.93						
Ideate	.72***	.77***	.83					
Prototype	.74***	.82***	.80***	.84				
Test	.75***	.81***	.76***	.83***	.85			
TCK	.71***	.75***	.72***	.74***	.71***	.71		
TPK	.59***	.63***	.64***	.64***	.60***	.69***	.84	
TPCK	.61***	.67***	.67***	.65***	.64***	.59***	.82***	.82

Note: The value of the diagonal line is the square root of the average variation extraction (AVE) of the potential variable, and this value should be greater than the value of the off-diagonal line. *p<.05, **p<.01, ***p<.001

3.3 Path Analyses

To validate whether the proposed model could be established, we examined whether the first-order factors converged to the second-order constructs. The results show that the fit indices of the second-order model indicated that our hypothesized model adequately explained the data (GFI = .85, IFI = .90, TLI = .91, CFI = .92, RMSEA = .048). According to the results of Figure 1, the two factors of divergent thinking were successfully included in one second-order factor. The three factors of convergent thinking were also successfully included in one second-order factor. The SEM result showed that divergent thinking significantly positive factor explaining the variation of TCK, TPK, and TPCK (β = .89, 94, 90 p < .001). The results imply that pre-service teachers would be able to get a better TCK, TPK, and TPACK in the future if they have divergent thinking. In other words, when teachers consider how technology can be used in teaching or courses, they can effectively impact teachers' TPACK through a process of human-centered and creative thinking. In addition, although the results show that convergent thinking cannot predict TPK and TPCK, it can be seen more importantly from the figure that convergent thinking can directly predict TCK (β= .30, p < .001). Convergent thinking may be effective promote pre-service teachers to use technological knowledge to prepare physical education courses and teaching materials. What's more, convergent thinking is the final stage of implementing ideas into action, as well as a period of repeated content knowledge experimentation.

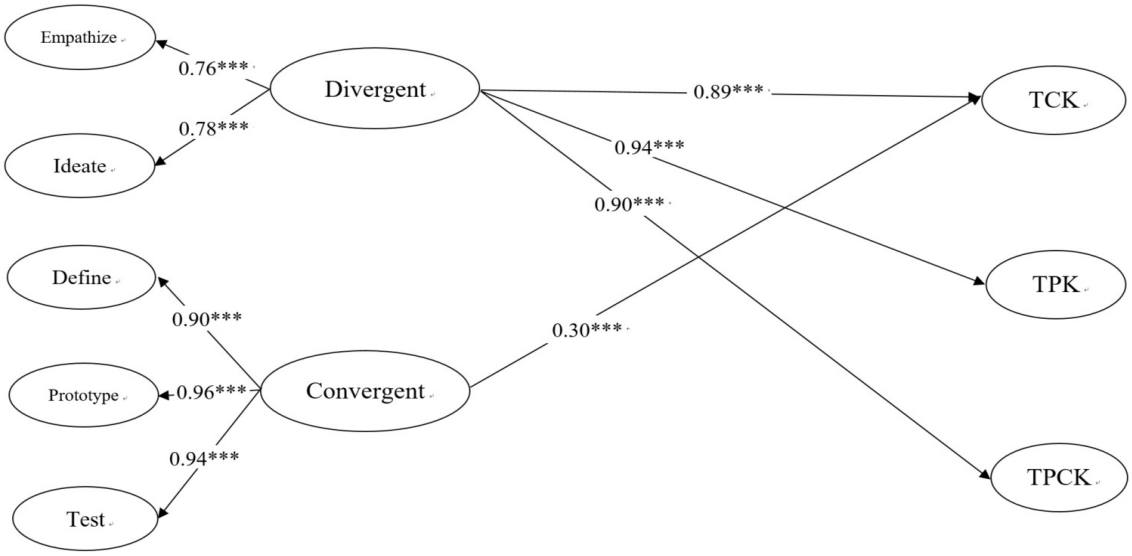

Figure 1. The structural model between Design Thinking and TPACK.

4. Discussion

According to the results of the research question, divergent thinking and TPACK can have predictive effects. Bryant, Aldous, and Chambers (2020) show how the hierarchical phases of design thinking can be used when enacting curricula, pedagogy, and assessment practices for movement in physical education, and how the design thinking process can function as a means of sensitizing practitioners. In other words, the pre-service teacher can empathize and ideate to finding appropriate instructional methods to change issues or activities in the classroom (Armstrong & Johnson, 2019). PEPT is difficult to integrate TPACK into physical education since it impacts how teachers see physical activities (Phelps, et al., 2021). Since traditional physical education teaching still places the teacher at the center, many students' perspectives and opinions are overlooked. Design thinking hopes to encourage physical educators to start "thinking like designers" while planning and implementing meaningful movement experiences for students to improve teaching effectiveness. Based on this, PEPT may be able to effectively affect PEPT if it can create appropriate teaching materials through empathy and a lot of brainstorming, as well as combining technology and physical equipment. Krause et al. (2020) also showed that PEPT really needs a way to promote or transfer knowledge to apply technology in physical education. They also encourage PETE to develop an appropriate approach as soon as possible.

In addition, through the results of the SEM model, it's clear to see that convergent thinking and TCK can have predictive effects. The skill of TCK is a challenge for pre-service teachers who have not yet joined the teaching scene because they have not yet contacted students and lack a lot of practical experience (Baek et al., 2018). Based on this, PEPT often creates immature course material, a situation that is similar to a previous study (Wyant, Jones, & Bulger, 2015). Henriksen et al. (2017) the teachers did not consider themselves curriculum designers at the start of the course. But it was through exposure to and familiarity with design thinking techniques that they came to see themselves in this light (Norton & Hathaway, 2015). Therefore, it also demonstrates that design thinking can assist teachers in effectively mastering certain fundamental design principles and concepts while designing or organizing courses. Past studies have also shown that PETE does not have many ways to support TCK (Semiz, & Ince, 2012). This also involves sports including multiple types, and it is difficult for teachers to master all of them, especially for pre-service teachers. As a result, convergent think can improve PEPT in collecting together and integrating information to improve the relationship between teaching materials, courses, and technology. That is, physical educators must be more than knowledge brokers; they should also be learning builders (Armstrong & Johnson, 2019). Phelps et al. (2021) emphasized that PETE will revise the material because it finds that it has insufficient basic knowledge in technology-assisted teaching. To put it another way, this is a major step in opening PETE's practical scientific and technological knowledge, allowing him to put TPACK into effect through repeated experiments.

Through this study can determine the relationship between PEPT design thinking perceptions and their potential level of TPACK. The results of the second-order model suggest that divergent thinking can have a significant impact on TPACK. For example, to integrate technology, teaching elements related to the course can be accomplished through empathy and problem-solving. Furthermore, the findings suggest that convergent thinking can predict TCK. In other words, it shows that inexperienced pre-service teachers can enhance their teaching efficacy by experimenting with teaching materials and developing ideas continuously. However, in the face of the impact of the current Covid-19 epidemic on global school education, the application of technology has become the main way to sustain learning, and technology for physical education is the solution that physical education teachers urgently need. The future study is suggested to increase the number of samples so that the relationships between design thinking and TPACK can be clearer and representative. Finally, further study can assess the difference between design thinking and TPACK between in-service and pre-service teachers.

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