Development TPACK-Based Online Mathematic Instructional Design Model: A Meta-Synthesis Approach

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ABSTRACT
The Covid-19 pandemic has resulted in the transition from face-to-face to online-based learning, which will certainly be an alternative in the future. To integrate technology for online learning, pedagogy, technology, and content knowledge are required, including TPACK. There are various TPACK development models, namely ISD, TPACK-COIR, TPACK-COPR, and TPACK-IDDIRR. These models focus on technology integration without considering other factors such as online learning conditions, motivation, and self-efficacy, necessitating further studies. Therefore, this study uses a meta-synthesis method with a qualitative approach to synthesize the TPACK model. A total of 235 articles related to TPACK development and 32 related to motivation and self-efficacy were reviewed. The model refers to Teacher Professional Development with a focus on increasing knowledge, self-efficacy, and motivation using the microteaching learning design (MLS) approach. The TPACK online mathematic instructional design model is developed iteratively through five stages, namely introducing, exemplifying, collaborating, implementing, and reinforcing.

Keywords: *TPACK, Id Model, Mathematics, Online Learning, Meta-synthesis*

1. INTRODUCTION

Globalization has had a significant impact on all sectors of life, especially education ([1], [2], [3], [4], [5]). With the advent of technology, it has become an essential component of the learning process ([6], [7]). Education was already on a trajectory toward digitalization, and this trend was expected to continue even before the COVID-19 outbreak. However, the pandemic has accelerated the pace of these developments ([8], [4]). As a result, education systems around the world have rapidly adapted to online learning platforms and incorporated technology into their teaching methods.

Due to the Covid-19 pandemic, online learning was initially introduced as a necessity, but many students were not entirely comfortable with this mode of learning ([9], [10], [11]). Online learning has negative effects on learning motivation ([12]), students' isolation ([13], [14]), and academic performance ([15]). It is defined as experiences using various devices with internet support in synchronous or asynchronous approaches ([16]). Online learning cannot be compared with conventional methods and must be considered within the context of the sophistication of the underlying technology. One example of a suitable technology for learning is

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computers, which can be used to present information by utilizing various software.

The effective and efficient use of technology in the mathematics learning process is closely related to the teacher-teaching factor. Mathematics is an abstract science that can be challenging for students, and this difficulty can lead to a loss of enthusiasm, which presents a unique challenge in learning through technology ([17], [18]). In conventional settings, teachers are typically the focal points of attention. However, when technology is used in the learning process, teachers often transition into the role of student mentors. Meanwhile, students who were originally passive recipients of information must now become actively involved in the learning process ([17], [18]). Therefore, teachers must have extensive and technical knowledge of the technology being taught and used, as well as pedagogical abilities in technology-based classroom management ([19]).

In reality, many teachers have not fully utilized technology due to obtaining their bachelor's degree before advanced learning with technology was available ([20]). It is not surprising that teachers may lack preparation in using contemporary technology, which may impede the optimal utilization of available technological resources, especially in the context of online learning. Therefore, in online mathematics learning, teachers must possess pedagogy and technology skills in addition to mastering the mathematical material. These three required knowledge areas are included in the Technological Pedagogical and Content Knowledge (TPACK) framework ([20], [21], [22])

According to Sojanah et.al. there is a tendency to be at a low level related to the TPACK knowledge possessed by teachers [23]. This can not be separated from factors with low tendencies, such as teacher experience, training, facilities, infrastructure, self-efficacy, and motivation. TPACK exhibits a positive relationship with all of these factors. Therefore, it is undeniable that self-efficacy and motivation are integral components of TPACK, with self-efficacy being particularly emphasized by several studies ([24], [25], [26]). Inadequate TPACK knowledge may have a detrimental effect on technology-based learning, particularly in the realm of online learning. Aspiring teachers represents a rational demographic for developing their full potential related to TPACK. This cannot be separated from millennial students who are literate and have an explicit understanding of contemporary technology.

