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Developing Pre-Service Science Teachers' TPACK Self-Efficacy of Chemistry Competencies through Case-based Learning Intervention

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Abstract: Technological Pedagogical and Content Knowledge, called TPACK, is essential for 21st chemistry teachers since technologies can enhance science teaching and learning quality if appropriately implemented. Meanwhile, developing students' competencies in science are required to respond to social needs. Due to that challenge, this study focuses on preparing preservice science teachers to promote students' chemistry competencies through TPACK training. In this study, 32 pre-service science teachers from Chemistry Education Department, Yogyakarta State University, Indonesia, were invited. This study used a quasi-experimental research design to collect data before and after the intervention. The results revealed significant differences between pre-service science teachers' TPACK self-efficacy scores at the pretest and post-test.

Keywords: TPACK, chemistry competency, self-efficacy, digital technology, case-based learning

1. Introduction

Undoubtedly the Circular Economy is a promising approach to sustainable development. To be active citizens, students must have competencies to sustain our environment, and teachers must equip them with competencies to achieve the goal. In terms of chemistry education, the most recent version of the Chemistry Curriculum in Senior High School that emphasizes chemistry competencies has been established in China to meet this challenge. Furthermore, other developing countries worldwide, including Indonesia, can adapt the curricula.

Meanwhile, technological advancement has inevitably led to the transformation of all disciplines. In terms of the chemistry classroom, Nugraheni, Adita, & Srisawasdi (2020) stated that technology could support various learning strategies to teach chemistry. Hence, teachers can apply several technologies to assist students in achieving these chemistry competencies (Nugraheni, Prasongsap, & Srisawasdi, 2021). To achieve this goal, teachers should appropriately integrate technologies in their chemistry classrooms. Nevertheless, several previous studies (e.g., Niess, 2005; Angeli & Valanides, 2009; So & Kim, 2009) indicated that teachers had difficulties integrating technologies in their classrooms to teach specific content, particularly in determining the most effective teaching tool. Moreover, due to the lack of pedagogical knowledge, teachers sometimes unsuccessfully effectively integrate technology into their classroom instruction (Hew & Brush, 2007; Kramarski & Michalsky, 2010, Chai, Koh, & Tsai, 2013; Cetin-Dindar et al. (2017)). Many researchers proposed that pre-service teachers require TPACK training to deal with this obstacle throughout their initial education. For instance, Cetin-Dindar et al. (2017) conducted a course to integrate various technologies (e.g., animations, data logging, instructional games, simulations, virtual lab, virtual trips) into the chemistry classroom. The results revealed that some TPACK components on pre-service chemistry teachers can be improved by the implementation of the intervention. In addition, Zimmerman, Melle, & Huwer (2021) developed a university seminar for prospective chemistry teachers' professionaldevelopment. The results revealed that the seminar appropriately fosters pre-service chemistry teachers' TPACK. However, there is no research about TPACK that focuses on chemistry competencies. Hence, TPACK training, especially for preparing pre-service science teachers to foster students' chemistry competencies, is prominent to be conducted. As above mentioned, a research question is does a case-based learning intervention affect changes in pre-service teachers' TPACK self-efficacy of chemistry competency? and a hypothesis of this study is the case-based learning intervention could improve pre-service teachers' TPACK self-efficacy of chemistry competency.

2. Literature Review

2.1 Technological Pedagogical and Content Knowledge (TPACK)

In 2006, Mishra and Koehler introduced Technological Pedagogical Content Knowledge (TPACK) as a conceptual framework. This framework was based on Shulman's (1986) Pedagogical Content Knowledge (PCK). TPACK describes the integration of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). Furthermore, the framework describes the prominent knowledge of how teachers could integrate technology to teach specific subject content with specific pedagogies in their classrooms (Jimoyiannis, 2010; Srisawasdi, 2012).

