

# Technological Pedagogical Content Knowledge (TPACK) with Information and Communication Technology (ICT) Integration:

## A Literature Review

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**Abstract**—This research aims to get an overview of knowledge of learning technology and to identify factors that influence the use of technology in learning. Seeing this condition, it is necessary to do critical analysis in depth from the papers reviewed by the use of Information and Communication Technology (ICT) carried out by the teacher, especially the ability in learning. The data from the paper were analyzed to find out how much the teacher's capability to use ICT in learning. The intended ability is including mastery of teacher related to technology, pedagogy and subject content as explained in the TPACK framework. From the results of the analysis and synthesis, it can then be used as input for the development of the teacher's capability to use technology.

**Keywords**—TPACK;TPACK-ICT; TPACK ICT Integration

### I. INTRODUCTION

Teacher Competency is important for teaching-learning process. These things related to the framework of knowledge that should be mastered by a 21st-century teacher, there is Technological Pedagogical Content Knowledge (TPACK) [1-3]. Technological Pedagogical Content Knowledge (TPACK) is the interaction complex knowledge between technology, pedagogic, and content [4]. TPACK is good basic teaching with technology, pedagogic technic is technology that uses in a constructive way to teach the content, the knowledge of what makes that concept its hard or easy to learn and how technology can overcome some problem faced [5-7]

TPACK (Technological Pedagogical and Content Knowledge) described teacher capability to how to facilitate learning from certain content through pedagogy approach and technology. This is because the teaching and learning process this time is reflected in the integration development between computer and application technology in the curriculum [8]. Therefore, needed the way to measure 21st-century teacher along with the rapid development of information and communication technology through analysis of TPACK (Technological Pedagogical and Content Knowledge)'s capabilities. There are seven variables which influence TPACK namely (1) Technological Knowledge (TK) is the study about

how to operate computer and relevant software, (2) Pedagogical Knowledge (PK) is the ability in learning management, (3) Content Knowledge (CK) is the subject matter such as Science, Mathematics, language and so on, (4) Technological Content Knowledge (TCK) is knowledge study about how the content can be examined or represent by technology such as using computer simulation to represent and study network topologies, (5) Pedagogical Content Knowledge (PCK) is knowledge how to represent and formulate subjects that make it understood by students, (6) Technological Pedagogical Knowledge (TPK) is knowledge about how technology can facilitate pedagogical approaches such as using game design to support practicum about OSI Layers computer networks, (7) Technological Pedagogical And Content Knowledge (TPACK) is knowledge about how to facilitate student learning from certain content through pedagogical and technological approaches [9-12]. Meanwhile, the use of ICT in the learning process still needs more attention. To be able to maximize the use of ICT in learning activities, the main thing that must be considered is the ability of teachers to implement ICT correctly [13]. To implement ICT, it can use TPACK (Technological Pedagogical and Content Knowledge) framework. TPACK framework is a reference for the use of technology in learning that shows the relationship between the three basic knowledge that must be mastered by the teacher, namely technological knowledge, pedagogy, and content.

This research aims to get an overview of knowledge of learning technology and to identify factors that influence the use of technology in learning. Seeing this condition, it is necessary to do critical analysis in depth from the papers reviewed by the use of Information and Communication Technology (ICT) carried out by the teacher, especially the ability in learning. The data from the paper were analyzed to find out how much the teacher's capability to use ICT in learning. The intended ability is including mastery of teacher related to technology, pedagogy and subject content as explained in the TPACK framework. From the results of the analysis and synthesis, it can then be used as input for the development of the teacher's capability to use technology.

## II. THEORETICAL FRAMEWORK

### A. Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) is a framework to identify the knowledge, the teacher must teach in effectively with technology framework. The basic concept of TPACK presence is: at the first time TPACK was introduced by Mishra and Koehler [1]. They discussed TPACK as a teacher framework or designer to integrate TIK in learning. TPACK concept appeared in learning technology based on pedagogy content knowledge (PCK) model which pioneered by Shulman [14,15].

There are three important components knowledge that must be owned as an educator there are, mastering the subject matter in accordance with the qualifications and competencies included in the curriculum, pedagogy, and technology. They describe it in one unit that is interrelated with each other. This is in line with the demands of 21st-century learning where ICT mastery is a prerequisite for teachers [1,16]. Besides that, TPACK can also be used as the main pillar in developing self and learning innovations for teachers. Furthermore, the great hope of becoming a professional teacher who is able to integrate ICT and technology can overcome the problem of learning participants so that it is easier to understand the material contained in the curriculum. Whereas in the process of learning ICT, it becomes the main attraction. TPACK's basic concept emphasizes the relationship between subject matter, technology and pedagogy [17]. Whereas in the process of learning ICT, it becomes the main attraction. TPACK's basic concept emphasizes the relationship between subject matter, technology, and pedagogy [17].