There are existing TPACK development models as quoted from Zhang & Tang, which can increase TPACK for both current and prospective teachers, namely TPACK-COIR [27], [28], TPACK-COPR[29] (Jang & Chen, 2010a), and TPACK-IDDIRR [30]. Although TPACK is not specifically mentioned, two additional ISD models are related to the technology integration model with learning ([30], [31]) Employing technology-based, online learning necessitates special handling compared to other forms of technology. It is inappropriate to equate PowerPoint technology with platforms like ZOOM, Google Meet, and Learning Management Systems (LMS) which are commonly used in online learning. Meanwhile, the developed models only focus on technology integration and do not include other factors such as motivation and self-efficacy [32]

Further studies are required to design a TPACK development model by taking into account other factors, such as self-efficacy and motivation, as associated with online learning, especially mathematics [33]. In designing this development model, it is adjusted to the basic principles of TPD (Teacher Professional Development) namely narrative, constructivist, contextualized, interactionist, and dynamics [34]. The main focus of TPD is to improve the personal domain, which involves knowledge and beliefs [34]. Therefore, this study aims to develop a TPACK-Based Online Mathematic Instructional Design Model for preservice teachers.

2. METHODS

This study adopted a meta-synthesis method aimed to exceed summaries and offer novel interpretations of the results. There are eight phases in this approach, namely (1) The first phase determines the main focus of the study. (2) The second phase focuses on finding samples, which were selected based on the criteria of 3 main topics, namely TPACK, motivation of prospective teachers, and self-efficacy, all of which must be qualitative. A meta-synthesis that includes instructional steps is conducted on the subject of the TPACK development model. Meanwhile, a search was carried out on motivation and self-efficacy using web elicitation related to questions with the keywords “motivation”, “self-efficacy”, “pre-service”, and “increase”, which were published internationally from 2012 to 2022 range. (3) In the third phase, articles that are incompatible with the study focus were released. (4) The fourth phase includes reading the results from a predetermined sample, which focuses on getting used to the content of the TPACK development model. (5) The fifth phase

includes finding the linkage of articles for each topic. (6) In the sixth phase, translation is carried out, which involves discussing the theoretical framework, elements, characteristics, similarities, and modifications relevant to each article sample in relation to the TPACK model. Meanwhile, in an attempt to increase the motivation and self-efficacy of prospective teachers, the steps taken will be identified. (7) The seventh phase includes the synthesis of the translation including the similarity of each article. (8) The eighth phase is showing the results of the analysis using the TPACK development model.

3. RESULTS

The results of the first phase focus on the topics of TPACK, self-efficacy, and motivation, while the second focused on sample discovery. The sample was selected based on 2 major criteria, namely TPACK and "Motivation and self-efficacy". The search for samples related to TPACK was carried out through web science and obtained 235 articles. Regarding the topic of the TPACK development model, a meta-synthesis with instructional steps was carried out. Meanwhile, a search on motivation and self-efficacy was conducted using web elicitation related to questions, with the keywords "motivation", "self-efficacy", "pre-service", and "increase", which were published internationally from 2012 to 2022. The top 32 answers published in the article were retrieved.

In the third phase, a selection was carried out by removing articles that were not reputable, and a total of 177 reputable articles were obtained. Meanwhile, the selection related to the topic of self-efficacy and motivation was sorted into 23 articles that were reputable with a Scopus index Q1 to Q3.

The fourth phase includes reading the results from a predetermined sample, which is focused on getting familiar with the content of the TPACK development model. After filtering through the literature on the topic, 49 articles related to the development of TPACK were identified. Furthermore, it was filtered again into 5 articles that have the topic of the TPACK development model with systematic instructional steps, namely ISD model 1 ([30]), ISD model 2 ([31]), TPACK-COPR ([29]), TPACK-COIR ([35]), and TPACK IDDIRR ([32]). Furthermore, related to the topic of self-efficacy and motivation, the articles were filtered, and 17 were obtained with the theme of self-efficacy and motivation related to technology. It was filtered again into 10 articles where from the 10 articles there were 8 were obtained from the Scopus Q1 index and 2 from Q2. The following is an overview of phases 1-5 related to the study conducted.