TPACK comprises seven constructs. Each construct can be defined as follows: (1) Content Knowledge (CK) refers to the knowledge of the subject matter to be studied or instructed; (2) Pedagogical Knowledge (PK) refers to the knowledge of the methods of classroom practices (instructional methods); (3) Technological Knowledge (TK) refers to the knowledge of technologies as well as the skills required to operate technologies, (4) Pedagogical Content Knowledge (PCK) refers to knowledge of specific teaching practices that are appropriate for specific subject content, (5) Technological Content Knowledge (TCK) refers to the knowledge of how technologies can be used to manipulate specific subject content into appropriate representations (6) Technological Pedagogical Knowledge (TPK) refers to the knowledge of the specific technologies that can be used to support the teaching and learning processes; and (7) Technological Pedagogical Content Knowledge (TPACK) refers to the knowledge of how to use appropriate technologies to support learning of content through specific pedagogical strategies (Mishra and Koehler, 2006). Figure 1 depicts the TPACK framework proposed by Mishra and Koehler (2006).

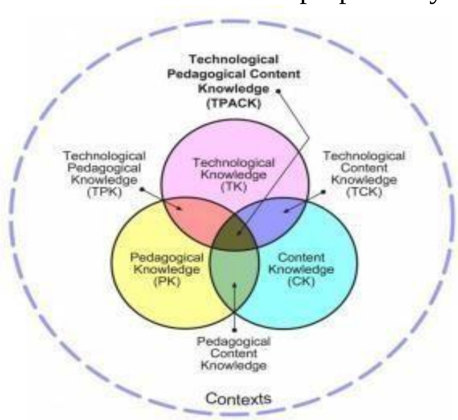

Figure 1. TPACK Framework (Mishra and Koehler, 2006).
(http://tpack.org)

2.2 Technological Pedagogical and Content Knowledge emphasized Chemistry Competencies (TPACK-CC)

TPACK-CC is TPACK that focuses on Chemistry Competencies. This study followed six chemistry competencies. Five chemistry core competencies are adapted from China Senior High School Chemistry Curriculum as follows:" macroscopic identification and microscopic analysis (C1), changesand equilibrium (C2), evidence-based reasoning and modeling (C3), scientific inquiry and innovation (C4), scientific attitude and social responsibility (C5) (Wei, 2019)." Meanwhile, the sixth competency (C6) (i.e., the link between macroscopic, microscopic, and symbolic) was developed by Nugraheni, Prasongsap, & Srisawasdi (2021).

According to the learning matrix developed by Nugraheni, Prasongsap, & Srisawasdi (2021), TPACK-CC in this study is divided into three clusters. The first cluster is TPACK-CC, which focuses on C1 & C2. The second cluster is TPACK-CC, which focuses on C3 & C6. Furthermore, the third cluster is TPACK-CC, which focuses on C4 & C5. This paper merely describes the first cluster. In the first cluster, C1 and C2 are defined as CK. Meanwhile, TK is a 360^o camera and vivista software. Furthermore, the PK is guided inquiry.

3. Methodology

3.1 Sample

In this research, 32 pre-service science teachers from Chemistry Education Department, Yogyakarta State University, Indonesia, were invited. They were 28 (87.5 %) females and 4 (12.5%) males. All of the participants are in their second year. The participants' average age is between 21 and 22 years old. All participants in this study had previously completed courses related to chemistry (e.g., General Chemistry, Organic Chemistry, Analytical Chemistry, and Physical Chemistry), general pedagogical courses (e.g., Introduction to Education, Educational Psychology), and subject-specific pedagogical courses (e.g., Strategy of Chemistry Teaching, Curriculum of Chemistry).

3.2 Research Design

This study employed a quasi-experimental research design, in which data were collected before and after the intervention. The implementation of the intervention followed the "SPA" model (Pondee, Panjaburee , & Srisawasdi, 2021). Table 2 shows the details of the intervention.

Table 1. *The Details of Intervention*

Phase	Day	Topic	Learning Strategy	Knowledge Domain
Showing the Case (S)	1 (1 hour)	Showing some successful cases of using 360^o video in the chemistry laboratory	Interactive lecture	CK, TK, TCK
Practice in Team (P)	1 (3 hours)	Practicing 360^o camera to make 360^o video in the chemistry laboratory	Hands-on practical work	CK, TPK, TPACK
	2 (1 hour)	Enriching 360^o video with vivista	Hands-on practical work	CK, TPK, TPACK

Application of the Case (A)	2 (3 hours)	Designing a lesson plan to foster students' chemistry competencies	Hands-on practical work	CK, TK, PK, TCK, TPK, PCK, TPACK

Figure 2. An illustration of the S phase, showing some successful cases of using 360º video in the chemistry laboratory.