The interaction between the three components has the power and attractiveness to foster active learning that is focused on learning participants. This can also be interpreted as a form of shifting learning that was initially teacher-centered shifting to learning participants. The framework needed by a teacher is understanding of the effectiveness of learning integration. TPACK emphasize the relations between technology, curriculum content and pedagogy approach which interact one each other to produce TIK based learning [18-20].

In the TPACK scheme, there is a relationship between the constituent components, intersecting the material (Content). Pedagogy (Pedagogy) and technology (Technology) that influence in the context of learning. The components, namely C, P, and K, then C become (Content Knowledge). P becomes (Pedagogy Knowledge) and T becomes (Technology Knowledge) and the relationships between components can be explained as follows:

Content Knowledge (PCK), which is knowledge about the subject matter to be learned. The material is contained in the curriculum. That the subject matter includes knowledge in the form of concepts, theories, ideas, frameworks, methods that are equipped with scientific methods and their application in daily life. Learning participants must focus on the subject matter in the curriculum [19].

Pedagogy Knowledge (PK) describes knowledge in depth related to the theory and practice of teaching and learning

which includes goals, processes, assessment learning methods, strategies, and others. Pedagogical knowledge requires an understanding of cognitive, affective, social aspects and the development of learning theory and how it can be applied in the learning process [21].

Technology Knowledge (TK) is the basics of technology that can be used to support learning. For this reason, teachers need mastery in information processing, communicating with ICTs in learning. Furthermore, mastering this technology is the demand of the 21st century [16]. Pedagogy Content Knowledge (PCK) includes the interaction and occurrence of intersection between pedagogy (P) and subject matter (C). This includes the learning process related to the subject matter being studied as well as the learning participant assessment system. The learning model is expected to make learning participants effectively [22].

Technology Content Knowledge (TCK) is included in understanding technology and subject matter that can help and influence other components. In formulating instructional goals, there is often a misconception and scientific ego. For example, people who are experts in ICT are positioned as people who are only in the ICT field. In fact, ICT experts are needed as a catalyst, which is to facilitate understanding of subject matter [23].

Technology Pedagogy Knowledge (TPK) is a series of understanding how learning changes occur by utilizing the technology used to support active learning and can assist and simplify the concepts of the subject matter. In fact, with the presence of ICTs in learning optimally to open insights, participants learn to understand the subject matter that is microscopic, abstract and complex. This is the role of ICT can be interpreted as a source of learning [24].

Technology Pedagogy Content Knowledge (TPACK) summarizes a series in learning where the ability to master technology is integrated that cannot be separated from each other from its constituent components (C), (P) and (K). TPACK requires the occurrence of multi-interactions and combinations of components namely unique and synergistic ICT-based subject matter, pedagogy and technology [25].

TPACK has a strength that the previous concept i.e. PCK. Among them in compiling instructional designs, compiling learning instructions, learning models and strategies, assessment systems and in designing curriculum. The determining factor of TPACK for all components is integrated with ICT. Thus, TPACK contributed greatly to changes and learning paradigms.

### B. Integration of Information and Communication Technology.

In the context of formal education (school), especially related to the vehicle for cultural transformation, ICT has a function in the learning process, at least, is as a learning aid. The function of ICT as a learning aid can be in the form of teaching aids for teachers, learning aids for students, as well as tools for interaction between teachers and students [26]. The other functions are knowledge warehouse, learning aids, educational facilities, competency standards, school

management aids, and educational infrastructure. In the case of the learning process or the teaching and learning process in which students also study with the teacher, the use of ICT cannot be separated from its function [7]. Thus, it is clear that in order to achieve competencies or skill as expected of students in facing their future, a teacher must utilize ICT in learning. The importance of the use of ICT in learning given the potential of ICT itself in facilitating and optimizing the learning process [27]. In a broader context, namely education, the potential of ICT that seems clear at least is to expand learning opportunities, improve learning quality and efficiency, allow for independent learning and cooperative learning, and encourage the realization of lifelong learning. Some examples of the use of ICT in learning that occur today include the use of learning audio programs, video learning programs, the use of TV education, the use of social networking, and e-learning. Multimedia learning is a form of computer-based learning aids that are supported by various multimedia components such as text, sound, images and videos [28,29]. By utilizing ICT in learning the teacher becomes more served by his teaching needs so that the learning process teaches much easier and more enjoyable/exciting which in turn will have an impact on obtaining optimal learning outcomes.