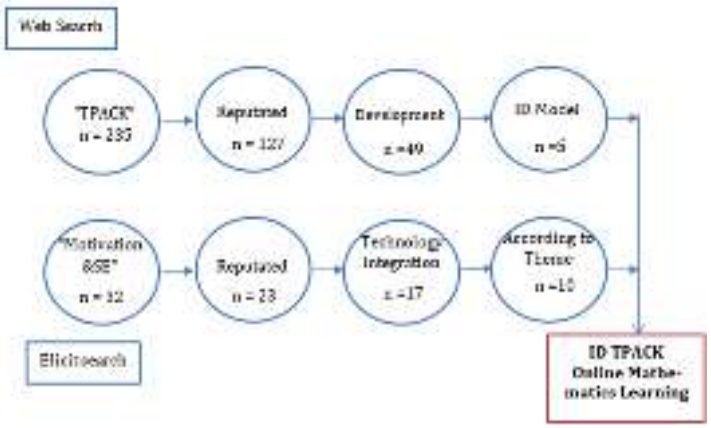

Figure 1. *Meta Syntesis Process*

The sixth phase includes translations related to the topic of the TPACK model including the theoretical framework, elements, features, similarities, and adjustments for each sample article. The translation was carried out regarding 5 articles that had a special instructional model, namely ISD model 1, ISD model 2, TPACK-COPR, TPACK-COIR, and TPACK IDDIRR.

It was found that the model initiated by Angeli focused on instructional design and PCK because the term TPACK had not yet appeared but was still related to the integration of technology. The steps contained in the Angeli model are topic identification and selection, content change, selection of appropriate technology tools, adjustment of representation to student characteristics, integration of technology in learning, performance assessment, reflection, and improvement. The key feature of this model is that it includes specific stages for technology integration instructions, in addition to demonstration stages for utilizing technology.

Meanwhile, the second model, developed by Angeli & Valanides, maintained its main focus on instructional design and PCK, as the term TPACK has not yet emerged, but has also discussed technology integration. This model has 4 steps, namely (1) the identification of topics with consideration of the environmental context, (2) changes in content including the background of learners, pedagogy, and technology, (3) implementation of lesson plans and assessment of student learning outcomes, and (4) reflection on teaching performance for later revision. The features contained in this model are developed by considering teacher beliefs and experiences, as well as contextual factors.

Regarding the model compiled by Jang & Chen, a special name has been given, namely TPACK-COPR which has the main focus of TPACK and collaboration. The steps contained in this model are Comprehension, Observation, Practice, and Reflection. Its main feature is that the development model starts from understanding the TPACK concept to building a knowledge base related to technology integration. The model compiled by Jang has

also been given a special name, which is TPACK-COIR. This model has a theoretical framework and discussion groups, and its steps are Comprehension, Observation, Instruction, and Reflection. The main feature of TPACK-COPR is that the model is developed using predefined instructional tools. The model compiled by Lee & Kim. was named TPACK IDDIRR and its steps include introducing, demonstrating, developing, reflecting, and revising. Its main feature is the use of a design approach with repeated steps according to the existing stages.

From the five models, there are 5 similarities that can be concluded, namely the existing model must present systematic instructional procedures, demonstrate examples of technology integration, integrate design-based learning activities, there are repeated steps in the model, and build new theories related to learning with technology. From these similarities, adjustments were made, namely the introduction of the TPACK concept at the beginning, paying attention to the repetition procedure, adjusting the learning experience, in this case online learning, and adding elements of self-efficacy and motivation. The description is illustrated in the table 1 below.

Meanwhile, related to articles on the topic of motivation and self-efficacy, there were 8 Scopus Q1 indexed articles and 2 Q2 articles, the following results were obtained in table 2.

From the table presentation, it can be concluded that increasing self-efficacy can be done by means of microteaching, field experience, course design and lesson plans. Meanwhile, related to motivation, it can be done using UTAUT theory by using modeling and mentoring, field experience, SNs (Social Network Site), and SQD (synthesis of qualitative evidence).

The seventh phase includes materials related to the development and analysis of the proposed model. The analysis of the developed model is based on the results of the synthesis that has been carried out, which is summarized in the following table.