In the S phase, the instructor presented four successful research cases of using 360º video in the chemistry laboratory, as shown in Figure 2. All of the cases addressed the difficulties of chemistry learning in the chemistry laboratory by using 360º video.

Figure 3. An illustration of the P phase, practicing 360º camera to make 360º video in chemistry laboratory (left), enriching 360º video with vivista (right).

In the P phase, the pre-service science teachers were assigned to record 360º video in the chemistry laboratory using 360º camera, as shown in Figure 3. Then, they were asked to enrich the video by using vivista software.

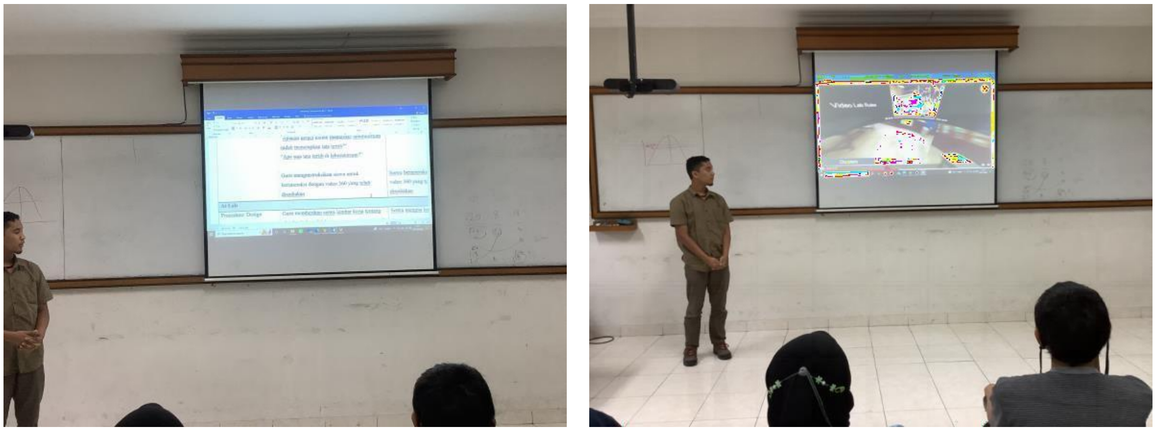

Figure 4. An illustration of the A phase, designing a lesson plan to foster students' chemistry competencies by integrating 360^o video and vivista into the learning activity.

In the A phase, the pre-service science teachers were instructed to design lesson plans to foster students' chemistry competencies by integrating 360^o video and vivista into the learning activity, as shown in Figure 4.

3.3 Data Collection

This study investigated the effect of implementation intervention on pre-service science teachers' TPACK self-efficacy. TPACK self-efficacy questionnaire was employed in this study. The questionnaire was adapted from Schmidt et al. (2009). The questionnaire consists of 28 items. These instruments followed seven constructs of TPACK (i.e., TK, CK, PK, TPK, TCK, TPK, TPACK). The survey was presented with a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Furthermore, the Cronbach's alpha values of each item, as shown in Table 2.

Table 2. *Cronbach's alpha values of each item*

Item	Cronbach's alpha	
	Pretest	Posttest
1	0. 93	0.92
2	0.93	0.92
3	0.92	0.92
4	0.92	0.93
5	0.92	0.93
6	0.92	0.92
7	0.92	0.92
8	0.92	0.92
9	0.92	0.92
10	0.92	0.92
11	0.92	0.92
12	0.92	0.92
13	0.92	0.92
14	0.92	0.92
15	0.92	0.92
16	0.92	0.92
17	0.92	0.92

18	0.92	0.92
19	0.92	0.92
20	0.92	0.92
21	0.92	0.92
22	0.92	0.92
23	0.92	0.92
24	0.92	0.92
25	0.92	0.92
26	0.92	0.93
27	0.92	0.92
28	0.92	0.92
Overall	0.92	0.92

The Cronbach's alpha values in the table indicate that the internal consistency of this instrument is good.

