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Current trends in TPACK research in science education: a systematic review of literature from 2011 to 2017

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Abstract. This paper reviews the research published from 2011 to 2017 that focuses on the characteristics and emerging topics on Technological Pedagogical Content Knowledge (TPACK) in Science education. A systematic search of the relevant research was undertaken of electronic databases including ERIC and Scopus using several key terms. Focussing on peer-reviewed journal articles, the screening process began with a perusal of the title and abstract, followed by the analysis of the purpose, method, findings, discussion and conclusion. The results showed that most of the research used pre-service teachers as the participants (56%). One-third used in-service teachers (31%) or both of them (13%). Furthermore, our results showed that the majority of studies use general science context (69%). Fewer studies focussed on specific subject domains, including biology (13%), Chemistry (19%), and Physics (6%). Based on the analysis of the current research, we found five key emerging trends, including the identification of teachers' TPACK (100%), the relationship between TPACK and other components of technology integration (19%), strategies to developing preservice teachers TPACK (50%), how teacher implement TPACK (44%), and developing an instrument for TPACK (19%). Based on the analysis, we suggest some topics that need further investigation.

1. Introduction

Universities that focus on teacher education play a fundamental role in education because they interpret and implement the curriculum into the actual teaching and learning process [1]. Professional teachers must have four competencies including pedagogy, personality, social, and professional [2]. The professional skills of teachers are not only about their mastery of the specific subject matter but also their ability to integrate information and communication technology (ICT) due to the growing demand for the use of technology in all aspects of life [3][4]. Hence, technological knowledge becomes an essential component as a component of pedagogy and content knowledge for teachers. Therefore, it is essential to know the level of preservice teachers' knowledge of content, pedagogy, and technology, especially as a lack of understanding of these components would hinder the goals of curricular [1].

The framework to identify the extent that prospective teachers demonstrate their mastery of content, pedagogy, and their readiness to integrate ICT in Technological Pedagogical Content

Knowledge (TPACK) is well established [5]. The framework evaluates how experiences in teacher education influence the development of related knowledge and attitudes for effective technology-enhanced teaching practices [6]. TPACK has three main components, including Pedagogical Knowledge (PK), Content Knowledge (CK), and Technological Knowledge (TK) [5]. Technological Pedagogical Content Knowledge (TPACK) refers to knowledge emerging from the interactions between content, pedagogy, and technology. Clearly, research that informs teacher education programs in the development of the preservice science teachers' TPACK in their institution is needed [6] [7].

We believe it is essential to identify the current trends of current studies. An understanding of these trends would provide insights for researchers in understanding the current TPACK research progress [8]. Second, we can then identify the gaps in the research and areas for further investigation. Currently, however, reviews of the current research on TPACK specifically in science education context are limited. One examination of the published research in (TPACK) study from 2002 to 2011 was broadly focussed, including Science, mathematics, and language [8]. The current study is a systematic review focusing only on Science published between 2011 to 2017. Our research question is "What are the characteristics and emerging trends of research published from 2011 to 2017 in TPACK in Science Education?" Our methodology is based on a systematic review of primary research that includes a clear description of both the search strategy and the selection of studies [9]. Our approach depends on the use of electronic databases such as ERIC and Scopus.

2. Method

The manual search of documents was undertaken by looking through journals that had a connection with TPACK. First, we define the keywords or a set of key terms to search literature in electronic databases. The keywords to search the database are TPACK, preservice teachers, science, biology, chemistry, physics, with some modification using "AND" and "OR." Four criteria were applied to specify the studies that will be reviewed including the year of publication, journal, subjects, and language. Firstly, the year of publication in this study is only the studies published in the last seven years from 2011 to 2017. Secondly, the databases to search the journal articles only include ERIC (Educational Resources Information Center) and Scopus. Resources such as Google Scholar, A+ Education, ISI Web of Science, and IEEE library are excluded. Thirdly, the research must be peer-reviewed and directly related to TPACK. Fourthly, the subject matter of the reviewed study must be science and the domain (biology, physics, chemistry, or general sciences). Finally, the language of the included studies must be English, but is not limited to any country. After potential articles were identified, the screening process focussed on title and abstract. Based on the initial search, 88 and 232 potential journal articles were found in ERIC and 232 and Scopus, respectively.