Table 3 Synthesis Collection

Aspect	Model Design Considerations
Model Design	Introduction of the TPACK concept at the beginning, paying attention to the repetition procedure, adjusting the learning experience, in this case, online learning, and adding elements of self-efficacy and motivation
Self-efficacy	*Microteaching*, *field experience*, *course design* dan *lesson plans*
Motivation	*Modeling and mentoring*, *field experience*, SNs (*Social Network Sites*), dan SQD (*synthesis of qualitative evidence*)

Several aspects were taken into consideration, including model design, self-efficacy, and motivation. A step-by-step learning model was obtained which consisted of introducing, exampling, collaborating, implementing, and reinforcing. The first step includes an introduction to the TPACK concept related to its theoretical framework. The main focus of introducing TPACK is to select technology and methods, prepare and develop assessment criteria, design learning activities that utilize technology, and integrate technology, methods, and mathematical content. Meanwhile, the exampling stage is carried out by giving examples using SNs and asynchronous videos ([36]). This stage is consistent with the principles of modeling and mentoring according to the motivational aspect ([37]).

The collaborative step involves peer teaching through making lesson plans, and it is considered one of the methods associated with online learning experiences. Creating learning plans aligns with the self-efficacy aspect, particularly in the lesson planning section ([38]). Meanwhile, the implementation step involved microteaching, which is consistent with the online learning experience in accordance with the design aspects of the model ([39]). The use of the microteaching strategy is also consistent with the aspect of self-efficacy. To transform the design model into an iterative procedure, the last step that can be included is assessing and reflecting. Assessment takes the form of "peer assessment", specifically regarding the appearance of their microteaching partner. Reflecting, on the other hand, is made by prospective teachers after receiving an assessment from their peers. This reflection stage can make the development iterative because they can return to the collaborative step. Prospective teachers who have reflected on their appearance can become shared learners in the next microteaching. Furthermore, the TPACK development model consisting of introducing, exampling, collaborating, implementing, and reinforcing was then named TPACK IECIR.

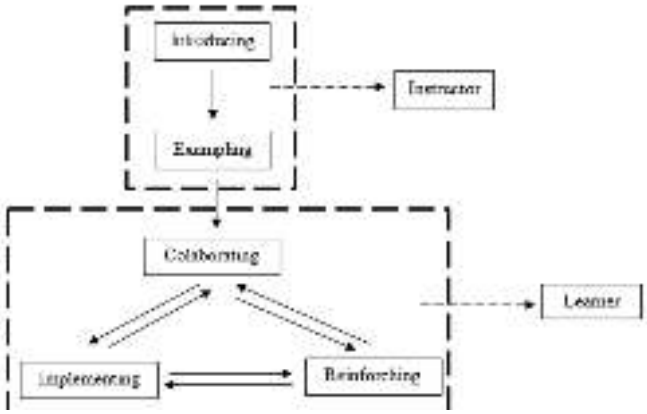

Figure 2. *TPACK IECIR*

Table 1 Synthesis Collection

No.	Description	TPACK Model's				
		ISD ([30]	**ISD** [31]	**TPACK-COPR** [29]	**TPACK-COIR** [28]	**TPACK IDDIRR** [32]
1	Theoretical framework	Instructional design, PCK	Instructional design, PCK	TPACK, pairs/ collaboration	TPACK, group discussion	TPACK, group lesson plans
2	Stages	1. Identify the topic 2. Choose a topic 3. Change the content 4. Choose the right technology tool 5. Adjusting the representation to the characteristics of students 6. Integrating technology into learning 7. Assessing student performance 8. Reflect 9. Repair	1. Identify the topic (with consideration of school context, previous class Experience, and personal beliefs) 2. Changing content (student background, pedagogy, and technology) 3. Implement lesson plans and assess student learning outcomes 4. Reflect on personal teaching performance to revise lesson plans	1. TPACK comprehen-sion (TPACK-C) 2. Observation of Instruction (TPACK-O) 3. The practice of Instruction (TPACK-P) 4. Reflection on TPACK (TPACK-R)	Comprehension (TPACK-C) Observation (TPACK-O) Instruction (TPACK-I) Reflection (TPACK-R)	Introduce (TPACK-I) Demonstrate (TPACK-D) Development (TPACK-D) Reflect (TPACK-R) Revise (TPACK-R)
3	Feature	1. There are special stages related to instructions from technology integration 2. There is a demonstration of the use of technology	Consider teacher beliefs, previous experience, and contextual factors	Understand the TPACK concept first to build a knowledge base related to technology integration	Use predefined instructional tools in the development	Using a by-design approach with repeated steps according to the existing stages
4	Similarity	1. Presenting systematic instructional product 2. Demonstrate examples of technology integration 3. Integration of design-based learning activities 4. There are repeated steps in the model 5. Building new theories related to learning with technology				
5	Adjustment	1. The importance of introducing the TPACK concept at the start 2. Adding elements of self-efficacy and motivation 3. It is important to add revisions for the loop to take effect 4. Adjustment of the learning experience, in this case online learning				