### III. METHOD

The method used in writing this article is the literature review, which is an international literature search conducted using the SCOPUS database, ScienceDirect, SAGE Journal, and Taylor & Francis. In the early stages of searching journal articles, it obtained 120 journal articles from October to November 2018 using the keywords "TPACK", "Technological Pedagogical Content Knowledge", and "TPACK with ICT" were identified that have not been explored with relevance to articles to compile. From these articles, only about 30 articles are considered relevant. The scope of the paper will be limited within the last 10 years (2008 to 2018) with the aim that search engines can produce papers that are more focused on the development of the latest problems and solutions. From these papers, only the top few papers will be taken that are truly focused on proposing a new model for integrating ICT into Technological Pedagogical Content Knowledge.

Each of these papers will discuss at a glance about what part will be studied, the scope of research will be studied, what is the focus of the research, and how the result of these research. At last, this literature review can be contributing to help the reader build TPACK learning with utilizing ICT as learning sources and factors that influence of the use of technology in learning.

The steps to get the results of the review article can be clearly determined in the following prism diagram:

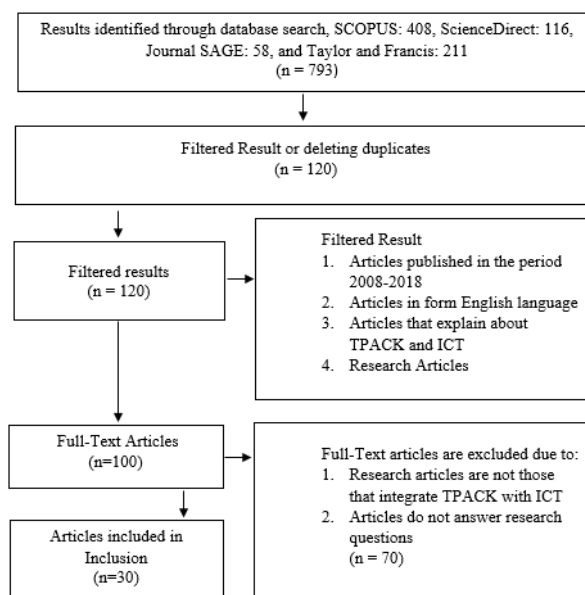


Fig. 1. Prism diagram.

### IV. RESULT AND DISCUSSION

#### A. Teacher capability in ICT implementation

The availability of ICT in schools at this time does not automatically guarantee better and effective use. There are still many teachers who will be raised to make this ICT can be applied in education to support the teaching-learning process [13]. The special knowledge to optimize ICT as a supporting media for learning about a certain subject/matter is referred as Technological Pedagogical Content Knowledge (TPACK) [1]. TPACK can be used to improve student learning, support students, parents, and make schools more interesting, relevant for students, and can provide equal opportunities for each student, and no less important is to support teacher professional development.

This is because that mastery and knowledge of information technology will make it easier for teachers to find sources of learning so that students will not feel bored in attending the lesson in class [27]. A teacher who is able to develop varied learning methods and is able to present or provide creative and varied subject matter will automatically be able and successful in displaying an interesting learning atmosphere that makes students feel at home in the classroom. TPACK is basically an approach that combines three types of knowledge: content knowledge, pedagogical knowledge, and technological knowledge. TPACK is the theoretical basis of this research because it will support and assist teachers in identifying what they need to know about the use of ICT in learning.

The use of blended learning in the learning process is very helpful for the teacher to achieve the learning goals he has planned [30]. This is because e-learning has very high flexibility. It can be done anytime and anywhere. Students can also interact with the media that allows them to reflect on the learners they have been working on [31]. Blended learning also provides opportunities for students to study outside the

classroom with unlimited learning resources both learning resources from national and international products. Besides that, blended learning also makes the world of learning more varied with simultaneous visual, image and sound display, so that students can directly utilize various media that will have an impact on the way students interact, learn and process information [32]. Video media proved to be an effective way to motivate and involve students in learning and to explain concepts.