A final analysis yielded a total of 16 articles. From these, we identified key characteristics of the study, including country, participants, and the science domain. The data are extracted using vote counting. We also analyzed the topic of the research by coding and grouping the research that has a similar topic. We considered the themes of the research by using the explanation of the authors evident from the purpose and focus of the study. Then, the data are presented in the table with Microsoft Excel. The data are analyzed quantitatively by looking at the percentage of each category. Then, the result of the analysis was described quantitatively by comparing and contrasting the data in each category using descriptive percentage.

3. Result and Discussion

3.1. The characteristics of the reviewed studies

Our results showed that the research represented several continents, including Asia (Turkey, Singapore, Taiwan, Israel), Australia, Europe (Netherland), Africa (Tanzania), and North America (United States) (Table 1). Most of the studies used pre-service teachers as the participants 9 out of 16 or 56%, with 31% based on in-service teachers. Several researchers used both pre-service and in-service teachers (13%). Based on the science domain, our investigation showed that the majority of studies use general science context in their research (69%). Only little studies which specifically focus on specific subject domain including biology (13%), Chemistry (19%), and Physics (6%). The next section discusses the result of our analysis of the themes of the reviewed studies.

3.2. *Emerging themes appear in the reviewed studies*

Based on the analysis of previous research on investigating TPACK of science teachers, there are five key emerging themes including measuring (students) teachers TPACK (56%), the relationship between TPACK and other components of technology integration (18%), strategies to developing preservice teachers TPACK (50%), how teacher implement TPACK (44%), and developing an instrument for TPACK (19%).

Table 1. The emerging themes of the reviewed studies

Article	The themes of reviewed studies				
	Relationship between TPACK and some variables	Strategies for developing TPACK	Identifying TPACK	how teacher implement TPACK	developing an instrument for TPACK.
[10]		✓	✓		
[11]	✓		✓		
[12]			✓	✓	
[13]	✓	✓	✓		
[14]		✓	✓		
[15]		✓	✓	✓	
[16]		✓	✓	✓	
[17]			✓		✓
[18].		✓	✓		
[19]			✓		✓
[20]		✓	✓		
[21]			✓	✓	
[22]			✓	✓	
[23]		✓	✓	✓	
[24]	✓		✓		
[25]			✓	✓	✓
Total (%)	3 (19)	8 (50)	16 (100)	7 (44)	3 (19)

3.2.1. Measuring and identifying preservice teachers TPACK and its components . We found that all studies identifed participants' TPACK in various ways. There are two main methods to identify participants' TPACK, including self-report and performance. The distinction between them is that TPACK reflects knowledge (via self-report), and in the other end as competency or performance that can be observed (via performance) [8]. It seems that 25% of research used more than one method, meaning that they combine both self-report and performance.

Self-report we found in current research can be divided into three subcategories, including self-reporting in a specific context [10, 11, 13, 17, 19, 20, 23, 24, 25] and self-reporting in an experienced TPACK [12, 16, 25]. This method has some strengths and weaknesses. Although self-reports can be used to collect data in a short time with a significant number of participants, it cannot reflect the real performance in the classroom. Also, it depends on the participants' honesty in the survey [24]. We found that self-report is the most commonly used method (50%) of the total studies).

When using performance, researchers identified participants' capacity to plan, implement and evaluate teaching activity (25% of the total studies). Planning teaching activity includes designing a lesson plan for microteaching or actual teaching practice in the classroom [14, 15, 18, 21, 22, 23]. Some researchers also measure TPACK through observing how participants implement technology in microteaching or actual settings [14, 15, 16, 20, 22, 23]. Other researchers measured participants' TPACK through assessing their reflection of teaching [15, 20, 23]. The strengths and weaknesses of this method contrast with self-report approaches. Although the method doesn't rely on participants' honesty it is time-consuming with participants needing to be observed one by one [14]. Research which used only performance to identify TPACK is four studies (25%). We found that planning and implementing TPACK were the most common methods used by researchers in Science education followed by teachers' reflection.