Table 2 Synthesis of Self-Efficacy dan Motivation

Theoretic Framework	[39]	[40]	[41]	[42]	[43]	[44]	[45]	[46]	[47]	[48]
Self Efficacy	√	√			√				√	√
Motivation			√			√				
TPACK								√	√	
UTAUT			√				√			
Technology Integration				√						
Micro-teaching	√									
Field Experience		√				√				
Modeling and Mentoring				√						
Course Design					√					√
SNSs							√			
SQD								√		
Lesson Plans									√	

4. DISCUSSION

TPACK IECIR has systematic steps, namely introducing, exampling, collaborating, implementing, and reinforcing. The first step, which is "introduction", is important to obtain a complete understanding. TPACK is not only a combination of PK, TK, and CK components but a complex integration between these 3 components. This result is consistent with the development model proposed by ([32]), suggesting that prospective teachers who have completed the stages have a better understanding of TPACK as the integration of PK, TK, and CK.

The second stage, which is exampling, is carried out using SNs and asynchronous video. SNs have great potential in terms of providing effective and easy interaction and communication during the e-learning process process ([36]). Meanwhile, asynchronous video is an efficient method to engage prospective and in-service teachers who use technology in intellectual conversations and expand communication ([37]).

The third stage involves collaboration using peer teaching techniques to design lesson plans. These techniques provide authentic teaching and experiential learning opportunities for prospective teachers to develop content in teaching objectives and to deliver TCK and TPK to their peers in a simulated environment ([48]). Meanwhile, lesson plans can provide an insightful picture of the use of technology by teachers in the classroom ([38]).

The fourth stage is implementing, which is carried out by microteaching. This technique can increase the knowledge of prospective teachers in choosing technology tools and compiling teaching materials ([49]). It can also be used as a step in developing TPACK for prospective teachers ([50]).

The last is reinforcing, which consists of two steps, namely assessing and reflecting. These steps are consistent with the study of increasing self-efficacy by Bandur ([39]). In order to increase self-efficacy, the verbal and social persuasion steps involve accepting critical and constructive peer feedback, which is reflected in the assessment step. On the other hand, the reflection step represents the physical and emotional arousal experienced by prospective teachers as they reflect on their microteaching and make corrections based on identified deficiencies. In addition, two steps to increase self-efficacy, namely Performance accomplishments and Vicarious experience, are represented by microteaching steps at the implementation stage. Performance accomplishments are represented by the experience of prospective teachers in doing microteaching. While vicarious experience is represented by peer observations regarding microteaching that has been carried out.

Motivation is represented during the sampling stage, which involves the teacher providing examples to inspire and motivate the prospective teachers. By providing an example, the teacher will become a role model, which in turn influences SI (Social Influencer). This SI will have a significant impact on PU (perceived usefulness). The perceived usefulness of the model is the most significant aspect that influences the motivation of prospective teachers to use technology ([51])

5. CONCLUSION

The TPACK development model for online mathematics learning for prospective teachers is included in the IECIR TPACK. The steps in this model include Introducing, Exampling, Collaborating, Implementing, and Reinforcing. In the introduction stage, the concept of TPACK is presented in relation to the theoretical framework. Meanwhile, in the exampling stage, samples were given using SNs and asynchronous video. For the collaborative stage, peer teaching is carried out by making lesson plans while implementation uses a microteaching strategy. Finally, at the reinforcing stage, peer assessment is carried out regarding the appearance of microteaching and reflection. The collaborative, implementing, and reinforcing stages are carried out iteratively. A test related to the model that has been developed can be conducted to see the results of the development and make revisions related to the designed model.

AUTHORS' CONTRIBUTIONS

The contributions of this article is to enrich publication about TPACK. There are several model to increase TPACK which researchers take to develop according to the desired conditions

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