4. Results and Discussion

The intervention's effect on pre-service science teachers' TPACK-self efficacy for each component is shown in Table 3.

Table 3. *The mean of each factor at pre-test and post-test*

Aspect	Item	Pretest		Posttest	
		Mean	SD	Mean	SD
TK	Item 1	2.47	0.72	4.06	0.35
	Item 2	3.47	0.76	4.28	0.46
	Item 3	2.66	0.55	3.97	0.47
	Item 4	2.38	0.66	3.69	0.74
	Item 5	2.47	0.62	3.88	0.49
	Item 6	2.84	0.68	4.09	0.39
	Item 7	3.47	0.80	4.03	0.54
	Average	2.82	0.68	4.00	0.49
CK	Item 1	3.22	0.66	3.94	0.44
	Item 2	3.53	0.57	4.09	0.30
	Item 3	3.16	0.63	3.97	0.47
	Average	3.30	0.62	4.00	0.40
PK	Item 1	3.16	0.57	3.97	0.59
	Item 2	3.31	0.78	4.09	0.39
	Item 3	3.41	0.76	4.09	0.39
	Item 4	3.13	0.75	4.06	0.44
	Item 5	3.28	0.73	4.09	0.30
	Item 6	2.94	0.72	3.72	0.63
	Average	3.21	0.72	3.43	0.46
PCK	Item 1	3.13	0.66	4.03	0.40
TCK	Item 1	3.06	0.67	4.09	0.30

TPK	Item 1	3.34	0.60	4.00	0.44
	Item 2	3.13	0.66	4.16	0.37
	Item 3	3.59	0.56	4.13	0.42
	Item 4	3.53	0.57	4.06	0.56
	Item 5	3.38	0.55	4.06	0.50
	Item 6	3.38	0.49	4.03	0.40
	Item 7	2.97	0.78	4.16	0.45
	Item 8	2.81	0.74	3.91	0.47
	Item 9	3.13	0.83	4.03	0.40
	Average	3.25	0.64	4.06	0.44
TPACK	Item 1	2.84	0.85	4.06	0.35

Table 3 shows the descriptive analysis for each item in all components. As seen in table 3, the mean of all items in all components (TK, CK, PK, PCK, TCK, TPK, and TPACK) increases based on pre-service science teachers' pretest and post-test. The highest increase is in TPACK construct, while the lowest increase is in PK construct. Furthermore, the overall results as shown in Table 4.

Table 4. *Wilcoxon signed-rank test*

Test	N	Mean	SD	Z	Asymp.Sig. (2-tailed)
Pre-test	32	3.11	0.68	-4.94	0.000
Post-test	32	4.03	0.44		

To examine the differences between the pretest and post-test, Wilcoxon signed rank was employed since the data were not normally distributed. According to table 4, the value of Asymp.Sig. (2-tailed) is 0.000. Since 0.000 is lower than 0.05, so alternative hypothesis (Ha) is accepted. It indicates that there is a statistically significant difference between the pre-test and post-test.

In a nutshell, the findings of this study indicated that the intervention could enhance pre-service science teachers' TPACK self-efficacy. It is in line with some previous studies (i.e., Cetin-Dindar et al., (2017); Zimmerman, Melle, & Huwer (2021)). Cetin-Dindar et al. (2017) conducted a course to integrate various technologies (e.g., animations, data logging, instructional games, simulations, virtual lab, and virtual trips) into the chemistry classroom. The findings revealed that some TPACK components on pre-service chemistry teachers can be improved by the implementation of the intervention. In addition, Zimmerman, Melle, & Huwer (2021) developed a university seminar for pre-service chemistry teachers' professional development. The results revealed that the seminar appropriately fosters pre-service chemistry teachers' TPACK self-efficacy. Both studies employed the same instrument with this study to measure pre-service chemistry teachers' TPACK self-efficacy.

5. Conclusion

This study investigates the leveraging of TPACK-CC training on pre-service science teachers' TPACK self-efficacy. The findings revealed a significant difference between their TPACK-self-efficacy scores at the pretest and post-test. The results indicate that the intervention enhanced pre-service science teachers' TPACK-CC.

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