3.2.2. The relationship between TPACK and other components of technology integration. TPACK is correlated with other components of technology integration, including Technology Integration Self-Efficacy (TISE) [13, 24] and the demographic characteristics of the participants such as teaching experience, gender, and age [11]. It means that teachers' belief and motivation to successfully integrate technology into their future practice and demographic characteristics can be a predictor of their TPACK.

3.2.3. Strategies to develop preservice teachers' TPACK. Some approaches to improve TPACK and self-efficacy which were found in the reviewed studies are professional development program to develop their technological skills [13, 15, 20, 23]. Some researchers are focusing the program on some technologies such as Facebook groups [25] and YouTube [13] to facilitate learning. The TPACK-based course was also used [10, 14, 16] to support the design of lesson plans [18].

3.2.4. How teacher implement TPACK. Implementing TPACK means how "student" teachers apply TPACK in their teaching. For example: How school teachers developed the skills needed to integrate ICT into their teaching in a variety of technologies that they had not used previously [15, 16, 20]. How technology-related practices were integrated such as the use of sophisticated hardware to foster inquiry-based science to support students' investigations [21, 22] and integrating videos and visualizations that supported understanding abstract chemistry concepts [13]. Also, how pre-service and in-service science teacher implement TPACK-Practical is explored [12].

3.2.5. Developing an instrument for TPACK. Some research focuses on developing an instrument of TPACK. For instance, two articles develop a questionnaire for measuring teachers' self-efficacy beliefs for integrating Facebook into teaching [11, 25]. Two articles developed Technology Use in Science Instruction (TUSI) instrument to investigate the extent to which technology is integrated into science instruction [2, 17]. One article [19] developed a Science teachers' TPACK-Practical Standard-setting using an evidence-based approach to measure teachers' proficiency level. Generally, the steps they used to develop the instrument include creating items, establishing content validity, refining the item pool based on content expert feedback, piloting testing, checking statistical reliability and item analysis, and finalization of the instrument.

4. Conclusion

Over recent years, TPACK research in Science education context shows variability in the demographic characteristics and in emerging themes. First, our investigation shows that TPACK research in science education varies regarding the participants and science domain. Over half of the reviewed studies used pre-service teachers as the participants. However, some research used in-service teachers or both of groups. Based on the science domain, our investigation shows that the majority of studies use general science context. Few studies focused on specific subject domain including biology (13%), Chemistry (19%), and Physics (6%). Secondly, we found five key emerging topics including identifying (students) teachers TPACK (100%), the relationship between TPACK and other components of technology integration (19%), strategies to developing preservice teachers TPACK (50%), how teacher implement TPACK (44%), and developing an instrument for TPACK (19%). The method to identify TPACK also shows a variation including via self-report (50%), via performances in teaching practices (25%) and both methods (25%).

Although our study identified only 16 articles, future research should verify the generalisability of our findings with broader domains. These studies in a broader context may indicate greater variability within specific themes such as cell biology, ecosystem, or chemical-bound. Future researchers can also explore the relationship between TPACK and other components which still not explored in Science education such as digital nativity [27], pedagogical beliefs [29] Instructional Technology Outcome Expectations [29], the use of social media [30], and ownership of technological tools. The limited number of research in this review also due to the limitation of the educational databases we used to choose the studies which only included ERIC and Scopus. Future researchers should consist of more databases and resources such as A+ Education, ProQuest, google scholar, and ISI web of science to acquire a broader overview of the studies. This paper has implication for teacher preparation program in some developed countries especially Indonesia. Further research of TPACK need to be conducted due to limited research in Indonesia. TPACK is a critical component for teachers to improve the quality of education because teacher is key components to translate intended curriculum into actual teaching and learning practices in the classroom.

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