### B. TPACK Competence for Teachers

The achievement of ICT competencies for teachers globally has begun to be formulated and published by UNESCO, the PBB agency that handles education. ICT Competencies Teachers based on the ICT Competency Framework for Teachers (ICT-CFT) framework according to Koh et al., consist of three levels of ability, namely [7]; 1) Technology Literacy, 2) Knowledge Deepening, and 3) Knowledge Creation. The level of ICT capability of teachers in the three aspects of competence is explained as follows: (1) Technology Literacy, Technology Literacy is the basic competency of ICT teachers in utilizing ICT to prepare students to be able to master new technology as a provision for students to develop themselves as lifelong learners. (2) Deepening Knowledge, at this level the professional development of teachers must focus on providing knowledge and skills to utilize more complex methodologies and technologies. Changes in the curriculum must link the knowledge acquired in schools to real-world problems, which may require students' collaborative skills at the local and global level. (3) Knowledge Creation, this competency requires teachers to be able to develop more complex skills in the use of technology and collaboration skills with colleagues to design project-based learning that is challenging for students.

### C. Technological Knowledge

Technological knowledge refers to teacher knowledge of technology that is commonly used in daily life, especially digital technology and information and communication technology. The existence of this capability needs to be held in view of the ongoing developments and technological changes.

TABLE I. TECHNOLOGICAL KNOWLEDGE

Technological Knowledge
I know how to solve technical problems related to digital technology.
I able to learn technology easily.
I follow the latest important technological developments.
I often play with technology
I know many different types of technology
I have the technical skill to use technology
I have enough opportunities to work with different technologies

Based on the results of previous researchers' studies, the most valuable technological knowledge is "I follow the latest important technological developments". Where this is inversely proportional to the statement "I have technical skills to use technology" which only gets an average value. These results indicate that teachers do not all have good skills related to technology, they only follow developments. But overall, they have sufficient technological knowledge with an average value.

### D. Technological Knowledge of Integration in Teaching Materials

Technological knowledge of integration in teaching materials is referred to teacher knowledge in applying technology to set and deliver teaching materials well and unique. The use of technology that is appropriate to the characteristics of the teaching material to be delivered can make students more quickly grasp the teaching material and master it. Therefore, the accuracy of the use of technology is very influential on the success of learning.

TABLE II. TECHNOLOGICAL KNOWLEDGE OF INTEGRATION IN TEACHING MATERIALS

Technological Knowledge of Integration in Teaching Materials
I know about the technology that I can use to understand and do literacy.
I know about the technology that I can use to understand and do grammatical and vocabulary studies.
I know about the technology that I can use to understand and learn language skills.
I know about the technology that I can use to understand and practice a language.

Based on previous research as well, the knowledge of technology integration in teaching material with the highest value is "I know about the technology that I can use to understand and learn language skills" with an average value. Where this is inversely proportional to the statement "I know about the technology that I can use to understand and do grammatical and vocabulary studies" which only get less than average scores. This indicates that teachers do not all have good skills related to technology, they only follow developments. However, they have knowledge of Technology Integration in Teaching Materials which is sufficient with an average value. The lowest value is knowledge of technology integration with teaching material and technological knowledge. This reflects that there are still many teachers who don't really understand the teaching material that they will convey in school and also how to integrate technology and teaching materials. This shows that teachers still having difficulties in the practice and application of the knowledge they have. It can be seen from the teaching material, teachers have good knowledge and good technological knowledge too. Even so, the teacher has the highest TPACK than the other. This indicates that knowledgeable teachers are very familiar with technology. It could be because now their lives are only in direct contact with technology and also tend to agree and like that technology can also be integrated with the learning process or in the context of education, they are mostly interested in communication and information technology.

In the literature, it was also found that current teachers who are prepared to become professional teachers are required to have knowledge in making knowledge content accessible with the help of technology by students through several pedagogical methods [33]. In addition, C S Chai et al., also added that technological progress has been very easy to learn and apply by the current generation [4].



## V. CONCLUSION

Technological Pedagogical Content Knowledge (TPACK) framework has a significant impact on teacher and teacher educator. Technological Pedagogical Content Knowledge (TPACK) described various types of knowledge that teachers need to teach effectively with technology and various complex procedures in the field of interaction study. Increasing teacher professionalism starts with individuals taking teacher education or equivalent to undergraduate education. At this stage, they are provided with knowledge and skills in the fields of scientific study and pedagogy. The implementation of teacher education must have a large portion in terms of pedagogical practices, which involve the ability to master subject/ material, teaching, and technology. TPACK is now able to facilitate all these things, the rest are teacher institutions that have the obligation to organize education in the direction needed. Many innovations in the implementation of teacher education have been carried out, from those oriented to self-competence to the development of learning infrastructure. TPACK-ICT is an effort that can be done by teacher institutions to build a learning environment among prospective teachers.

Seeing the important role of teachers in the 21st Century, teachers in Indonesia should be able to make a positive contribution in terms of Indonesia's human development. These contributions can be in the form of efforts to improve the learning process in the classroom on an ongoing basis. The use of information and communication technology in learning can be an alternative to these improvements. To be able to integrate information and communication technology in teaching is needed a Technological Pedagogical Content Knowledge (TPACK) framework by a teacher. Therefore, teachers in Indonesia should have this capability in order to realize national education goals so that the Indonesian nation can compete with other nations in the current 21st Century era.

## REFERENCES

- [1] P. Mishra and M.J. Koehler, "Technological pedagogical content knowledge: A framework for teacher knowledge," *Teachers College Record*, vol. 108, no. 6, pp. 1017–1054, 2006.
- [2] M.J. Koehler and P. Mishra, "What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge," *Journal of Educational Computing Research*, vol. 32, no. 2, pp. 131–152, 2005.
- [3] J. Hwee and L. Koh, "Modeling pre-service teachers' technological pedagogical content knowledge (TPACK) perceptions: The influence of demographic factors and TPACK constructs," *Asclite* 2011, pp. 735–746, 2011.
- [4] C.S. Chai, J.H.L. Koh and C.-C. Tsai, A Review of Technological Pedagogical Content Knowledge. *Educational Technology and Society*, vol. 16, no. 2, pp. 31–51, 2013.
- [5] H. Borko, J. Whitcomb, and D. Liston, Issues of technology and teacher learning. *Journal of Teacher Education*, vol. 60, no. 1, pp. 3–7, 2009.
- [6] L. Nadolny and A. Halabi, Student Participation and Achievement in a Large Lecture Course With Game-Based Learning. *Simulation and Gaming*, vol. 47, no. 1, pp. 51–72, 2016.
- [7] J.H.L. Koh, C.S. Chai, and W.Y. Lim, "Teacher Professional Development for TPACK-21CL: Effects on Teacher ICT Integration and Student Outcomes," *Journal of Educational Computing Research*, vol. 55, no. 2, pp. 172–196, 2017.
- [8] D.D. Holland and R.T. Piper, "Testing a Technology Integration Education Model for Millennial Preservice Teachers," *Journal of Educational Computing Research*, vol. 54, no. 2, pp. 196–224, 2016.
- [9] K.-H. Cheng, "A survey of native language teachers' technological pedagogical and content knowledge (TPACK) in Taiwan," *Computer Assisted Language Learning*, vol. 30, no. 7, pp. 692–708, 2017.
- [10] R.F. Cavanagh and M.J. Koehler, "A turn toward specifying validity criteria in the measurement of Technological Pedagogical Content Knowledge (TPACK)," *Journal of Research on Technology in Education*, vol. 46, no. 2, pp. 129–148, 2013.
- [11] L. Pareto and S. Willermark, "TPACK In Situ: A Design-Based Approach Supporting Professional Development in Practice," *Journal of Educational Computing Research*, 2018.
- [12] L. Nadolny, Z. Alaswad, D. Culver, and W. Wang, "Designing With Game-Based Learning: Game Mechanics From Middle School to Higher Education," *Simulation & Gaming*, vol. 48, no. 6, pp. 814–831, 2017.
- [13] J. Cabero and J. Barroso, "ICT teacher training: a view of the TPACK model / Formación del profesorado en TIC: una visión del modelo TPACK," *Cultura y Educación*, vol. 28, no. 3, pp. 633–663, 2016.
- [14] J. Voogt, P. Fisser, R.N. Pareja, J. Tondeur and J. van Braak, "Technological pedagogical content knowledge - A review of the literature. *Journal of Computer Assisted Learning*," vol. 29, no. 2, pp. 109–121, 2013.
- [15] C.S. Chai, J. Hwee, and C.C. Tsai, "Exploring the Factor Structure of the Constructs of Technological, Pedagogical, Content Knowledge (TPACK)," *The Asia-Pacific Education Researcher*, vol. 20, no. 3, pp. 595–603, 2011.
- [16] C.S. Chai, J.H.L. Koh, U. Natarajan, P.S. Tsai, M. Ramli, and A. Widodo, "Surveying Indonesian teachers' design belief and TPACK for 21st century oriented learning," 2017.
- [17] S. Pamuk, M. Ergun, R. Cakir, H.B. Yilmaz, and C. Ayas, "Exploring relationships among TPACK components and development of the TPACK instrument," *Education and Information Technologies*, vol. 20, no. 2, pp. 241–263, 2015.
- [18] C.C. Tsai, C.S. Chai, B.K.S. Wong, H.Y. Hong, and S.C. Tan, "Positioning design epistemology and its applications in education technology," *Educational Technology and Society*, vol. 16, no. 2, pp. 81–90, 2013.
- [19] L.M. Archambault and J.H. Barnett, "Revisiting technological pedagogical content knowledge: Exploring the TPACK framework," *Computers and Education*, vol. 55, no. 4, pp. 1656–1662, 2010.
- [20] J. Harris, P. Mishra, and M. Koehler, "Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration refrained," *Journal of Research on Technology in Education*, vol. 41, no. 4, pp. 393–416, 2009.
- [21] D.A. Schmidt, E. Baran, A.D. Thompson, P. Mishra, M.J. Koehler, and T.S. Shin, "Technological Pedagogical Content Knowledge (TPACK)," *Journal of Research on Technology in Education*, vol. 42, no. 2, pp. 123–149, 2009.
- [22] S.M. Guerrero, "Teacher knowledge and new domain of expertise: pedagogical technology knowledge," *Journal of Educational Computing Research*, vol. 33, no. 3, pp. 249–267, 2005.
- [23] C. Angeli and N. Valanides, "Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in technological pedagogical content knowledge (TPCK)," *Computers and Education*, vol. 52, no. 1, pp. 154–168, 2009.
- [24] J. Lambert and Y. Gong, "21st Century paradigms for pre-service teacher technology preparation," *Computers in the Schools*, vol. 27, no. 1, pp. 54–70, 2010.
- [25] T.C. Lin, C.C. Tsai, C.S. Chai, and M.H. Lee, "Identifying Science Teachers' Perceptions of Technological Pedagogical and Content Knowledge (TPACK)," *Journal of Science Education and Technology*, vol. 22, no. 3, pp. 325–336, 2013.
- [26] M.L. Niess, Investigating TPACK: Knowledge Growth in Teaching with Technology. *Journal of Educational Computing Research*, vol. 44, no. 3, pp. 299–317, 2011.

- [27] J. Tondeur, H. van Keer, J. van Braak, and M. Valcke, "ICT integration in the classroom: Challenging the potential of a school policy," *Computers and Education*, vol. 51, no. 1, pp. 212–223, 2008.
- [28] J.H.L. Koh, C.S. Chai, W. Benjamin, and H.Y. Hong, "Technological Pedagogical Content Knowledge (TPACK) and Design Thinking: A Framework to Support ICT Lesson Design for 21st Century Learning," *Asia-Pacific Education Researcher*, vol. 24, no. 3, pp. 535–543, 2015.
- [29] C.S. Chai, J.H. Ling Koh, C.C. Tsai, and L.L.W. Tan, Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers and Education*, vol. 57, no. 1, pp. 1184–1193, 2011.
- [30] A. Doering, G. Veletsianos, C. Scharber, and C. Miller, Using the "Technological, Pedagogical, and Content Knowledge Framework to Design Online Learning Environments and Professional Development," *Journal of Educational Computing Research*, vol. 41, no. 3, 319–346, 2009.
- [31] T. Kleickmann, D. Richter, M. Kunter, J. Elsner, M. Besser, S. Krauss, and J. Baumert, Teachers' Content Knowledge and Pedagogical Content Knowledge: The Role of Structural Differences in Teacher Education. *Journal of Teacher Education*, vol. 64, no. 1, pp. 90–106, 2013.
- [32] B. Wu, Y. Hu, X. Gu, and C.P. Lim, Professional Development of New Higher Education Teachers With Information and Communication Technology in Shanghai. *Journal of Educational Computing Research*, vol. 54, no. 4, pp. 531–562, 2016.
- [33] C.S. Chai, J.H.L. Koh, and C.C. Tsai, "Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK)," *Educational Technology & Society*, vol. 13, no. 4, pp. 63–73, 2010.